SOUTH AFRICA'S THIRD NATIONAL COMMUNICATION

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

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SOUTH AFRICA'S THIRD NATIONAL COMMUNICATION PROJECT TEAM

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Chapter 4: Promethium Carbon

Chapter 5.1: Council for Scientific and Industrial Research

Chapter 5.2: Gondwana Environmental Solutions

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Acronyms

ABET	Adult Based Education and Training
ACCESS	Applied Centre for Climate and Earth Systems Sciences
ACCAI	Africa Climate Change Adaptation Initiative
ACC	Africa Adaptation Climate Change in Africa
ACDI	African Climate and Development Initiative
ACEP	African Coelacanth Ecosystem Programme
ACMP	Association of Cementitious Material Producers
ACRG	Atmospheric Chemistry Research Group
AEON	African Earth Observation Network
AERONET	Aerosol Robotic Network
AFIS	Advanced Fire Information System
AFOLU	Agriculture, Forestry and Other Land Use
AISA	African Institute of South Africa
ANC	African National Congress
APEDIA	Academic Partnership for Environment and Decelopment Innovations in Africa
ARC	Agricultural Research Council
AREP	Atmospheric Research and Environment Programme
ARS AfricaE	Adaptive Resilience of Southern African Ecosystems
ARSAIO	Atmospheric Research in Southern Africa and Indian Ocean
ASCLME	Agulhas and Somali Current Large Marine Ecosystems
ASSAR	Adaptation at Scale in Semi-Arid Regions
AU	African Union
BGIS	Biodiversity GIS
CACGP	International Commission on Atmospheric Chemistry and Global Pollution

CAPS	Curriculum and Assessment Policy Statement
CAS	Commission for Atmospheric Science
CBO	Community Based Organisation
CC	Climate Change
CCE	Climate Change Education
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CGS	Council for Geoscience
CHE	Council of Higher Education
CIP	Climate Information Portal
CO2	Carbon dioxide
CO2eq	Carbon dioxide equivalent
COGTA	Cooperative Governance and Traditional Affairs
CoPs	Communities of Practice
CORDEX	Co-ordinated Regional Downscaling Experiment
CP	Consortium Partners
CPUT	Cape Peninsula University of Technology
CRDS	Cavity Ring Down Spectroscopy
CSAG	Climate System Analysis Group
CSIR	Council for Scientific and Industrial Research
CSIS	Climate Services Information System
CTCN	Climate Technology Centre and Network
CUIP	Climate User Interface Programme
CWRR	Centre for Water Resources Research
DAEA	Department of Agriculture and Environmental Affairs
DAFF	Department of Agriculture, Forestry and Fisheries

DANIDA	Danish International Development Agency
DBE	Department of Basic Education
DEA	Department of Environmental Affairs
DEAD&P	Department of Environmental Affairs and Development Planning
DEBITS	Deposition of Biogeochemically Important Trace Species
DEDEA	Department of Economic Development and Environmental Affairs
DERO	Desired Emission Reduction Outcome
DHET	Department of Higher Education and Training
DMR	Department of Mineral Resources
DNA	Designated National Authority
DoA	Department of Agriculture
DoE	Department of Energy
DOH	Department of Health
DRR	Disaster Risk Reduction
DST	Department of Science and Technology
DSTV	Digital Satellite Television
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
ECDEDEA	Eastern Cape Department of Economic Development and Environmental Affairs
EE	Energy Efficiency
EEP	Energy and Environment Partnership
EF	Emission Factor
ELTOSA	Environmental Long Term Observatories of Southern Africa network
EM	Emission Factor
EO	Earth Observation

EO2HEAVEN	Earth Observation and Environmnetal Modelling for Mitigation of Health Risks
ESD	Education for Sustainable Development
ESS	Earth System Science
ETDP	Education Training and Development Practices
FAO	Food and Agriculture Organization
FET	Further Education and Training
FMI	Finnish Meteorological Institute
FSA	Forestry South Africa
GAW	Global Atmospheric Watch
GBIF	Global Biodiversity Information Facility
GCA	Global Carbon Atlas
GCIS	Government Communication and Information System
GCOS	Global Climate Observing System
GCRP	Global Change Research Plan
GCSRI	Global Change and Sustainability Research Institute
GDARD	Gauteng Department of Agriculture and Rural Development
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GEOSS	Global Earth Observation System of Systems
GFCS	Global Framework for Climate Services
GFETSF	General and Further Education and Training Sub-framework
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GOODS	Global Ocean Observing System
GTI	GeoTerraImage

GWC	Growth without constraints
GWP	Global Warming Potential
HEI	Higher Education Institution
HEQSF	Higher Education Qualifications Sub-framework
HSRC	Human Sciences Research Council
HWP	Harvested wood products
HySA	Hydrogen South Africa Programme
ICAN	International Coastal Atlas Network
ICSU	International Council for Science
ICT	Information and communication technology
IEP	Integrated Energy Plan
IGAC	International Global Atmosphere Chemistry
IOC	Intergovernmental Oceanographic Commission
IOCAFRICA	Intergovernmental Oceanographic Sub-Commission for Africa and Adjacent Island States
IODE	International Oceanographic Data and Information Exchange
IPAP	Industrial Policy Action Plan
IPBES	International Platform for Biodiversity and Environmnetal Services
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use
IRENA	International Renewable Energy Agency
ISCW	Institute of Soil Climate and Water
IUCN	International Union for the Conservation of Nature
Kt	Kilotonne
LLL	Limpopo Living Landscapes
LTAS	Long Term Adaptation Strategy

LTER	Long Term Ecosystem Research
LTMS	Long-Term Mitigation Scenario
LTSM	Learning and Teaching Support Material
MACC	Marginal abatement cost curve
M&E	Monitoring and Evaluation
MRC	Medical Research Council
Mt	Mega tonnes
NAAQMN	National Ambient Air Quality Monitoring Network
NAC	Net annual cost
NACI	National Advisory Council on Innovation
NAEIS	National Atmospheric Emissions Inventory
NALEDI	National Labour and Economic Development Institute
NAMA	Nationally Appropriate Mitigation Action
NC	National Communications
NCCC	National Committee on Climate Change
NCCRD	National Climate Change Response Database
NCCRP	National Climate Change Response Policy
NCPC	National Cleaner Production Centre
NDA	National Designated Authority
NDHSP	National Department of Health and Strategic Plan
NDP	National Development Plan
NECSA	Nuclear Energy Corporation South Africa
NDE	National Designated Entities
NERSA	National Energy Regulator of South Africa
NFCS	National Framework for Climate Services
NGHGIS	National Greenhouse Gas Inventory Management System
NGO	Non-Governmental Organisation

NIE	National Implementing Entity
NMMU	Nelson Mandela Metropolitan University
NPC	National Planning Commission
NRF	National Research Foundation
NSI	National System of Innovation
NTCSA	National Terrestrial Carbon Sinks Assessment
NWIBR	National Waste Baseline Information Report
NWU	North-West University
ODINAFRICA	Ocean Data and Information Network for Africa
OFO	Organising Framework for Occupations
OEM	Original Equipment Manufacturer
OQSF	Occupational Qualifications Sub-framework
PPD	Peak, plateau and decline
PES	Payment for Ecosystem Services
QCTO	Quality Council for Trade and Occupations
RE	Renewable Energy
REDISA	Recycling and Economic Development Initiative of South Africa
REI4P	Renewable Energy Independent Power Producer Procurement Programme
RSSC	Regional Science Service Centre
RVAC	Risk and Vulnerability Assessment Centre
RVSC	Risk and Vulnerability Science Centre
SAAMIIPP	Southern Africa Agricultural Model Intercomparison and Improvement Project
SAAQIS	South African Air Quality Information System
SABAP	Southern African Bird Atlas Project
SABC	South African Broadcasting Corporation

SABIF	South African Biodiversity Information Facility
SABS	South African Bureau of Standards
SACCCS	South African Centre for Carbon Capture and Storage
SACE	South African Council of Educators
SADC	Southern African Development Community
SADCO	Southern African Data Centre for Oceanography
SAEON	South African Environmental Observation Network
SAEOSS	South African Earth Observation System of Systems
SAFFG	South African Flash Flood Guidance System
SA-GEO	South African Group on Earth Observations
SAIAB	South African Institute of Aquatic Biodiversity
SA-ICON	South African Carbon Observatory Network
SAISI	South African Iron and Steel Institute
SALDN	South African Lightning Detection Network
SALGA	South African Local Government Association
SANAE	South African National Antarctic Expedition
SANAP	South African National Antarctic Programme
SANBI	South African National Biodiversity Institute
SANEDI	South African National Development Institute
SANParks	South African National Parks
SANSA	South African National Space Agency
SAPIA	South African Petroleum Industry Association
SARChI	South African Research Chairs Initiative

SARFFG	South African Regional Flood Guidance System
SARUA	Southern African Regional Universities Association
SAQA	South African Qualifications Authority
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SAURAN	Southern African Universities Radiometric Network
SAWEP	South African Wind Energy Project
SAWS	South African Weather Service
SETA	Sector Education and Training Authority
SHADOZ	Southern Hemisphere Additional Ozonesondes
SNC	Second National Communication
SOCAT	Surface Ocean CO2 Atlas
SOCCO	Southern Ocean Carbon and Climate Observatory
SOSCEx	Southern Ocean Seasonal Cycle Experiment
START	System for Analysis Research and Training
SWWS	Severe Weather Warning System
TAP	Technology Action Plan
TDA	Transboundary Diagnostic Analysis
TECH4RED	Technology for Rural and Educational Development
TIA	Technology Innovation Agency
TLIU	Technology Implementation Unit
TNC	Third National Communication
TRS	Total Reduced Sulphur
TSP	Total Suspended Particles
TUT	Tshwane University of Technology
TVET	Technical, Vocational Education and Training

UCT	University of Cape Town
UH	University of Helsinki
UL	University of Limpopo
UKZN	University of KwaZulu-Natal
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UP	University of Pretoria
USAID	United States Agency for International Development
UT-LS	Upper Troposphere-Lower Stratosphere
UWC	University of Western Cape
WAM	With additional measures
WASA	Wind Atlas for South Africa
WCRP	World Climate Research Programme
WDCBHH	World Data Centre for Biodiversity and Human Health
WEM	With existing measures
WESSA	Wildlife and Environment Society of South Africa
WIO	West Indian Ocean
WITS	University of the Witwatersrand
WMO	World Meteorological Organization
WOM	Without measures
WRC	Water Research Commission
WWF	World Wide Fund for Nature

Executive Summary

The initial National Communication in accordance with Article 12 of the United Nations Framework Convention on climate Change (UNFCCC) was prepared in 2004, followed by the second communication in 2011. This document constitutes South Africa's Third National Communication (TNC). The document follows suggested UNFCCC guidelines for developing countries in reporting on national circumstances; a national Greenhouse Gas (GHG) Inventory for the period 2011-2012; climate change over South Africa in terms of trends and projected changes, vulnerability assessments and national adaptation strategies; measures to mitigate climate change; and other information relevant to the Convention (including a technology needs assessment, research and systematic observations and climate change education, training, awareness and capacity building needs).

National Circumstances

Chapter 1 provides an overview of the national circumstances in terms of describing the geography, climate, environmental and socio-economic profiles of the country with emphasis on sensitivity to climate change and climate variability. South Africa has made significant advances in climate policy since the publication of the Second National Communication. These advances are highlighted through national development programmes, plans and strategies from 2011-2015. Chapter 1 describes the planning and reporting documents prepared at a national level as part of international reporting commitments. These documents serve to inform national and regional priorities to address climate change concerns within the framework of national development programmes, plans and strategies.

South Africa's institutional arrangements for preparing National Communications are outlined along with the national institutional framework for the effective implementation of measures to meet the objectives of the convention.

National Greenhouse Gas Inventory

The National greenhouse gas inventory for the period 2000 to 2012 is presented in Chapter 2 and the results are illustrated in Figure ES1 (below). The annual GHG inventories for the period 2000 to 2010 were recalculated based on availability of improved activity data and updated emissions factors.

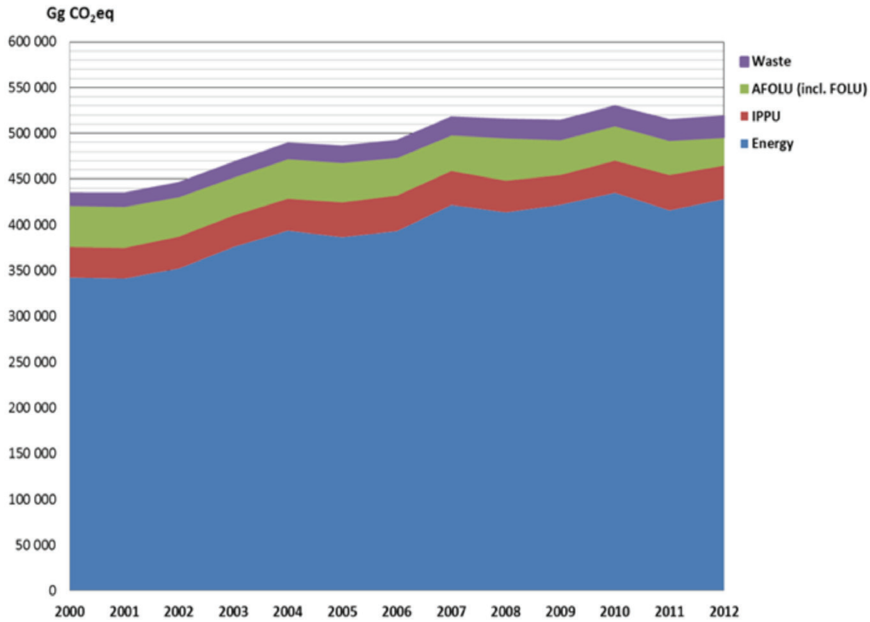

Figure ES1: South Africa's Greenhouse Gas Inventory for the period 2000-2012 (DEA, 2017).

South Africa's net GHG emissions for 2012 amounted to 518.3 $GgCO_2e$, which includes the contribution from forestry and other land-use (FOLU), as this sector acts as a carbon sink by absorbing and holding carbon. The gross annual GHG emissions (excluding FOLU emissions) for 2012 totalled 539.1 $GgCO_2e$. With the inclusion of FOLU, The energy sector accounted for 78.9% of the net emissions in 2000 and this increased to 82.6% in 2012, amounting to 428.1 $GgCO_2e$ of the 2012 net GHG inventory. This showed a 25% increase in emissions from the energy sector from 2000 to 2012. The GHG emissions from the IPPU, AFOLU and Waste sectors increased collectively by 20.9% from 2000 to 2012; with emissions from the IPPU and Waste sectors showing an increase of 10.6% and 78.5% respectively, while emissions from the AFOLU sector decreased by 32.1% between 2000 and 2012.

South Africa's net GHG emissions in 2012 were predominantly CO_2 (83.7%), followed by CH_4 (10.7%) and N_2O (4.9%), with F-gases contributing less than 1% to the National GHG Inventory. The CO_2 and CH_4 emissions contributing to the net National GHG Inventories (i.e. the inventories which include FOLU contributions) increased by 21.2% and 14.6% respectively for 2000 and 2012, and showed a 23.9% and 15.1% increase respectively in the 2000 and 2012 gross National GHG Inventories (i.e. the inventories excluding the FOLU contribution). N_2O emissions showed a decline of 5.6%, while PFC emissions doubled between 2000 and 2010. HFC emissions (only included from 2005) increased by 65.8% between 2005 and 2012.

The recalculation of emissions for the period 2000-2010, was conducted as improved activity data and emissions factor were available. For the Energy sector, country-specific CO_2 emission factors were incorporated, and these changes led to a 1.5% and 1.6% change to the 2000 and 2010 estimates. This translated to a 1.3% increase in the net national net total for 2010. The IPPU emissions were recalculated due to updates in the iron and steel production emission factors, updated ferromanganese activity data and updated Ozone Depleting Substances (ODS) and zinc production data. The recalculation resulted in a 20% reduction in the GHG emissions from the IPPU sector in 2010; mostly because of the adjusted emission factor for the iron and steel production calculations. The recalculations performed for the AFOLU sector had the largest impact on the total emissions with a 50.4% and 49.6% increase for 2000 and 2010, respectively. The majority of these changes were due to the availability of updated land change maps and corrected HWP estimates. These increases impacted the national net total by a 3.5% and 2.4% increase in 2000 and 2010, respectively. The 2012 NIR reports that recalculations of the 2000 GHG emission for the Waste sector led to a reduction of 1.2% of the annual estimates for 2000, but the estimates for 2010 increased by 2.8%. These changes were as a result of the availability of updated information and statistics of waste generated and waste disposal.

South Africa's climate: Observed trends and projected futures

South Africa has been warming significantly over the period 1931-2015. Over the western parts of the country, including much of the Western and Northern Cape, and also in the east over Gauteng, Limpopo and the east coast of KwaZulu-Natal, the observed rate of warming has been 2 °C/century or even higher – in the order of twice the global rate of temperature increase. Associated increases in the annual number of hot days have also occurred, but there have been decreases in the annual number of cold nights over most of the country. There is strong evidence of statistically significant increases in rainfall occurring over the southern interior regions, extending from the western interior of the Eastern Cape and eastern interior of the Western Cape northwards into the central interior region of the Northern Cape, over the period 1921-2015. Extreme daily rainfall events have increased over these same areas, with these increases also being statistically significant and extending northwards into North West, the Free State and Gauteng. Over Limpopo there is strong evidence of statistically significant decreases in annual rainfall totals.

Significant progress has been made in South Africa since the Second National Communication (SNC), in terms of the local generation of detailed regional climate futures for the country. Extensive ensembles of projected climate change futures have been available for the TNC, derived using both statistical and dynamical downscaling techniques. These projections make feasible the identification of plausible climate futures for each of the South African provinces, and in some cases, the identification of actionable messages for adaptation. A key feature of the projected climate change futures of South Africa is that temperatures are to increase drastically under low mitigation. For the far-future period of 2080-2099, temperature increases of more than 4 °C are likely over the entire South African interior, with increases of more than 6 °C plausible over large parts of the western, central and northern parts. Such increases will also be associated with drastic increases in the number of heat-wave days and very hot days, with potentially devastating impacts on agriculture, water security, biodiversity and human health. The model projections are indicative that a modest-high mitigation pathway can still significantly decrease the amplitude of this warming – most projections suggest that under RCP4.5, for example, temperature increases over the interior can be constrained to 2.5 to 4 °C. Nevertheless, it should be realised that South Africa is committed to relatively large (compared to the global average) increases in near-surface temperatures, even under high-mitigation futures.

Under low mitigation it is also likely that the larger Southern African region will experience generally drier conditions, already by the mid-future (2046-2065) but particularly in the far-future (2080-2099). This pattern is projected robustly by GCMs and their statistical and dynamic downscalings, and is of great significance: South Africa exhibits even under present-day climate a generally dry and warm climate – should this low mitigation future of significantly hotter and drier conditions materialise, it will greatly limit the available opportunities for adaptation. It may be noted that under low mitigation, a minority of downscalings are indicative of rainfall increases over the central interior of South Africa, and/or over the southern interior regions and the Cape south coast. Moreover, extreme convective rainfall events are projected to plausibly increase over the interior regions under low mitigation, even in the presence of a generally drier climate. Under high mitigation, the projections are indicative of potentially very different rainfall futures for South Africa. Even under RCP4.5, a modest-high mitigation pathway, the projected pattern of drying is significantly weaker. In fact, a fairly large number of projections are indicative of generally wetter conditions over the central and eastern interior regions, whilst the remaining projections remain indicative of generally drier conditions. This, in combination with the significantly reduced warming that is projected for southern Africa under high mitigation, emphasise how important it is for South Africa to strive for a (global) high mitigation pathway.

Risk and vulnerability analysis

The concept of vulnerability has become increasingly important in the climate change research community, with extensive developments taking place in the vulnerability assessment field over the last few decades. The complexity involved in defining and measuring the various geographical, spatial, temporal and social dimensions of vulnerability has resulted in a multitude of methodologies for assessing and understanding vulnerability. As a consequence there is generally a lack of consensus regarding the appropriate frameworks and 'best' methodologies for assessing vulnerability. In South Africa, there is no standard approach or best practise guidelines for measuring vulnerability. This makes monitoring of vulnerability and the evaluation of adaptation measures considerably challenging, and precludes comparing different sectors or localities as well as assessing vulnerability over time. A component of Chapter 3 is dedicated to strengthen future vulnerability assessment work in South Africa by building on a number of currently available tools such as the Let's Respond Toolkit, South African Risk and Vulnerability Atlas (SARVA), and the Climate Change Response Plan Toolkit. Building on South African expert insights and recommendations, practical translations of how to conduct vulnerability assessments are presented. A number of South African case study examples are presented.

In South Africa, there is a constantly growing body of sectoral knowledge on climate change vulnerability. The country saw a great expansion of information from the Second National Communication (2011) to the much more detailed and in-depth LTAS reports (2013/2014). Building upon the work conducted in the Long Term Adaptation Scenarios (LTAS) Research programme (DEA 2013), Chapter 3 reviews and prioritises the most significant climate change risks and vulnerabilities for the following sectors; Agriculture and Forestry, Water Resources, Forestry, Terrestrial Ecosystems, Coastal Zone, Health, Urban and Rural Settlements, and Disaster Risk Management. A summary of the key impacts of climate change on these sectors in shown in Table 1 on the next page.

Table 1: Summary of the vulnerability of key socio-economic sectors in South Africa to climate change

	Sensitivity analysis	Exposure Analysis			Adaptation priorities
Sector	*Current stresses to the systems*	*Change in climatic driver (top priority)*	*Potential future consequences*	*Geographical Area*	*Actions required to cope*
Agriculture and Forestry	• Land use and change • Water stress • Invasive alien plants	↓ rainfall	Reduction in yields	KZN, Mpumalanga, Western Cape	• Climate Smart Agriculture • Conservation Agriculture
		Δ rain distribution	Impact crop production	All 9 provinces	
		↑ heat waves	Increase pressure on water resources	All 9 provinces	
Coastal zone	• Direct wave impacts, coastal flooding and inundation, and erosion and under-scouring • Land use change	Provinces with a coastline: • Intrusion of saltwater • Loss of or changes to coastal wetlands • Higher (ground)water levels and limited soil drainage • Flooding of low-lying areas and resultant damage erosion of beaches and bluffs			• Land use planning • Designation of flood areas/ high risk areas and development - free zones • Construction of dykes, groynes, bank protection, sea walls • Beach nourishment, dune protection
Health	• Quadruple burden of disease in SA and people from neighbouring countries • Poor housing, infrastructure and service delivery • Change in geographical distribution of diseases e.g. Malaria might spread southward. New diseases might develop. • Water supply, agriculture, catastrophic events may have short and long term effects on the health of the population. It would be essential to include these contributing factors and their health impacts in the sensitivity analysis.	• A changing climate can have a myriad of impacts on the health sector • There is a lack of understanding on the linkages between climate and health in South Africa (e.g. quantitative link between high temperatures and mortality)			• Cross-sectoral cooperation and collaboration • Tailored Adaptation strategies to regions or communities based upon their risks and vulnerability • Measuring / monitoring the effects of climate change on health will be very important. This will assist us to develop data and information on vulnerability as we go. The data could inform future plans.
Terrestrial Ecosystems	• Habitat fragmentation • Land use change • Invasive alien plants	• Rising temp • Temp extremes • Dec/increase in rain amount • Rising CO_2 • Changes in fire	• Climate change will lead to changes across the biomes through the alteration of existing habitats, seasonal rainfall, species distribution, and changing ecosystems functioning. • Threats vary in importance between the biomes, increase over time, and increase with the level of GHG.		• Land use planning • Land management • Ecosystem-based adaptation • Mainstreaming of stewardship programmes • Monitoring and evaluation
Urban and Rural Settlements	• Deficit in infrastructure and provision of services	• Different human settlement types and locations having varying vulnerabilities and capacities will experience the hazards • Informal settlements and their population being the most exposed			• DRM • Mainstreaming of no-regret interventions • Principals of water sensitive urban design (WSUD) and consideration for ecological infrastructure
Water Resources	• High water demand: current water usage already exceeds reliable yield • High levels of variability in rainfall from year to year, resulting in frequent floods and droughts • Deteriorating water quality of major river systems, water storage reservoirs and ground water resources (e.g. acid mine drainage)	↓ rainfall	• Increase in water demand from agriculture, power generation, settlements		• National water policies, plans and funds mainstream climate change adaptation • Monitoring and information needs to be appropriately designed • Infrastructure development, operation and maintenance • Groundwater needs to be protected by preventing groundwater degradation and unwise exploitation
		↑ intense rainfall	• Increased erosions and sedimentation of dams and rivers		
		↑ temperature	• Increase evaporation loss from dams • Affect biological and microbiological processes		

The South African agricultural sector is highly diverse in terms of its activities and socio-economic context. The agriculture sector employs approximately 860 000 people and is critical in terms of national food security as well as supporting thousands of urban and rural households in terms of subsistence agriculture and small scale production. The sector is considered to be one of the most critical economic sectors in terms of potential impacts of climate change in South Africa. Agriculture is impacted directly by changes in precipitation, temperature and evaporation and through secondary impacts including disaster risk and health issues. The most significant climate change risks and vulnerabilities to agriculture in South Africa include increasing temperatures and more variable precipitation that are likely to have significant impact on a wide variety of crops and forestry products. The yields of rain-fed crops such as maize, wheat and sorghum are likely to be affected most drastically, whilst irrigation demands projected to increase due to increased temperatures. Moreover, more extreme temperature events will directly impact farm labour through enhanced heat stress conditions. Livestock production will also be negatively affected under oppressive temperatures. Adaptation strategies in agriculture include the implantation of Climate Smart Agriculture, improved water management, improved monitoring and early warning, the development of knowledge and decision support systems, and the development of new crop varieties and technologies to support farming.

The interaction between climate change stressors, estuarine processes and features and biotic responses are complex, with multiple interactions which can both amplify and moderate responses. Analysis shows that KwaZulu-Natal and West Coast estuaries will be the most influenced by climate change from a structural and functional perspective. This is contrary to the current monitoring programmes which are focussing on biotic responses in the biogeographic transition zones (e.g. the Transkei and western Southern Cape). In the case of KwaZulu-Natal the major driver of change is increased runoff into the numerous small, perched temporarily open/closed estuaries, which may result in more open mouth conditions, a decrease in retention time and a related decrease in primary productivity and nursery function. In contrast, west coast estuaries may be negatively impacted as a result of reduction in runoff, related decrease in nutrient supply and an increase in sea level rise. This in turn may increase salinity penetration in permanently open estuaries and increase mouth closure in temporarily open ones. Similar to KwaZulu-Natal, west coast estuaries will experience a decline in primary production and loss of nursery function. Although Wild Coast, Eastern and southern Cape estuaries may show some shifts in mouth states, nutrient supply, salinity distribution and ultimately production (e.g. fisheries), the most likely impacts of climate change along these coastal regions will be the change in temperature (nearshore and land), associated species range expansions or contractions and changes in community structure. The bimodal rainfall zone of the Southern Cape is projected to plausibly exhibit an increase in the frequency and magnitude of large floods as well as the duration and intensity of droughts. This region is characterised by medium to small catchments wherein bimodal rainfall ameliorates flow variability and confers a degree of stability on estuarine habitats. An increase in the magnitude of floods can cause deeper scouring of mouth regions, thereby increasing tidal amplitude and exposure of subtidal habitats and communities. The effect of sea level rise, and related increase in tidal prisms, will be less apparent along the KwaZulu-Natal coastline, where with the exception of estuarine lakes and bays, the majority of estuaries are perched whilst it will be more apparent along the southern and Western Cape coast with their more extended coastal floodplains.

South Africa exhibits multiple risks that contribute to the overall burden of disease (i.e. the quadruple burden of disease), which currently puts stress on the health sector. This stress may make the sector as a whole more vulnerable to climate change due to additional stress a changing climate may put on the system. South Africa does have health policies in place, but action is needed to implement these. The challenging burden of disease in South Africa may make people more vulnerable to the health impacts from climate change (e.g. through pre-existing conditions). However, the impact of pre-existing conditions on the resultant health impact from climate change in South Africa is not quantified. There is a lack of understanding on the linkages between climate and health in South Africa (e.g. quantitative link between high temperatures and mortality). Thus, the current impact of climate-related diseases is not quantified, nor is the vulnerability of communities to such risks. Without a better understanding of the current health burden, it is not possible to understand how climate-sensitive health risks will change in a changing climate. A quantitative vulnerability and risk assessment for the health sector should be performed; this would help to identify the most important health risks, as well as begin to identify the most vulnerable populations or communities. Adaptation strategies can then be tailored to region or communities based upon their risks and vulnerability. The South African health system is also vulnerable to the health status and disease burden of people from neighbouring countries. For example, a majority of malaria in South Africa is not from local transmission. The potential impact on the health sector from climate change has both public and occupational health implications, and both of these aspects need to be considered in adaptation plans.

The climate variability and change threats to terrestrial ecosystems include rising average temperatures, more temperature extremes, changes in rainfall intensity and magnitude, a higher likelihood of extreme events (such as droughts, floods, heat waves, etc.) throughout South Africa, shifting rainfall season, sea level rise and rising atmospheric concentrations of carbon dioxide (CO_2). In addition, non-climatic conditions such as changes in the occurrence, seasonality and severity of fire and land use change resulting from climate variability and change are also presented in this report. These threats vary in their importance between the biomes, increase over time through the 21st century, and increase with the level of greenhouse gas emissions globally.

The nature of human settlements in developing countries makes them particularly vulnerable to the potential impacts of climate change. Each of the settlement types (urban, informal settlements, rural and coastal) have variable vulnerability and exposure to the projected impacts of future climate changes. These variabilities are as a result of Apartheid legacy, spatial variabilities, planned and unplanned growth and dispersion patterns, topography and numerous socioeconomic factors. Addressing the vulnerabilities of the risk areas is a priority for building resilience to climate changes. Different human settlement types and locations having varying vulnerabilities and capacities will experience the hazards associated with the present and future climate changes to an unequal extent. Higher vulnerability and lower coping capacity areas will have increased risk exposure to climate related hazards; informal settlements and their population being the most exposed. Projected climate changes are likely to compound the impacts felt by the most exposed populations and therefore building adaptive capacity in these areas should be a priority. A deficit in infrastructure and provision of services in some areas acts as barriers to adaptation and increases vulnerability to climate change. This can be compounded by a lack of resources, unclear regulations and unexpected consequences resulting from previous mal-adaptation or poor development practices. Reducing capacity for necessary operation and maintenance is also contributing to the failure of critical infrastructure needed to mitigate the potential impacts and development risks associated with climate change. The development of human settlements impacts on many other sectors such as transport, energy, water and food production and as such a renewed focus on climate compatible development for human settlements will result in reduced climate change risks and vulnerabilities in these associated sectors.

In terms of disaster risk management, climate change is likely to increase existing vulnerabilities to disaster risk. South Africa's history and resulting urban form has resulted in a high level of vulnerability to disaster risk that must be addressed. Addressing existing issues of lack of development will also provide benefits in terms of reducing the risks and vulnerabilities to climate-related disasters. One of the most significant developments since the SNC, has been the Disaster Management Amendment Act No.16 of 2015. The Act now explicitly provides for the inclusion of climate change in disaster risk assessments through all spheres of government and mandates measures to reduce the risk of disaster through adaptation to climate change and the development of early warning mechanisms. Mainstreaming risk reduction, adaptation and management into development activities are important policy goals for responding to climate change and disaster risk and requires a shift in thinking towards more pro-active risk reduction and adaptation planning from a current largely re-active system.

Under an unconstrained greenhouse gas emissions scenario, modelling results suggest a change in runoff that lies between a 20% reduction to a 60% increase. If global emissions are constrained the risk of extreme increases and reductions in runoff are sharply reduced, and the impacts lie between a 5% decrease and a 20% increase in annual runoff. Climate change will affect water quality but in many areas the impacts may be masked by changes in land use, or compliance to effluent standards. Some of the impacts can be foreseen and can be mitigated by careful planning to include potential climate change in water quality management strategies.

Climate Costs

Given the significant vulnerabilities identified across the sectors of water, agriculture, forestry and health, and for urban and rural settlements, the coastal zone and ecosystems, Chapter 3 builds a strong case for an important future area of work in vulnerability analysis, namely the estimation of climate costs. It is important to quantify how future changes in the mean climate and in the attributes of extreme events may increasingly impact on the South African economy. Such costs may be incurred directly through for example reduced crop yield and damage in infrastructure, but also indirectly through downstream effects to the economy (e.g. reduced crop yield leading to increasing food prices). Moreover, it is important to estimate to what extent investments in adaptation interventions can alleviate climate costs, as a justification for these interventions. Such cost estimations will be of immense value for South Africa (and for developing countries in general) to negotiate fair support from for example the Adaptation Fund of the United Nations Framework Convention on Climate Change (UNFCCC). It is important for such estimations of climate costs, and the costs of adaptation investments, to be performed against the background of the socio-economic futures of South Africa – this is due to the strong dependence of climate vulnerability on the socio-economic state of a country. An increased research thrust is therefore also needed for the development of socio-economic futures for South Africa, including how these futures may be influenced by a changing climate.

Status quo analysis of adaptation options

South Africa has presented its commitment to responding to climate change challenges through the development of the National Climate Change Response Policy (NCCRP) in 2011. However, the country is a developmental state that seeks to develop the economy and reduce the levels of inequality and poverty experienced. It is recognised that climate change is likely to impact on the ability to meet these development goals. As such the country has presented its commitment to tackling climate change through the development of its Intended Nationally Determined Contributions (INDCs). The INDC outlines the overall aspirations for adaptation and provides the timelines and levels of investment needed to achieve these goals. Whilst the INDC represents the broader vision for adaptation planning that is aligned with the National Development Plan, significant progress has already been made with respect to developing the adaptation response strategies that are aligned to short-to-medium term policies and strategies.

At a sectoral level, adaptation plans have been developed for the key socio-economic sectors identified in the NCCRP as being vulnerable to climate change. In the water sector for example, the Climate Adaptation Strategy for the sector outlines a number of strategic adaptation actions for addressing climate change impacts. These options range from planning for new dams to developing new groundwater sources and further highlights the need to improve flood warning systems and to ensure that water allocation is sufficiently flexible to cope with climate change. Importantly, the strategy also highlights the need to protect water allocations to poor and marginalised communities, particularly under drought conditions. In the case of Agriculture, Forestry and Fisheries, sector-related climate change strategies have also been initiated which includes a Climate Change Sector Plan and a Climate Change Adaptation and Mitigation Plan that addresses agriculture and forestry. Climate Change Adaptation Plans have also been developed for South Africa's Biomes, presenting potential adaptation responses to guide current and future decision makers in protecting South Africa's natural ecosystems and biodiversity in the face of climate change. A climate change adaptation plan has been developed for the health sector that focusses on nine health and environmental risks and further seeks to improve health systems readiness to climate change.

Adaptation planning within South African cities is occurring alongside the need to address the problems of poor spatial and development planning inherited from the apartheid era. Human settlement typologies in the country are diverse, each with its own set of developmental challenges and potential to be impacted by climate change. A Climate Change Adaptation Sector Plan for Rural Human Settlements has been developed to support the creation of sustainable livelihoods that are resilient to climate change. This plan calls for access to climate resilient services and infrastructure in rural areas to be promoted through climate resilient rural housing programmes that include rainwater harvesting, solar water heaters and off-grid/mini grid electrification, environmentally-friendly and socially acceptable sanitation solutions. In addition to this plan, policies that impact on human settlement design and development require the inclusion of climate change considerations. For example, spatial planning and land-use management legislation requires incorporating environmental requirement such as climate change. The Integrated Coastal Management Act 24 of 2008 also requires that coastal provinces and municipalities develop management programmes that allow for potential climate change impacts to be taken into account in all coastal planning and management. Further to this, amendments to the country's disaster risk management legislation require all organs of state to not only indicate how it will invest in disaster risk reduction but also climate change adaptation. As such, at both a provincial and local government level, numerous adaptation plans have been developed or are underway. At a national level, the country has also embarked on a process to develop a National Adaptation Strategy that will consolidate and prioritise these local, provincial and sectoral adaptation options. The country has also recognised that it has a responsibility to effectively report on its adaptation initiatives and investments, and has thus developed a Monitoring and Evaluation (M&E) system that will be used to track progress toward becoming climate resilient.

South Africa's Measures Undertaken to Mitigate Climate Change

Policies and measures to mitigate climate change

The South African Constitution is the supreme law governing the country and all other laws and policies need to align with it. Key policies and measures guiding the country's efforts to stabilise GHG emissions have been developed in conjunction with private sector and civil society. A number of these policies and measures incorporate a climate change focus, demonstrating the nation's commitment to mitigation and adaptation efforts. These policies include the National Development Plan 2030, the New Growth Path and the National Climate Change Response White Paper. The government has also made significant investments in research and mitigation activities to ensure the national climate change goals are met, for example, the Long Term Mitigation Scenarios study and the Mitigation Potential Analysis that followed. South Africa is actively driving future mitigation measures to respond to climate change by means of the Draft Carbon Tax Bill, for example, which was released in 2015 for public comment and is expected to be implemented in 2017. Other key anticipated activities to support carbon tax include the development of desired emission reduction outcomes and company level carbon budgets. South Africa has also implemented many sector-specific climate change initiatives in the energy, industry, transport, agriculture forestry and other land use and waste sectors.

Energy

In the energy sector, South Africa's policies and measures to mitigate climate change broadly aim to provide support for mitigation actions, diversify electricity generation and liquid fuel sources, facilitate carbon capture and storage, promote energy efficiency and reduce coal bed methane. Government's initiatives include the Department of Energy's Renewable Independent Power Producer Procurement Programme, which has been widely recognised as an innovative and successful measure for developing the local renewable energy market. A further highlight is the cumulative, national energy efficiency savings of at least 23% which occurred between 2000-2012. These energy efficiency savings surpassed the target of 12% outlined in the National Energy Efficiency Strategy.

Industry

One of the actions of the National Development Plan in the context of climate change related to the industry sector is the carbon-pricing mechanism. Carbon pricing is supported by a wider suite of policy mitigation instruments to drive energy efficiency. Green industry investments are a key focus area and updates are made annually through the Industrial Policy Action Plan. In this sector, the Department of Trade and Industry has provided various incentives related to the development and use of green technologies adding to the mitigation efforts in the sector. Mitigation initiatives are also supported by National Treasury through various tax rebates in the Income Tax Act of South Africa. The Department of Energy has been driving the development of low-carbon initiatives in the industry and South Africa is a host party to 56 registered projects and 35 registered programmes forming part of the Clean Development Mechanism.

Transport

The transport sector mitigation opportunities identified for the country fall under the following broad categories: modal shift; demand reduction measures; more efficient vehicle technologies; more efficient operations and alternative lower-carbon fuels. The Department of Transport leads the development of initiatives aimed at reducing emissions in the transport sector, the biggest being public transportation. Some of the activities that the country is developing and implementing include biofuel programmes as well as support of the local electric vehicle industry in South Africa through several strategic new technology interventions.

Agriculture, Forestry and Other Land Use

This category includes production and removal of emissions. There are three key policies that relate to climate change mitigation. The National Forests Act which supports activities that sequester GHG emissions such as those relating to sustainable management, conservation and protection of natural forests and woodlands. The Woodlands Strategy Framework outlines mitigation principles for the sector. Woodlands which cover about 30% of the land surface area are important due to their fire adaptation potential and potential as carbon sinks or sources. The Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries of 2013 outline mitigation elements for this sector and promotes minimum tillage and land use changes that convert land from GHG sources to sinks.

Waste

The two main policies for the waste sector are the National Environmental Management: Waste Act and the National Policy on Thermal Treatment of General and Hazardous Waste which recognise the significance of mitigating climate change. The National Waste Management Strategy (a legislative requirement of the Waste Act) promotes waste minimisation, re-use, recycling and recovery and has a key output of reducing the GHG emission to mitigate climate change and improve air quality. These objectives are supported by the Municipal Waste Sector Plan which highlights waste reuse, waste recycling and flaring or recovery of landfill gas.

Monitoring and evaluation of policies to reduce GHGs

South Africa has initiated the development of a National Climate Change Response Monitoring and Evaluation System Framework which is planned for official endorsement in 2016. The main objective of the system will be to track the country's transition towards its long-term vision of a climate-resilient and lower carbon economy and society. Mitigation and lower carbon development strategies will be formulated for each significantly emitting sector or sub-sector. The strategies will include measurable and verifiable indicators for each programme and measure. The monitoring and evaluation system will cover all aspects of climate change monitoring and evaluation and will be coordinated by the Department of Environmental Affairs. The system should be completed and implemented in 2017.

South Africa's projections to mitigate climate change

As part of the Mitigation Potential Analysis, 2014 process, projections were made for 2020, 2030 and 2050 with projected GHG emissions trajectories categorised by the sectors, energy, transport (subcategory of energy), industrial processes and products use, agriculture forestry and other land use, and waste. At the time of writing the mitigation chapter, the Mitigation Potential Analysis represented the most current research undertaken at a national level on mitigation. The Mitigation Potential Analysis required reference data as a baseline for the projection scenarios. The Mitigation Potential Analysis therefore used the National GHG Inventory: 2000-2010 as the departure point for the projection scenarios because it was the latest availble inventory in the public domain at the time of research related to the Mitigation Potential Analysis. The national inventory has subsequently been updated to include data up to 2012, but was not publicly available at the time of writing the mitigation chapter and was therefore not used as a basis for the projections in this chapter.

Socio-economic projection scenarios

Three mitigation trajectories were developed for South Africa's economic growth path: low; medium and high economic growth. The baseline economic growth trajectory was forecast at 4% for the medium term and 4.3% per annum over the long term. The low economic growth trajectory was forecast at 3.8% growth rate for both the medium and long term. The medium economic growth trajectory was forecast at 4% for the medium term and 4.3% per annum over the long term. The high economic growth trajectory was forecast at 4.8% over medium term and 5.4% per annum over the long term. Projections increase steadily between 2000 and 2050. For 2020, the low and high economic growth trajectories are 3% lower and 3% higher than the medium growth trajectory (663 270 kt CO_2e) respectively. For 2050, the low economic growth trajectory's total GHG emissions are 15% lower than that of the medium economic growth of 1 592 605 kt CO_2e. The high economic growth trajectory's total emissions volume is 18% greater than that of the medium economic growth trajectory. The economic growth trajectories greatly influence emission projections particularly in the sectors of energy, transport and industry, where the largest differences compared to the medium trajectory are seen. In the energy and transport sectors, the high economic growth trajectory's emissions in 2050 are 14% higher than the medium economic growth trajectory. The low economic growth trajectory shows the opposite behaviour with emissions 13% lower than the medium economic growth trajectory for these sectors. Similarly, in the industry sector, an increase or decrease in economic growth significantly influences the total emission volumes. In 2050, emissions are 33% higher than the medium growth trajectory and 23% lower in the low economic growth trajectory.

Projections based on Mitigation Potential

Three emission trajectories were used in this scenario: without mitigation measures (WOM), with existing measure (WEM) and with additional measures (WAM). Total emissions volumes in the WOM category in 2020 and 2050 are 699 300 kt CO_2e and 1 692 472 kt CO_2e respectively. In 2020, the WEM trajectory total emissions volume of 663 270 ktCO_2e is 5% lower than the WOM trajectory, while in 2050 the total emissions volume amounted to 1 592 605 ktCO_2e (6% lower than the WOM trajectory). The WAM projection trajectory includes emissions reduction initiatives that have been earmarked for implementation across all the sectors considered. The WAM trajectory is broken up into various pathways, which assume different levels of implementation of the national mitigation potential (100%, 75%, 50% and 25%). These four pathways have different emissions associated with them. The higher the level of implementation of measures, the higher the potential emission reductions.

Emissions from International Bunkers

For the purposes of this report, the term 'International Bunkers' is used to describe emissions from the international aviation industry. Beyond 2020, there are limited numbers of abatement options remaining after the existing voluntary sectoral agreement to reduce emission from the aviation industry has been accounted for (1.5% per annum until 2020 for the international air transport industry). Biofuels will provide the most abatement potential and their cost is decreasing over time. South Africa is developing a National Civil Aviation Policy that will be used to guide the country on how best to mitigate emissions in the aviation sector.

Mitigation and financial needs assessments

The financial assessments, of the different mitigation opportunities in South Africa, relate to the potential mitigation options in marginal abatement cost curves (MACCs). These present costs and potential for emissions reduction from different measures and rank them from cheapest to most expensive to demonstrate marginal costs of achieving incremental levels of emissions reduction. The national approach for mitigating climate changes focusses on the energy sector as it has the highest contribution to South Africa's GHG emissions. For estimation of potential mitigation, all the proposed measures are assumed as implemented and evaluated against the WEM scenario. Under this "with all measures" scenario (WAM) the national mitigation potential has been estimated at 100 Mt CO_2e in 2020, 340 Mt CO_2e in 2030 and 852 Mt CO_2e in 2050. Compared with the WEM reference case; this represents a reduction of 15%, 40% and 54% for the years 2020, 2030 and 2050 respectively. The largest contributor to abatement in 2050 is the power sector within the energy sector. The MACC for the year 2020 also shows the energy sector to have the greatest potential for abatement although it would come at higher costs.

The national net annual cost (NAC) for South Africa is estimated at R 40 billion/year for the year 2020 if all measures are implemented with greater investments being taken in the Energy sector category followed by smaller in proportion investments in the industry sector.

The subsector of the energy sector with the greatest potential for abatement is electricity and heat production (28 585 kt CO_2e), where onshore wind and solar photovoltaic technologies would be the most significant contributors. The NAC for the energy sector and subsectors show the greatest cost for delivering emission reduction for 2020 to be from electricity and heating and the roads subsectors.

The abatement potential for the industry sector is estimated at 44 843 kt CO_2e for 2020 and the category has a predominantly negative marginal cost and largest emissions saving (83%) possible from interventions in the metal sector. Further significant abatement is possible from the commercial/institutional and the residential subsectors (22 026 kt CO_2e), where efficient lighting and improved thermal design of new buildings may have a major impact. The NAC for 2020 shows the higher costs for emission reduction coming from the production of ferroalloys, iron and steel, although these subsectors also have the greatest potential for emission reductions within this category.

In the waste sector (excluding industrial waste), if all mitigation potential activities were implemented, then almost 10 000 kt CO_2e could be reduced in 2020 with marginal cost of R 3 500 per tonne CO_2e abated. The main measures contributing to abatement are related to landfill gas recovery.

The MACCs for mitigation measures in the agriculture, forestry and other land use sector show potential for abatement greater than 5 000 kt CO_2e in 2020, with expanding plantations possibly contributing 45% of these reductions. The NAC for this category in 2020 is estimated at R 153 million, with almost 90% of this being allocated to restoration of mesic grasslands if all measures are implemented.

South Africa's sequestration potential

South Africa's National Sinks Assessment finds that the grassland and savanna biomes are considered the most important carbon sinks as they account for 90% of Gross Primary Production in South Africa. The National Sinks Assessment recommends that climate change mitigation activities should, therefore, be focussed within these biomes, to ensure material contributions are made to the national GHG budget.

The South African Centre for Carbon Capture and Storage is currently implementing the South African Carbon Capture and Storage Road Map to conclusively prove the Carbon Capture and Storage technology. The Road Map has five phases of which two are complete and phase three is being implemented where pilot projects are planned for a CO_2 capture plant and CO_2 storage operation. Under the CO_2 storage pilot, the first injection of 10 000 tonnes of CO_2 into a geological formation is scheduled for 2017. This will be a first for South Africa and will serve as a test for leakages and other structural challenges. The other two phases will commence pending the success of phase three. Completion of the Road Map is contingent on various financial and regulatory conditions and additional funds will be required.

Other information relevant to the convention

Technology Needs Assessment

The institutional arrangement to facilitate climate technology transfer into South Africa is facilitated by the National System of Innovation (NSI), with the Department of Science and Technology (DST) serving as its custodian. The NSI involves six sectors, namely government departments, academic institutions, science council non-government organisations, the private sector and funding agencies, all of which intersect at the national level to facilitate successful technology transfer. The South African Climate Technology Needs Assessment (TNA) is supported by the institutional arrangement provided by the NSI.

Policies and strategies that support the TNA include the National Development Plan (NDP) which provides the platform for South Africa to tackle the issues of poverty and inequality that face the country. In addition to the NDP, as the overarching strategy, government sectoral plans serve as medium term frameworks to implement government initiatives that include infrastructure. More specifically to climate change, the National Climate Change Response Policy (NCCRP) White Paper provides a policy framework for the country's response to both climate change mitigation and adaptation. Interventions proposed in the NCCRP aim to ensure that the country is able to manage impending climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity. All of the above provide the necessary policy and general government strategic framework to implement the outcomes of the TNA, supported also by the ten-year innovation plan to transform South Africa into a knowledge-based economy.

The South African climate technology transfer will focus on a list of priority adaptation sectors namely water; agriculture; biodiversity; human settlements; and forestry. The mitigation sectors are energy, industry, waste and AFOLU. On the basis of these priority sectors, the technology prioritization will be conducted on a sector by sector basis. The current technology needs assessment will include a comprehensive barrier analysis to categorise and characterise the prioritised technologies towards a technology action plan.

Research and Systematic Observations

The Department of Science and Technology (DST) is responsible for implementing the National Research and Development Strategy (DST, 2002) and the 10-Year Innovation Plan for South Africa (DST, 2007) which was developed in response to the National Climate Change Response Policy (NCCRP). It developed the 10-Year (2008 – 2018) Innovation Plan which identified five grand challenges for research. One of the grand challenges (Global Change Science) relates directly to climate change, while two others (Energy Security and Space Science and Technology) assist indirectly with climate change research. Much of South Africa's recent research has been developed around these grand challenges. In addition, the National Research Foundation (NRF) supports global change research and the Green Fund provides support for green initiatives. Government funds and international investment are also critical for the continued development of climate change science, technology platforms and systematic observations in South Africa.

All 23 universities, and 11 research organisations, are involved in promoting climate change research and systematic observations throughout South Africa. There are also contributions from some municipalities and provincial government departments. Over the past decade the number of published journal articles and book chapters related to climate change and its impacts in the country has been rising at an average rate of 16% per year.

Research covers climate systems, variability and land interactions (which includes atmospheric, marine, land and water research with a strong climate modelling and prediction component); GHG inventory support (improved activity and emission factor data); climate change impacts and adaptation (including ecosystems and biodiversity, agriculture, coastal regions, and health impacts); energy and mitigation research (including hydrogen and fuel cell technology, renewable energy, bio-fuels, alternative energy sources, energy storage technology, and carbon capture and storage).

Systematic climatic observations are carried out by the South African Weather Service (SAWS) and the Agricultural Research Council (ARC). There are weather stations throughout the country as well as stations in Antarctica, Marion Island and Gough Island. Air quality is measured at Cape Point, which is a Global Atmospheric Watch station, and from the air pollution monitoring networks (approximately 90 stations) across South Africa. Ocean research was significantly enhanced by the addition of the SA Aghulas II, which was handed over to the Department of Environmental Affairs (DEA) in 2012. On land the South African Environmental Observation Network (SAEON), with its six nodes (arid lands; Egagasini (coastal); Elwandle (coastal); fynbos; grassland, forests and wetlands; and Ndlovu (savanna) nodes) continues to be supported. There are also several flux sites where carbon dioxide is monitored on a continuous, long term basis. Over the last few years additional sites have been established to support this flux network. Global change research is supported by satellite-based observations.

South Africa has or is developing several data management and dissemination systems, such as the National Climate Change Response Database, National GHG Inventory Management System, South African Air Quality Information System, National Atmospheric Emissions Inventory System, and the National Climate Change Response Monitoring and Evaluation system. South Africa's climate change researchers collaborate with numerous local, regional and international organisations and contribute to many regional and international programmes, thereby contributing to the larger global change knowledge base.

Inclusion of Climate Change Education (CCE) in Formal Education and Training and Technical and Vocational Education and Training

South Africa has given attention to climate change in educational policy. Building on an earlier commitment to integrate an integrated, active learning approach to environmental education into all phases and levels of the education and training system as articulated in the 1995 White Paper on Education and Training (1995), the National Climate Change Response White Paper (Republic of South Africa [RSA], 2011, Section 11.2) includes a strategic goal of improving climate change education and training in South Africa, pointing out that there is a need to support understanding of the concept of climate change across disciplines and sectors in South Africa.

While progress has been made with integrating CCE into formal education, initiatives that have been started can and must still be enhanced by stronger national co-ordination to ensure systematic upscaling, co-ordination and expansion of climate change education and training initiative in key areas. Co-operation between the education sector and the environmental sector at national level is critical for this process.

Climate change has been integrated into the national Curriculum and Assessment Policy for Basic Education (Grades 1-12), but the topic-based approach is currently fragmented, and does not allow for adequate knowledge progression in climate change education and learning. There is need to strengthen an inter-disciplinary social-ecological systems approach to climate change education within a clear conceptual framework that allows for progression in learning. A national multi-stakeholder initiative has been established amongst key environmental sector partners, including DEA and Higher Education Institutions involved in Teacher Education to strengthen the systemic impact of teacher education in areas such as climate change. This programme, named the Fundisa [Teaching] for Change programme, is showing good results, and requires upscaling, and further integration into the Department of Basic Education Professional Development structures and programmes.

The Technical and Vocational Education and Training (TVET) sector is considered key in building green skills for the green economy. These 'green' skills are necessary for advancing mitigation, adaptation and climate resilient development, especially in the agriculture, water, energy, mining, waste, and biodiversity management sectors. While some pilot initiatives have been put in place the green skills agenda in the TVET sector is under-developed. There is need for lecturer training, and curriculum innovation in this sector to address climate change responsiveness, especially also in the Agricultural Colleges, where climate smart agricultural principles need to be more fully integrated into curricula. Further impetus for green skills labour market intelligence, research and planning is needed at all levels of the system, to ensure that green skills planning in South Africa is pro-active, rather than reactive. This green skills intelligence requires scaling up to articulate green occupations with the national Organising Framework for Occupations in preparation also for the National Skills Development Strategy IV period.

In Higher Education institutions, there has been an emergence of a range of teaching and research programmes focussing on climate change, and the Department of Science and Technology have supported this via pro-active funding and development of the Global Change and Energy Grand Challenges, under which a number of SARChI Chairs and Centres of Excellence have been established to develop high level scientific skills for climate change research, mitigation and adaptation. There is an expressed need for engaging more of the social sciences and humanities in climate change research, for more systemic approaches and for strengthening inter- and transdisciplinary programmes, and associated incentive systems for higher education and research communities. Additionally there is an expressed need for curriculum innovation forums to strengthen curriculum innovation in response to climate change issues.

Climate change awareness and action

Chapter 5, Section 5.3 identifies a wide range of climate change awareness and action programmes around the country, operational at different levels. There are a number of government initiated climate change awareness and action programmes at national, provincial and local government levels, but the links between these initiatives can be strengthened, especially for monitoring and evaluation purposes.

Within the NGO sector, there are also a myriad of diverse climate change awareness and action programmes on offer. These practices could potentially be better aligned with national policy directions for climate change responsiveness. A national strategy that includes the NGO sector could potentially strengthen the outcomes and impacts of these programmes. The Climate Change Adaptation Forum is a good example of how networked co-ordination across programmes can facilitate synergy and impact.

There is also a range of internationally funded climate change awareness and action programmes that are seeding innovation in approaches to climate change awareness and action, including social learning approaches at landscape level, or in response to critical issues or development priorities. These innovations need to be widely shared in order to facilitate wider uptake and thus also strengthen the impact of investments being made via funding partnerships.

The business sector is also engaged in climate change awareness and action programmes. Business and Labour have both agreed that education and training in new technologies, processes and decision making will be required for making the green transition, and for developing the green economy. Some business training programmes such as the National Cleaner Production Centre's Industrial Energy Efficiency Improvement Project in South Africa are showing significant benefits. Since 2010, this one programme has saved industry over R 1.54 billion in energy costs amounting to 1 343 GWh or approximately 1 million tons of carbon emissions saved. Strategic planning is required at the highest level to maximize such opportunities via skills development. While these opportunities exist, skills planning and development are still re-active rather than pro-actively aligned with green economy developments.

The Media are also engaged in climate change awareness and action programmes. Television, newspapers and magazines are currently three of the strongest forms of media to be used for climate change awareness and action. Areas that are as yet un-developed for climate change education and public awareness is use of social media and community radio. Facebook alone reaches 11.8 million people in South Africa, and Twitter is gaining ground as a medium of choice for communications. Yet few climate change campaigns or awareness raising initiatives are currently using these media forms. Similarly, community radio reaches 8.6 million listeners per week, yet community radio stations are lacking in climate change knowledge and journalistic support. Training of journalists in climate change-related stories, approaches and priorities is also needed.

In developing an action plan for awareness raising and materials, it was found that as there are so many diverse programmes, materials and initiatives already in existence investment would be better allocated towards enabling synergies, and policy alignment amongst these initiatives. There is also need to support education, training, media and social learning practitioners to adapt climate change information to local contexts and circumstances, and to develop quality criteria for their programmes and activities. Active learning, social learning and empowerment oriented approaches should be strengthened in all materials.

Overall, it is suggested that a national strategy on climate change education, awareness and action with indicators that are policy aligned can support a more cohesive approach to climate change education, training, awareness and action.

Capacity building needs

There are a number of areas where capacity building for enhancing climate research and systematic observations, climate change mitigation, climate change adaptation, and climate change education, training and public awareness is required. These include:

Capacity building for climate change research and systematic observation

- Strengthen climate change social science research.
- Support the development of more integrative and systemic approaches to studying climate change.
- Develop more sustained and sustainable funding frameworks for climate change research and systemic observation.
- Continue to support research into systemic observations, with emphasis on gaps and needs for further research.

Capacity building for GHG Inventory Development, climate change adaptation and climate change mitigation

- Improve capacity for updating data and associated reporting capacity.
- Provide sustained funding and support to mitigation efforts including the GHG Inventory Improvement Programme.
- Support training and implementation for mitigation assessment and practice. Such training should be in the form of short courses to support immediate needs, and as a postgraduate course to develop longer term capacity for the future. The courses should be designed to cover the various aspects of the GHG inventory update process.
- Support sector-specific priority data generation processes to improve the GHT inventory, especially related to country specific emission factors in all sectors. There is an urgent need to improve data in the transport and waste management sectors, as well as land use change maps and agricultural data in the AFOLU sector.
- Support South Africa's capacity to adapt to climate change. It is essential that if South Africa wants to successfully translate existing and forthcoming climate change response strategies and plans into adaptation action greater attention needs to be paid to strengthening its existing adaptive capacity.
- More resources (in terms of finances, human capacity, access to information and research) and institutional capacities (cross-sectoral climate specific fora and working groups, partnerships and learning possibilities) are required for all three spheres of government as well as individual sectors (e.g. agriculture, water resources).
- New skills sets and dedicated climate change personnel are particularly important for addressing long term climate change. Until now little practical experience for implementing interventions related to long term climate change exist (with the exception of some interventions focussing on topics such as sea level rise). However, this will be critical for taking advantage of arising opportunities and for moving South Africa into a climate resilient future.
- Local governments, who have the primary responsibility for planning and management at the urban and local scale, need to be given more support.

Capacity building for climate change education, training, public awareness and social learning:

- Mainstreaming of climate change into national education and training quality management systems, and standards via the quality councils, DBE, DHET and SAQA.
- Strengthening analysis and integration of climate change knowledge into national curriculum (CAPS) to ensure progression and coherence with national climate change policy.
- Strengthening capacity in national teacher education institutions and the professional development units of the DBE to support teachers to develop in-depth understanding of climate change concerns and how to teach these.
- Developing the capacity of TVET college lecturers and curriculum developers to strengthen integration of green economy and climate change responses into the TVET system.
- Developing capacity of skills planners and skills intelligence researchers in the Sector Education and Training Authorities (SETAs) and in the Department of Higher Education and Training (DHET) system to accurately and timeously articulate green occupations and green skills demand to facilitate pro-active skills planning and analysis.

- Strengthening capacity of humanities, social sciences and arts-based disciplines to become more engaged in climate change issues in higher education, and strengthen capacity of the higher education and research sector to engage in systems-based, inter- and transdisciplinary approaches to research and curriculum innovation.
- Strengthen capacity of NGOs and all tiers of government to engage in inter-sectoral and multi-levelled co-operative efforts and alignment of their climate change education, training and public awareness efforts with national climate change policy directions.
- Strengthen the capacity of journalist and media practitioners to more effectively utilise a greater diversity of media to strengthen and expand climate change awareness and action, including use of social media and community radio in addition to other more mainstream media types.

Strengthen capacity of all climate change education, training, social learning and media practitioners to align their learning support materials with national policy direction for climate change response, and to regularly update and review their materials in relation to new knowledge of climate change impacts and projections. Additionally, support stronger quality monitoring, and capacity to adapt climate change information to local contexts in relevant ways, and strengthen orientations of programmes towards community engagement and participation in climate change related actions (not just transfer of information). This involves adopting stronger action learning and social learning approaches.

1 National Circumstances

1. National Circumstances

This chapter provides an overview of the national circumstances in terms of describing the geography, climate, environmental and socio-economic profiles of the country with emphasis on sensitivity to climate change and climate variability. South Africa has made significant advances in climate policy since the publication of the Second National Communication. These advances are highlighted through national development programmes, plans and strategies from 2011-2015. This chapter describes the planning and reporting documents prepared at a national level as part of international reporting commitments. These documents serve to inform national and regional priorities to address climate change concerns within the framework of national development programmes, plans and strategies. South Africa's institutional arrangements for preparing National Communications are outlined along with the national institutional framework for the effective implementation of measures to meet the objectives of the convention.

1.1 National, Regional and Local Climate Change Priorities

The South African Government's vision is to develop an effective climate change response whilst ensuring a long-term, just transition to a climate-resilient and low-carbon economy and society (DEA, 2011). Climate change is a measurable reality and South Africa is especially susceptible to its impacts. South Africa has an economically divided society due to a number of socio-economic disparities; as a result its population is characterized by a vulnerable majority. Subsequently adaptation to climate change impacts becomes even more important to contribute towards building societal resilience in the face of climate change impacts. In addition, South Africa needs to decouple economic growth from emissions, so as to facilitate a sustainable growth path for the country.

South Africa falls within the Southern African region, which influences the country's climate change impacts and adaptation responses. Countries within southern Africa are vulnerable to climate change (DEA, 2014b). Increased temperatures in central regions and general decrease in annual rainfall (across south Western Cape of South Africa and parts of Zimbabwe, Mozambique and Zambia) will negatively influence the sustainable development goal of zero hunger in the region. However, there is also the opportunity for risks to be mitigated, either through trade, technology transfer or information sharing among southern African countries.

1.1.1 National Priorities

The National Development Plan (NPC, 2012) and the National Climate Change Response White Paper (DEA, 2011) together provide the strategy for South Africa's transition to a lower carbon and climate resilient society. Both of these documents outline long term goals for climate change adaptation and mitigation. The National Development Plan aims to eliminate poverty and reduce inequality by 2030. Progress has been made since the country moved from Apartheid, which caused huge social and economic inequalities in the country, towards a democratic society. Even though the Apartheid governing structures have been removed, South Africa remains a highly disparate society with many people living in poverty and unemployment. Zero-poverty is an over-riding and crucial priority for South Africa, even as the country moves towards reducing emissions (DEA, 2015). Eliminating poverty requires addressing major challenges in creating employment, which in turn requires improving basic education, health and social welfare. Basic needs such as access to food, shelter and energy are also challenges that impact poverty. In terms of the Millennium Development Goals, South Africa has made progress towards achieving these ambitions, but still has some way to go to achieve its goal of a society without poverty and inequality. Four of the eight Millennium Development Goals reflect progress towards attainment (StatsSA, 2015b), namely:

- Eradication of extreme poverty and hunger;
- Achieve universal primary education;
- Promote gender equality and empower women; and
- Combat HIV and AIDS, malaria and other diseases.

South Africa adopted the Sustainable Development Goals in September 2015. The goals speak to eradicating poverty and reducing inequalities. In this regard the goals are directly linked to the objectives of South Africa's National Development Plan. Climate change is a cross-cutting development issue that affects every aspect of sustainable development and the entire 2030 agenda (UNDP, 2016). Scaling up climate action is essential for achievement of the Sustainable Development Goals.

Factors such as infrastructure development, public services quality and public health needs are major role players in how susceptible South Africa is to climate change. Given that the effects of climate change and environmental degradation fall most heavily on the poor, South Africa needs to strengthen the resilience of its society and economy to the effects of climate change. Working to improve South Africa's challenges, the National Development Plan focusses on the following priorities (NPC, 2012)

- Uniting South Africans around a common programme to achieve prosperity and equity;
- Promoting active citizenry to strengthen development, democracy and accountability;
- Bringing about faster economic growth, higher investment and greater labour absorption;
- Focussing on key capabilities of people and the state;
- Building a capable and developmental state; and
- Encouraging strong leadership throughout society to work together to solve problems.

More specifically, South Africa's transition to an environmentally sustainable, climate change resilient, low-carbon economy and just society will be well underway by 2030 (NPC, 2012). This transition will be facilitated by:

- Coordinated planning and investment in infrastructure and services that take account of climate change and other environmental pressures;
- Implemented adaptation and national development strategies;
- Focus on becoming a zero-waste society;
- Growth in the renewable energy sector;
- Domestic manufacturing of renewable energy technologies coupled with job creation;
- Reducing the country's carbon emissions;
- Conservation and restoration of protected areas through policy and regulatory frameworks for land use; and
- Public investment in new sustainable technology solutions such as agricultural technologies and the development of resilient and environmentally sustainable strategies.

The National Climate Change Response White Paper has two main objectives:

- Manage expected climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity.
- Make a fair contribution to the global effort to stabilise greenhouse gas 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 transition of South Africa's climate change response through national development programmes, plans and strategies from 2011-2015 is highlighted in Figure 1.1.

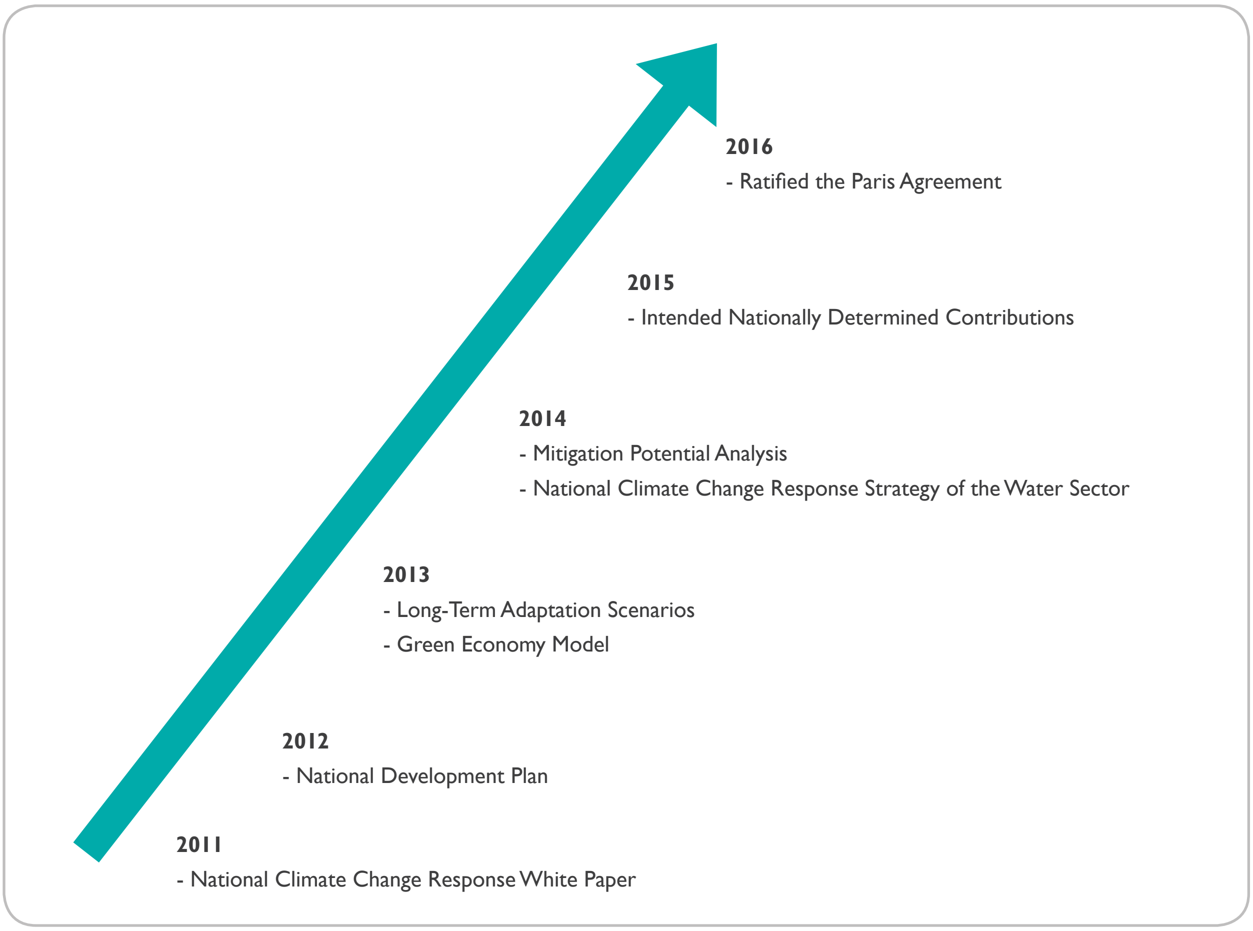

Figure 1.1: Transition of South Africa's climate change response

South Africa has 10 national priorities (DEA, 2011) in order to achieve the national climate change response objective as per the National Climate Change Response White Paper:

1. **Risk reduction and management:** Prioritise near-term adaptation interventions that address immediate and observed threats to the economy, ecosystem services and health and well-being of South Africans. Research and develop short-, medium- and long-term climate resilience, risk and vulnerability management policies and measures.
2. **Mitigation actions with significant outcomes:** Prioritise cost effective and beneficial mitigation policies, measures and interventions that reduce the greenhouse gas emission trajectory. Ensure that emissions peak between 2020 and 2025 and then plateau for approximately a decade and decline thereafter.
3. **Sectoral responses:** Prioritise the requirement for all key actors, organisations or participants in relevant sectors or subsectors to prepare, submit, implement,

monitor and report the implementation of detailed climate change response strategies and actions plans. The aim of these strategies and plans is to clearly articulate the roles, responsibilities, policies, measures and interventions or actions that contribute to the achievement of the national climate change response objective in a measurable way.

4. **Policy and regulatory alignment:** Prioritise interventions already envisaged by national policies, legislation or strategies that have climate change co-benefits. Particularly those that also contribute towards the national priorities of job creation, poverty alleviation or have other positive socio-economic benefits. Review existing national policies, legislation or strategies with a view to optimising the climate change co-benefits. Integrate climate change response interventions that stimulate new economic activities, as well as those that improve the efficiency and competitive advantage of existing activities, into the relevant existing or new policies, legislation or strategies.
5. **Integrated planning:** Mainstreaming of climate change considerations and responses into all relevant sector, national, provincial and local planning regimes.
6. **Informed decision-making and planning:** Prioritise research, systematic observation, knowledge generation, information management and early warning systems that increase our ability to measure and predict climate change and the implications of its adverse effects on the economy, society and environment.
7. **Technology research, development and innovation:** Prioritise cooperation and the promotion of research, investment in and/or acquisition of adaptation, lower carbon and energy efficient technologies, practices and processes for employment by existing or new sectors or subsectors.
8. **Facilitated behaviour change:** Prioritise the use of incentives and disincentives, including regulatory, economic and fiscal measures to promote behaviour change towards a lower carbon society and economy.
9. **Behaviour change through choice:** Prioritise education, training and public awareness programmes to build the general public's awareness of climate change. This will empower all South Africans to make informed choices that contribute to an economy and society that is resilient to climate change.
10. **Resource mobilisation:** Prioritise the development of comprehensive resource and investment mobilisation strategies, capacities, mechanisms or instruments that support and enable implementation of climate change responses at the scale required.

The national priorities highlighted in the National Climate Change Response White Paper and in the National Development Plan are the basis from which other programmes, plans and reports are developed on a national, regional and local level.

Planning and reporting documents are prepared both on a national level and as part of international reporting commitments. These documents assist South Africa in working towards our national climate change priorities. The national planning and reporting documents cover both adaptation and mitigation. The key document on adaptation is the Long-Term Adaptation Scenarios (DEA, 2013) and the key document on mitigation is the Mitigation Potential Analysis (DEA, 2014g).

The **Long-Term Adaptation Scenarios** detail national and sub-national adaptation scenarios for South Africa under future climate conditions and development pathways. The document details climate change trends and projections for South Africa. The scenarios summarise key climate change impacts and potential response options for water, agriculture and forestry, human health, marine fisheries and biodiversity.

The National Development Plan recognises that climate change will have a significant impact on the water sector. The National Climate Change Response White Paper states that the water sector is a critical component to climate change mitigation and adaptation. **The National Climate Change Response Strategy for the Water Sector** (DWS, 2014) is based on the format developed by the Southern African Development Community for climate change and water strategies. The water strategy emphasises good water management which is a critical foundation for adaptation to water- related climate change impacts.

Published in June 2007, the **Climate Change and Agricultural Sector in South Africa** (DAFF, 2007) document addresses adaptation and mitigation strategies for agriculture. **The Atlas of Climate Change and the South African Agricultural Sector: A 2010 Perspective** was subsequently published in 2010 (Schulze, 2010). This documents climate change predictions for the agricultural sector. A draft climate change sector plan for agriculture, forestry and fisheries is currently being developed. Once this plan is published it will cover climate change strategies and scenarios related to these sectors. Work has also been drafted on a **National Climate Change Monitoring and Evaluation System for the Agriculture, Forestry and Other Land Use Sector.** This system details the various mandates currently in place to collect data for the sector as well as the key indicators that need to be monitored. The Department of Environmental Affairs published the **South African National Terrestrial Carbon Sink Assessment** in May 2015, with the aim of assessing the national carbon sinks in relation to afforestation, forest restoration, wetlands, agricultural practices and urban greening. Further to this, the assessment quantified the potential future carbon stocks under climate change and different land use scenarios (DEA, 2015).

Various mitigation projects have been implemented since 2000 through public and private sector initiatives. The **Long Term Mitigation Scenarios** is one of the main studies in this regard and was published in 2007. Its aim was to explore various mitigation scenarios that could protect the climate while meeting the development challenges of poverty alleviation and job creation in South Africa. The **Mitigation Potential Analysis** (DEA, 2014g) built on the scenarios and represents a national, consolidated document. The study identified and analysed further mitigation options in key economic sectors. The key economic sectors include energy, industry, transport, waste and agriculture, forestry and other land use.

The Department of Energy published the **National Energy Efficiency Strategy** in 2005. The strategy had an economic wide target of 12% reduction of energy demand by 2015 against a baseline of 2000. Since the strategy, the department has developed an **Energy Efficiency Target Monitoring System** which has reported cumulative energy efficiency savings of at least 23% within the period of 2000 – 2012.

The **South African Green Economy Model** (UNEP, 2013) developed by the Department of Environmental Affairs in 2013 assesses the impacts of green economy investments in selected sectors on the country's economy. The model works on the basis that South Africa's transition to a green economy is reliant on a number of national efforts that are geared towards a resource efficient, low-carbon and pro-employment growth path. The modelling traces the effects of fluctuating Gross Domestic Product in the following four (of the nine) core sectors prioritised to support a local green economy:

- Natural resource management
- Agriculture
- Transport and
- Energy

In this green economy, growth in income and employment is driven by investments that: reduce carbon emissions and pollution; enhance energy and resource efficiency; and prevents the loss of biodiversity and ecosystem services.

The Department of Transport has set a strategic goal to reduce carbon emissions by 10%. A **Transport Sector Strategy on Climate Change** is currently being developed (NDOT, 2014).

The eighth edition of the **Industrial Policy Action Plan (IPAP) 2016/17 – 2018/19** was recently launched by the Department of Trade and Industry. The plan outlines South Africa's national industrial effort, with involvement from key stakeholders and economic partners. It is mentioned that more needs to be done to support domestic industries to adopt less carbon-intensive production processes, in addition to seizing the manufacturing opportunities available in the renewable energy and green industries space.

The Department of Science and Technology developed a Ten-Year Plan for South Africa from 2008-2018 on **Innovation Towards a Knowledge-Based Economy.** The purpose of the plan is to help drive South Africa's transformation towards a knowledge-based economy, in which production and dissemination of knowledge leads to economic benefits and enriches all fields of human endeavour. The plan is currently under mid-term review. There are five grand challenges highlighted in the plan namely:

- **The "Farmer to Pharma" value chain to strengthen the bio-economy** – This includes the development of biotechnology and pharmaceuticals, based on South Africa's indigenous resources and expanding knowledge base.
- **Space science and technology** – South Africa aims to become a key contributor to global space science and technology with a National Space Agency, a growing satellite industry, and a range of innovations in space sciences, earth observation, communications, navigation and engineering.
- **Energy security** – There is a need for safe, clean, affordable and reliable energy supply in South Africa. The country aims to meet its medium-term energy supply requirements while encouraging innovation in clean coal technologies, nuclear energy, renewable energy and the hydrogen economy.
- **Global climate change science with a focus on climate change** – South Africa's geographic position enables the country to play a leading role in climate change science.
- **Human and social dynamics** – South Africa aims to contribute to a greater global understanding of shifting social dynamics, and the role of science in stimulating growth and development.

The programmes developed under each of the five grand challenges will be further detailed in Chapter 5, Section 5.2 Research and Systematic Observations.

1.1.2 International Climate Change Response

South Africa is committed to the implementation of its international obligation. To this end South Africa developed the National Climate Change Response White Paper (NCCRP) in 2011. The NCCRP is a comprehensive plan aimed at addressing both mitigation and adaptation in the short, medium and long-term (up to 2050). Furthermore, as a signatory to the Convention, South Africa prepared and submitted the following documents:

- The first National Communication (2003)
- South Africa's Climate Change Technology Needs Assessment (2007)
- Second National Communication (2011)
- Biennial Update Report (2014)
- Intended Nationally Determined Contribution (2015)

Determined to play its part and contribute its fair share in the global arena **South Africa signed the Paris Agreement** during April 2016 in New York, and ratified the agreement on 1 November 2016.

Although the Department of Environmental Affairs is the custodian of climate change in the country there are a number of other main points of contact relating specifically to climate change, namely:

- Designated National Authority situated within the Department of Energy: Maintains the Clean Development Mechanism process and related offset projects.
- National Designated Entity situated within the Department of Science and Technology: Manages the development and transfer of technologies in order to facilitate the operationalization of the Climate Technology Centre and Network.
- International Climate Change Relations and Negotiations Chief Directorate situated within the Department of Environmental Affairs: Manages international climate change engagements. Specifically focussing on research, preparation, formulation, consultation and negotiation of the South Africa position under the UNFCCC and its Kyoto Protocol, IPCC, SADC, AU, other international fora and cooperation agreements.

The aim of South Africa's Climate Change Technology Needs Assessment (DST, 2007) was to identify and assess environmentally sound technologies that may, within national development objectives, reduce the impact of climate change and greenhouse gas emissions in South Africa. Subsequent desired outcomes of the assessment include its potential to open up access to funds, create an enabling environment for the transfer and uptake of technologies, and highlight opportunities for research and development cooperation. The Department of Science and Technology is currently in the process of updating the Technology Needs Assessment (Chapter 5, Section 5.1).

The Biennial Update Report (DEA, 2014) highlights South Africa's response to climate change from 2010 to 2014. The document includes transparent reporting on climate finance, an updated emissions inventory and an update on mitigation actions. Adaptation is addressed in the additional information chapter.

South Africa's Intended Nationally Determined Contribution (DEA, 2015) was based on three pillars, namely, mitigation, adaptation and means of implementation. South Africa's Intended Nationally Determined Contribution was based on the assumption that finance, technology and capacity-building support would be available to developing countries in the Paris Agreement. It emphasized the importance of all three of these to a low-carbon transition in South Africa.

South Africa's responses to climate change are framed within the country's national development agenda, particularly the elements outlined in the National Development Plan. South Africa played a key role in developing the 2030 Agenda for Sustainable Development which came into effect in January 2016, including the 17 Sustainable Development Goals which has dedicated Goal 13 to climate action. The country continues to progress in fulfilling the identified goals.

1.1.3 Regional Priorities

Regionally priorities are typically reflected on a provincial level. Each province within South Africa is developing a climate change response strategy as stipulated in the National Climate Change Response White Paper. These strategies evaluate provincial climate risks and impacts whilst integrating the principles of the National Climate Change Response Strategy at a provincial level. Of the nine provinces, five have completed climate change response strategies. Regional priorities are defined through a wide range of policy structures which vary across the provinces and are dependent on differing stakeholder inputs.

The completed regional documents include:

- Eastern Cape Climate Change Response Strategy (ECDEDEA, 2011);
- Gauteng Climate Change Response Strategy (GDARD, 2012);
- Kwazulu-Natal Progress Report on Climate Change Activities (DAEA, 2013);
- Limpopo Green Economy Plan (DEDET, 2013); and
- Western Cape Climate Change Response Strategy (WCG: DEAD&P, 2014).

These climate change response strategies identify regional priorities specific to each province, as seen in Table 1.1. These plans are discussed in further detail in Chapter 3, Section 3.7.3. Some of the common regional priorities are:

- Expand the green economy to reduce emissions through energy efficiency, cleaner production and green buildings;
- Understand and manage the impact that extreme weather events can have on infrastructure;
- Focus on climate resilient agriculture;
- Manage water resources effectively;
- Prioritise natural resource conservation;
- Implement effective disaster risk planning and reduction; and
- Improve tertiary institution research on changing climatic conditions, mitigation technologies and possible adaptation solutions.

Table 1.1: Provinces and the associated regional climate change priorities

Provinces	Regional Priorities
Eastern Cape (ECDEDEA, 2011)	• Consider risks, impacts and limitations imposed by climate change; • Impact of changing variables (e.g. more extreme weather events) on infrastructure development. Specific attention must be paid to high risk areas such as flood prone locations; • Incorporate climate change mitigation into development plans and programmes strengthening the green economy; and • Funding opportunities such as carbon credits and climate change adaptation funds need to be incorporated into development plans and programmes.
Gauteng (GDARD, 2012)	The Gauteng Climate Change Response Strategy prioritises implementable actions under mitigation and adaptation. Mitigation: • Energy efficiency across industry, mining and commerce; • Cleaner production; • Compressed natural gas for vehicles; • Renewable energy projects; and • Agricultural projects that reduce methane emissions. Adaptation: • Efficient and secure water demand management; • Climate resilient agriculture and agro-processing; • Food gardens in residential areas for subsistence consumption; • Conservation of natural resources and biodiversity areas; and • Disaster risk planning and reduction.
Kwazulu-Natal (DAEA, 2013)	• Promotion of the green economy; • Localisation of component manufacturing for the renewable energy sector; and • Increased focus on innovation, science and technology in green industries at tertiary institutions.
Limpopo (DEDET, 2013)	• Sustainable production and consumption; • Water management; • 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.

Provinces	Regional Priorities
Western Cape (WCG: DEAD&P, 2014)	The Strategy is a coordinated climate change response for the Western Cape province and will guide the collective implementation of innovative projects as well as the pursuance of opportunities that combine a low carbon development trajectory with increased climate resilience, enhancement of ecosystems and the services they provide as well as economic growth and job creations. The Strategy, which is aligned with the National Climate Change Response White Paper, will be implemented with an initial focus on the following focus areas: • Energy Efficiency and Demand-Side Management; • Renewable Energy; • The Built Environment, including Critical Infrastructure, Human Settlements and Integrated Waste Management; • Sustainable Transport; • Water Security and Efficiency; • Biodiversity and Ecosystem Goods and Services; • Coastal and Estuary Management; • Food Security; and • Healthy Communities.

1.1.4 Local Priorities

In South Africa, the focus on meeting local priorities is driven by municipalities. Climate change is a global phenomenon with specific and diverse localised impacts. Local impacts place particular emphasis and responsibility on local government for developing adaptation strategies and implementing coping mechanisms (FFC, 2012). In South Africa, local government is faced with multifaceted challenges such as increasing unemployment, poverty, critical infrastructure backlogs and service delivery constraints. Climate change is likely to exacerbate these challenges. In addition, socially vulnerable groups are more reliant on local government for effective adaptation risk management (Agrawal, 2008), which further emphasises the role of local government as facilitators for climate change related actions.

Climate Action Award:

The City of Johannesburg has been recognised for its leadership role in tackling climate change. The C40 Cities Awards ceremony was held in Paris, France, during COP 21 in December 2015. The City of Johannesburg was awarded for introducing the first listed green bond in South Africa. The recognition is a significant achievement for the City, and linking with international and local counterparts, such as C40 Cities, ICLEI and South African Cities Network, enables the sharing of best practice and approaches.

South Africa has three different types of local government:

- Eight **metropolitans:**
  - Buffalo City (East London);
  - City of Cape Town;
  - Ekurhuleni Metropolitan Municipality (East Rand of Gauteng);
  - City of eThekwini (Durban);
  - City of Johannesburg;
  - Mangaung Municipality (Bloemfontein);
  - Nelson Mandela Metropolitan Municipality (Port Elizabeth); and
  - City of Tshwane (Pretoria)
- 44 **district municipalities** which are made up of a number of local municipalities;
- 226 **local municipalities.**

One of the roles of provincial government is to support local government. In addition the South African Local Government Association (SALGA) is mandated to support, represent and advise local government action. This includes developing necessary capacity within municipalities. The association also ensures the integration of climate adaptation and mitigation actions into local government plans and programmes and lobbies for the necessary regulatory measures and resources to support local government in this regard.

Local government, supported by the National Disaster Management Centre within the Department of Cooperative Governance and Traditional Affairs, plays a crucial role in building climate resilience and adaptation through:

- Planning sustainable human settlements and integrating climate change resilience in urban development;
- Providing capacitated municipal infrastructure and services which are robust, flexible and have built-in redundancies to alleviate disaster pressures;
- Water and energy demand management; and
- Effective and appropriate local disaster response.

The National Climate Change Response White Paper specifies that climate change considerations and constraints should be integrated into municipal development planning tools such as Integrated Development Plans and municipal service delivery programmes. In addition, local climate change priorities are increasingly communicated in municipal Climate Change Action Plans. Currently these are mainly being developed by metropolitan municipalities but also by a few local municipalities. Metropolitan municipalities are prioritising the implementation of energy efficiency and renewable energy projects, as well as promoting efficient public transport and green buildings.

Climate Action Example:

One of the ways in which the City of Tshwane prioritises renewable energy is entering into long-term contracts with renewable energy generators. One such project is the development of a biogas plant in partnership with the private sector (C40 Cities. 2015. Climate Action in Megacities 3.0).

Local and district municipalities are primarily concerned about climate change in relation to the impacts on water supply and natural disaster frequency, and how these would directly impact agriculture and the environment. To improve resilience, municipalities need to conserve, rehabilitate and restore natural ecosystems. Part of resilience planning also involves having adequate support for vulnerable communities and citizens, as they are particu-

larly exposed to adverse weather. For this reason, municipalities prioritise early warning systems as well as disaster risk management and awareness. Most climate change projects at the local municipal level focus on awareness campaigns and education as well as some waste management initiatives. In addition, renewable energy is often considered in response to the energy crisis, with emission reductions being an added benefit.

Local and district municipalities can also include climate change strategies in their Spatial Development Plans/Frameworks. Within these respective plans and frameworks, there are typically strong links and references to national or provincial climate change strategies. A recent study, undertaken in 2015 by the CSIR, identifies minimum environmental requirements for such Spatial Development Plans/Frameworks. The aim behind standardising the environmental requirements is to increase the quality of planning in this regard, with the ultimate goal of improving the success rate of the proposed actions or measures.

In partnership with the South African Local Government Association and the Department for Cooperative Governance, the Department of Environmental Affairs published a toolkit to support local government in its responses to climate change. The Let's Respond toolkit (DEA, 2015) is a guide to integrating climate change risks and opportunities into municipal planning, specifically into the respective Integrated Development Plans. The toolkit was pilot tested across five municipalities. Expansion of this toolkit is currently underway to include a section on water.

In 2014, the Department of Cooperative Governance and Traditional Affairs published the Integrated Urban Development Framework (COGTA, 2014) with the aim of unlocking development synergies that come from coordinated investments in people and places. A focus on disaster risk reduction is key to successful urban development. Urban areas are particularly vulnerable to climate change risks because of the high concentrations of people, buildings and infrastructure.

The Department of Science and Technology plays a crucial role in localisation of technologies and beneficiation of local resources. Their work aims to combine technology development and human capital development. In line with their vision the Technology for Rural Education Development (TECH4RED) project was developed. The project is a joint initiative between the Department of Science and Technology, the Department of Basic Education, the Eastern Cape Department of Education and the Department of Rural Development and Land Reform. The project intends to improve rural education through technology-led innovation. Central to the project is the use of hydrogen fuel cell technology to provide backup power for electronic equipment, such as tablets, which have been introduced to schools in the Cofimvaba district of the Eastern Cape.

Figure 1.2: Minister of Science and Technology, Naledi Pandor, prepares to cut the ribbon to the hydrogen fuel cells providing standby power to Arthur Mfebe Senior Secondary School in Cofimvaba, Eastern Cape

(Source: http://www.itweb.co.za/index.php?option=com_content&view=article&id=143906)

1.2 Geography

South Africa is located in the southern tip of Africa, stretching latitudinally from 22°S to 35°S and longitudinally from 17°E to 33°E. The land area of the country is 1 219 602 km2. The Great Escarpment is South Africa's most prominent and continuous relief feature, meaning that it is the nation's highest elevation point. It divides the country up into the interior plateau, the eastern plateau slopes, the Cape Fold belt and the western plateau slopes. The interior plateau is 1 200 m above sea level and extends from the Kalahari Desert in the west, to grasslands in the east and the semi-arid Karoo in the south. The Great Escarpment comprises the Roggeveld scarp in the south west which is 1 500 m above sea level and the KwaZulu-Natal Drakensberg in the east which is 3 482 m above sea level. Topographical features of South Africa are shown in Figure 1.3.

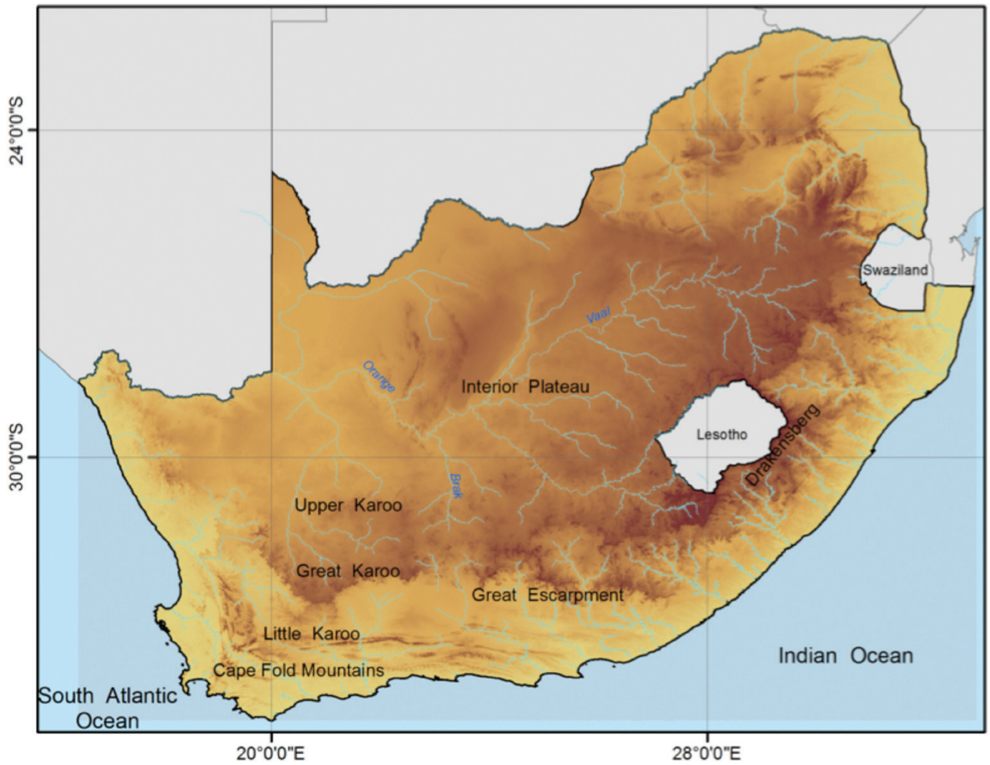

Figure 1.3: Topographical features of South Africa, including major rivers

South Africa's coastline is 3 000 km long, starting from the Mozambican border in the east to the Namibian border in the west. The Indian Ocean lies on the east coast of South Africa and the Atlantic Ocean lies on the west coast, with the two oceans meeting at Cape Point. Nearly a fifth of the coastline has some form of development within 100 m of the shoreline. Natural buffers against storm surges and rising seas have been degraded in parts of the coast line. As a result people and property are at risk to storm surges, especially as the effects of climate change increase.

The country has borders with six countries, namely Namibia, Botswana, Zimbabwe, Mozambique, Swaziland and Lesotho (which is landlocked by South African territory). The Prince Edward and Marion islands are also South African territories and are located 1 920 km south east of Cape Town (GCIS, 2015).

In 2015, South Africa has nine provinces: Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West and Western Cape, as shown in Figure 1.4.

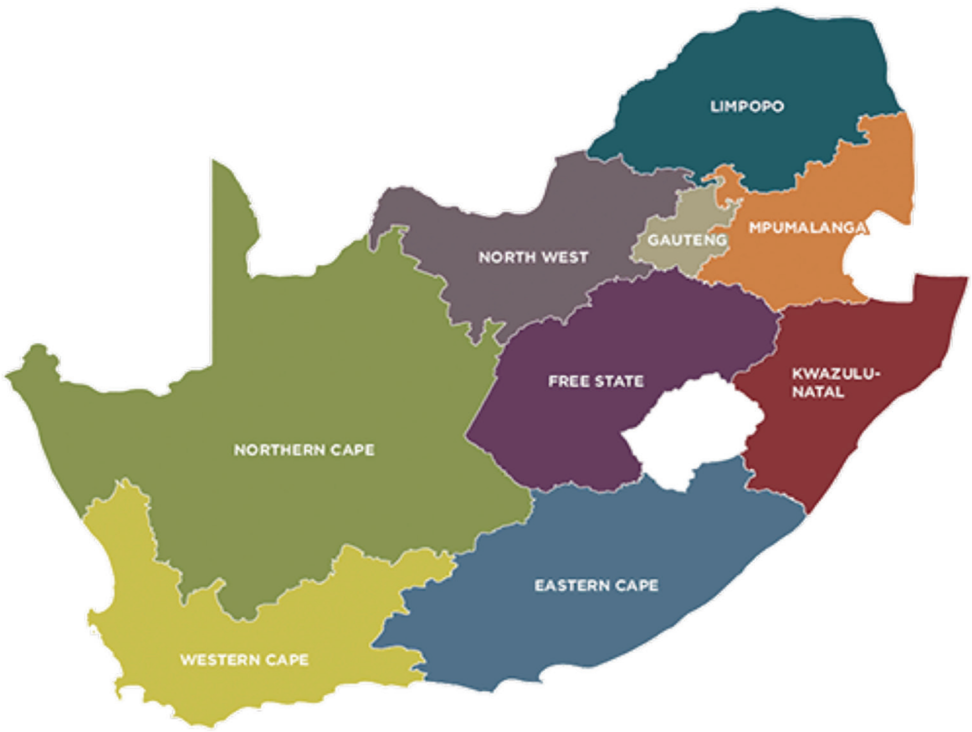

Figure 1.4: The nine provinces of South Africa

Source: http://www.provincialgovernment.co.za/.

1.3 Environment

South Africa represents just 1% of the earth's total land surface. The country boasts a rich biodiversity containing almost 10% of the world's total known bird, fish and plant species, as well as over 6% of the world's mammal and reptile species (GCIS, 2012). Biodiversity is vital for ecosystem health, and healthy ecosystems in turn directly impact on human well-being. Ecosystems and landscapes form the ecological infrastructure of the country and are the foundation for ecosystem services such as climate regulation, primary production and soil formation. Humans depend on healthy ecosystems for economic and livelihood activities. However, ecosystems are negatively impacted by existing pressures such as land use change and degradation. Climate change is exacerbating these existing pressures.

The combination of high levels of diversity and increasing environmental threats has resulted in the delineation of three internationally recognised biodiversity hotspots in South Africa:

- The Succulent Karoo;
- The Cape Floral Kingdom; and
- The Maputaland-Pondoland-Albany.

These biodiversity hotspots are currently not well represented in conservation areas. For this reason South Africa is looking to expand conservation areas to include larger tracts of the biodiversity hotspots. Through conserving biodiversity hotspots, South Africa can improve ecosystem health which will assist with ecosystem based adaptation. Ecosystem-based adaptation is defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the effects of climate change" (DEA, 2016).

South Africa has nine biomes, each of which will be affected by climate change as follows:

- The **Grassland** biome is the most threatened under all climate scenarios. Large portions of the biome are often replaced by Savanna and potentially Forest vegetation.
- The **Nama-Karoo** biome is the second most threatened under all climate scenarios. It is expected that the Savanna and Desert biomes will replace large portions of this biome.
- The **Indian Ocean Coastal Belt, Fynbos** and **Forest** biomes are the next most threatened areas. Under intermediate and high risk climate scenarios, the **Savanna** biome is expected to replace large portions of the Indian Ocean Coastal Belt. The north-eastern regions of the Fynbos biome are often replaced by Albany Thicket and Succulent Karoo, under all climate scenarios.
- The **Forest** biome is expected to reduce significantly as a result of increased fires and reduced rainfall under all climate scenarios.
- **Albany Thicket** is least threatened. Only under the high risk climate scenario will it be negatively impacted.
- The **Desert** biome is projected to expand across other biomes under all climate scenarios and especially under the high risk climate scenario.

Chapter Three of this Third National Communication will, however, provide more detail on adaptation and will expand on the various climate scenarios for South Africa's biomes.

1.4 Climate

1.4.1 Mean conditions – Typical climate conditions in South Africa

South Africa has both subtropical and temperate climate conditions. The climate is influenced by the ocean along the east and west coasts as well as the interior plateau. This results in a cool, wet climate in the Drakensberg region, to warm, subtropical in the north east. The country has a Mediterranean climate in the south west and a warm dry desert environment in the central west and north west. Average annual rainfall in South Africa is about 464 mm, with the Western Cape getting most of its rainfall in winter and the rest of the country receiving summer rainfall. Average temperatures in South Africa range from 15°C to 36°C in summer and -2°C to 26°C in winter (GCIS, 2015). South Africa's four seasons are as follows:

- Autumn: 1 March to 31 May;
- Winter: 1 June to 31 August;
- Spring: 1 September to 30 November;
- Summer: 1 December to 28/29 February.

1.4.2 Historical climate trends (1960 – 2010)

As described in the Long Term Adaptation Scenarios (DEA, 2013), the following climate trends have been observed in South Africa over the last five decades (Table 1.2). Projected Climate Futures for South Africa will be discussed in Chapter 3, Section 3.3.

Table 1.2: Observed climate trends for South Africa

Temperature	Rainfall
• Mean annual temperatures have increased by at least 1.5°C above the observed global average of 0.65°C as reported by the IPCC AR4 (IPCC, 2007). • Annual maximum and minimum temperatures show significant increases across all seasons, with the exception of the central interior. • High annual temperature extremes have increased significantly in frequency whereas low annual temperatures have decreased significantly in frequency, particularly in the western and northern interior regions of the country. • The rate of temperature change has fluctuated, with the highest rates of increase identified during the mid-1970s to the early 1980s and again in the late 1990s to mid-2000s.	• High, inter-annual rainfall variability has been identified. • Above average rainfall was experienced in the 1970s, late 1980s and mid-to-late 1990s. Below average rainfall was experienced in the 1960s and early 2000s. • Mean average rainfall was experienced in 2010. • Annual rainfall trends overall are weak and non-significant. There is a tendency however towards a significant decrease in the number of rain days. • There has been an increase in the intensity of rainfall events and increased dry spell durations. Marginal reduction in rainfall was experienced during the autumn months.

1.4.3 Natural Disasters

South Africa is generally exposed to the following natural disasters: drought, flooding, extreme storms and fires. Economic losses from weather-related and climate-related disasters have increased, with the greatest impact of these losses felt strongly in developed countries (IPCC, 2012). Furthermore, more than 95% of deaths from natural disasters took place in developing countries (COGTA, 2015).

Some examples of natural disasters in South Africa include:

- Floods: During March 2014 the country experienced severe flooding in the Mpumalanga province. Significant damages to municipal infrastructure, provincial roads and bridges as well as houses were reported. The floods in Mpumalanga were declared a provincial state of disaster as the municipalities in the province were unable to cope with the effects of the occurrence. The floods resulted in significant damages to municipal infrastructure, provincial roads, bridges and houses which cost over R 61 million to repair (COGTA, 2015).
- Drought: During 2014 and 2015 the KwaZulu-Natal Province received below normal rainfall throughout the season and as a result the water levels in various catchment areas were affected. Severe drought conditions were experienced across nine district municipalities and it was estimated that more than 80% of boreholes in the communities were dried up. A provincial state of disaster was declared by KwaZulu-Natal. The costs of providing emergency disaster relief, in the form of boreholes, exceeded R 24 million (COGTA, 2015).

Disaster risk profiles are determined by a number of factors. These include efforts related to socio-economic development, natural climate variations and human-based climate change. The Intergovernmental Panel on Climate Change (IPCC) defines disaster risk as the likelihood of severe alterations in the normal functioning of a community or society due to weather or climate events interacting with vulnerable social conditions (IPCC, 2012). Vulnerability is defined as the predisposition of a person or group to be adversely affected (IPCC, 2012). The development of a risk assessment methodology and vulnerability indices is discussed in Chapter 3, Section 3.5.

Figure 1.5: Flooding at the Crocodile Bridge Gate at Kruger National Park in Mpumalanga

Source: http://floodlist.com/africa/flooding-south-africa-kills-5-affects-kruger-national-park

Figure 1.6: The Umfolozi River in Ulundi, KwaZulu-Natal, negatively impacted by drought

Source: Department of Governance and Traditional Affairs, Province of KwaZulu-Natal

The levels of vulnerability across the South African landscape are detailed in Figure 1.7 . The most vulnerable areas are located in the Western Cape Peninsula, KwaZulu-Natal and Gauteng (COGTA, 2015). High vulnerability areas are also observed around metropolitan and greater city areas, due to their comparatively large populations.

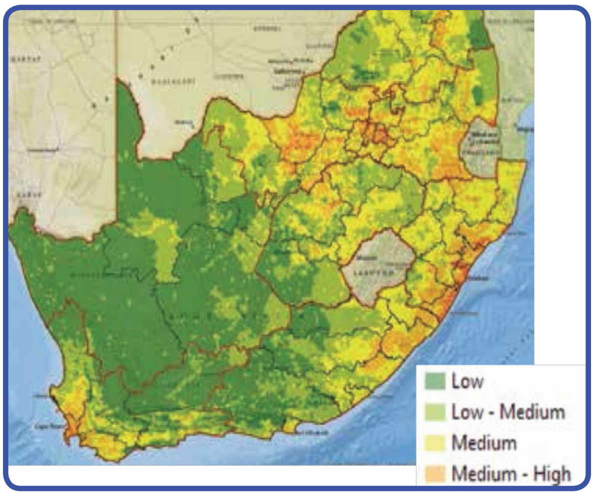

Figure 1.7: Vulnerability analysis (2014/2015) based on social, economic and environmental factors (COGTA, 2015)

The IPCC found that between the years of 1970 and 2008, over 95% of natural disaster related deaths occurred in developing countries (IPCC, 2012).

In order to address South Africa's vulnerability to natural disasters, the National Disaster Management Centre was developed as mandated by the Disaster Management Act of 2002. The objective of the National Disaster Management Centre is to promote an integrated and coordinated system of disaster management with special emphasis on prevention and mitigation across national, provincial and municipal organs of state (RSA, 2002).

More recently, the Disaster Management Amendment Bill (RSA, 2015) published in December 2015 which requires disaster management plans to be developed at national, provincial and municipal levels. These plans must include:

- Expected climate change impacts and risks; and
- Disaster risk reduction and climate change adaptation measures, including ecosystem and community-based adaptation approaches.

Disaster risk management is discussed in further detail in Chapter 3, Section 3.6.7.

1.5 Population

In South Africa, migration from rural to urban areas remains an important demographic process in shaping the age structure and distribution of the provincial population. Between the period of 2011–2016 it is estimated that approximately 247 437 people have migrated from the Eastern Cape; Limpopo is estimated to experience an out-migration of nearly 305 030 people. During the same period, Gauteng and Western Cape are estimated to experience an inflow of migrants of approximately 1 216 258 and 363 114 respectively, due to people seeking better opportunities in urban areas (StatsSA, 2017). Nonetheless, climate change impacts continue to exert pressure on urban governance and service delivery as the increasing urban population requires more services in the midst of climate change effects.

Table 1.3: South Africa's population across the provinces during 2014 (StatsSA, 2015a)

Province	Population Estimate	Percentage of total population (%)
Eastern Cape	7 061 700	12.6
Free State	2 861 600	5.1
Gauteng	13 498 200	24.1
KwaZulu-Natal	11 079 700	19.8
Limpopo	5 803 900	10.4
Mpumalanga	4 328 300	7.7
Northern Cape	1 191 700	2.1
North West	3 790 600	6.8
Western Cape	6 293 200	11.3
Total	55 908 900	100,0

The table that follows (Table 1.4) further details other relevant population indicators that have an effect on the country's vulnerability to climate change. As South Africa's population continues to increase, there is a strong likelihood of rising carbon footprints and increase in emissions. This also implies that the demands for services such as energy, transport, water, health, etc. will increase and consequently exerting pressure on the economy.

Table 1.4: Population indicators for South Africa (StatsSA, 2015a)

Population Indicator	Value
Growth rate	1.62% (2015 – 2016), increased from 1.22% (2002 – 2003)
Population aged younger than 15 years	30.1%
Population aged 60 years or older	8.0%
Life expectancy at birth	59.7 years for males
65.1 years for females	
Infant mortality rate	33.7 per 1000 live births
HIV prevalence rate	12.7% of the total South African population
Total number of people living with HIV	7.03 million

Approximately 51% of the population is female (StatsSA, 2015a). In rural South Africa, women's roles typically include food production, household water supply and the procurement of energy for heating and cooking (Babugura, 2010). For this reason women in rural areas are more vulnerable to the effects of climate change than men in the same areas, as their livelihoods depended on natural resources (UN, 2009).

About 30% of the population is aged younger than 15 years (StatsSA, 2014a). Children are one of the social groups most vulnerable to climate change due to their physical and emotional immaturity. Some of the leading causes of death in children are diarrhoea, malnutrition and malaria. These ailments which impact human health are particularly sensitive to climate change (UNICEF, 2011).

The following are examples of climate change impacts on human health in South Africa (DEA, 2014c):

- Increases in average temperatures and extreme events such as heatwaves are expected to increase **heat stress** which can increase morbidity and result in respiratory and cardiovascular diseases.
- Climate change induced changes in rainfall could increase vector-borne diseases such as malaria transmission due to the fact that mosquito populations increase with rainfall.
- Climate change is expected to increase droughts and high temperatures as well as rainfall variability. This would affect food systems which could lead to **food insecurity, hunger and malnutrition.**
- The frequency and intensity of **extreme weather events** is projected to rise due to climate change. An increase in floods and storms can cause an increase in respiratory and diarrhoeal diseases.

Additional detail on vulnerability of human health to climate change, current and future risks, as well as opportunities are discussed in Chapter 3, Section 3.6.4.

1.6 Economy

South Africa is classified as an upper middle income country (WB, 2014) with an economy that grew by 1.3% in 2015, down from 1.5% in 2014. The main contributor to the slowdown in 2015 was agriculture. Severe drought conditions saw the industry contracting by 8.4%, the largest annual fall in agriculture production since 1995. The decrease in 2015 was mainly due to a sharp drop in the production of field crops (StatsSA, 2015h).

South Africa's GDP grew by 0.6% during the fourth quarter of 2015. Figure 1.8 below details the percentage change in GDP year on year (GDP Y/Y) and quarter on quarter (GDP Q/Q) for the period 2008 to 2015. The large dip in percentage change during 2008 and 2009 is representative of the economic recession. The main features of the South African economy are presented in Table 1.5:

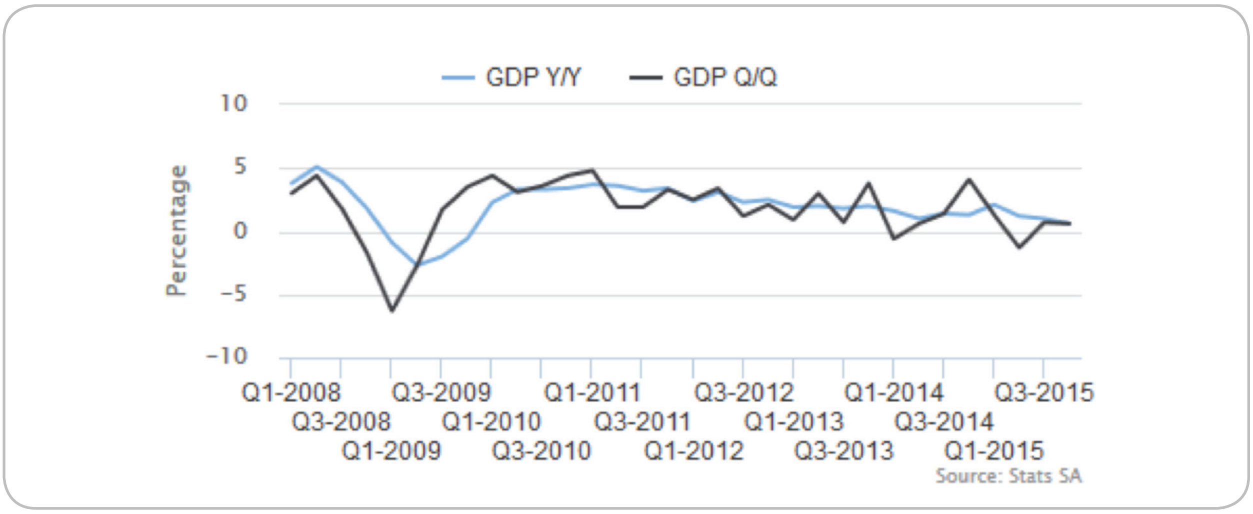

Figure 1.8: GDP percentage change year on year and quarter on quarter for 2008 – 2015 (StatsSA, 2015)

Table 1.5: Features of the South African economy

Key Statistics	South African Detail
Gross Domestic Product (GDP) (ZAR)	1 027 billion (fourth quarter 2015) (StatsSA, 2015d)
GDP Growth (%)	0.6 (fourth quarter 2015) (StatsSA, 2015d)
GDP by Sector (%)	Agriculture, forestry and fishing industry: 2.2 (StatsSA, 2015e) Mining and quarrying industry: 7.8 Manufacturing: 12.4 Electricity, gas and water: 2.2 Construction: 3.5 Wholesale, retail, motor trade, catering and accommodation: 13.6 Transport, storage and communication: 8.4 Finance, real estate and business services: 19.9 General government services: 15.4 Personal services: 5.3
Consumer Price Index (%)	4.8 (November 2015) (StatsSA, 2015c)
Producer Price Index (%)	4.3 (November 2015) (StatsSA, 2015f)
Labour Force	15.5 million (First quarter 2015) (StatsSA, 2015g)
Unemployment Rate (%)	26.4 (First quarter 2015) (StatsSA, 2015g)
Exports (ZAR)	94 billion (November 2015) (SARS, 2015)
Imports (ZAR)	92 billion (November 2015) (SARS, 2015)

The impacts of climate change on overall economic growth are predominantly negative (Treasury, 2014). Understanding the economic impacts of climate change is necessary for informing long term planning and policy making (Treasury, 2014). Climate change will specifically impact on growth, job creation and inequality. GDP expected losses induced by climate change over the next 35 years range from R 217 billion to R 651 billion, with a median loss of R 259 billion (DEA, 2014). The economic implications of climate change will have a significant impact on the ability to maintain economic growth into the future. It could also increase unemployment and inequality at sub-national and sector-based levels. This is particularly evident in the agricultural sector where unskilled labourers are unable to make the transition from agriculture to other sectors of the economy (DEA, 2014).

During the second phase of the development of South Africa's Long Term Adaptation Scenarios, the Department of Environmental Affairs published a factsheet series which includes a volume on the economics of climate change adaptation. This document identifies three key economic impact areas, as detailed in Table 1.6:

Table 1.6: Potential economic impacts under future climate scenarios (DEA, 2014)

Economic Impact Area	Details Specific to South Africa
Water availability for irrigation, municipal and industrial uses	Climate change will have a limited impact on national water supply due to the current high level development and integration of the major water supply infrastructure and supply systems. The water resource system is relatively robust across a wide range of possible climate scenarios. However, climate change is expected to impact regional water supply under the drier climate scenarios. The Western Cape is likely to be particularly affected. The greatest negative impact is expected in the Gouritz Water Management Area due to the fact that urban and bulk water supply are dependent on smaller and less integrated local resources, and drier climate scenarios are predicted for this area.
Yield impacts on dry-land agriculture	Agriculture employs a large number of people in South Africa and contributes directly contributes towards food security. It is the sector most negatively affected by climate change. There is a strong dependence on dry-land agriculture by rural populations with high poverty rates. This makes these rural populations even more susceptible to climate change impacts. There are two staple food crops in South Africa: maize and wheat. Yields of maize and wheat are likely to reduce by 3.5% and 4.3% respectively by 2050. In a worst case scenario, maize yields could reduce by up to 25%. However, under a wetter climate scenario, maize yields are expected to increase by 10%. Wheat, however, shows reduction across all future climate scenarios. The primary wheat growing area of South Africa is the Western Cape, which is predicted to have reduced average rainfall in the future. Both projected temperature increases and changes in rainfall are expected to impact dry-land agriculture. This would in turn, affect the larger agricultural economy.
Road infrastructure	Climate change is expected to result in increased disruptions to transport infrastructure due to extreme weather events. Road networks are susceptible to increased flooding and erosion (DEA, 2014a). There are significant advantages to implementing adaptation options such as repairing and rehabilitating existing road networks. The Eastern Cape has the greatest number of roads and therefore will have the most additional costs in light of climate change adaptation. Gauteng is the next most impacted province, as it has a high proportion of expensive primary and paved roads. The economic impact therefore arises from the rapid depreciation of road networks and the repairing thereof.

1.7 Energy

Energy utilisation in South Africa is characterised by high dependence on cheap and abundantly available coal. South Africa imports a large amount of crude oil. A limited quantity of natural gas is also available. The country also mines uranium which is exported. Enriched uranium is imported for South Africa's nuclear power plant, Koeberg. South Africa also makes use of renewable energy in the form of electricity generated by hydropower most of which is imported. Electricity is also generated from other renewable energy sources such as biomass and solar. The government intends to diversify energy supply and hence is promoting the use of renewable energy technology as well as other new energy technologies. In addition, it aims to improve energy efficiency throughout the economy (DoE, 2009). South Africa's total primary energy supply is depicted in Table 1.7 and Figure 1.9.

Table 1.7: Total primary energy supply for South Africa in 2006 (DoE, 2009)

Energy Category	Total primary energy supply (TJ)
Coal	3 721 156
Crude Oil	1 214 122
Gas	160 318
Nuclear	109 375
Hydro	11 069
Renewables	428 396
Total	5 644 436

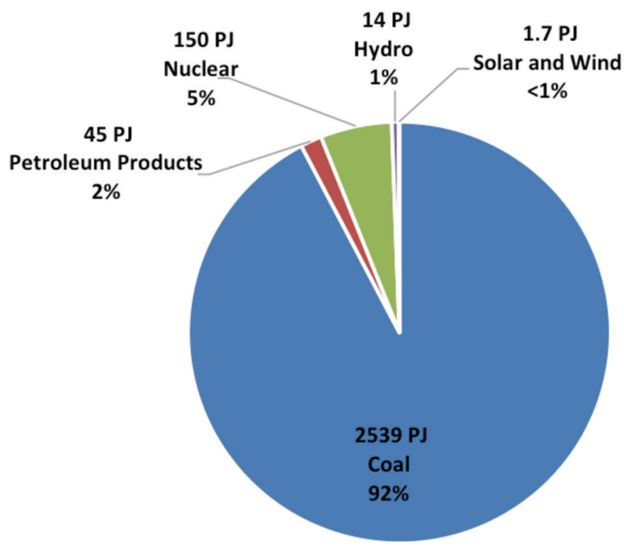

Figure 1.9: Energy carriers for power generation in South Africa (DoE, 2014)

The draft Integrated Energy Plan (IEP) was published by the Department of Energy in June 2013 for public comment. The aim of the plan is to determine the best way to meet current and future energy service needs in the most efficient and socially beneficial manner, through a mix of appropriate sources and forms of energy. The Integrated Energy Plan is both a methodology and a framework for analysing the energy system and linking policy formation to broader national goals. In addition to this, South Africa also has consolidated aggregated historical energy balances per commodity from 1992 to 2012.

1.7.1 Electricity

South Africa's primary source of energy is coal, mainly because it is abundant and relatively cheap by international standards. Eskom, a state owned utility, is the dominant generator in the country with a total nominal capacity of just over 45 GW. It generates approximately 95% of the electricity used in South Africa. Coal is Eskom's primary energy source (accounting for 90% of its fuel mix), supplemented by the Koeberg nuclear station in the Western Cape, hydroelectric and pumped storage schemes (DoE, n.d.) and recently an Eskom owned 100 MW wind farm. Energy production from coal is extremely emissions intensive and as a result South Africa was ranked as having the 13th highest emissions in the world for 2014 (GCA, 2014).

In 2008 Eskom introduced "load shedding", defined as rolling blackouts based on a rotating schedule, as demand rapidly started to exceed supply. Again in December 2014, Eskom reintroduced stage three load shedding across the country. Major contributors to load shedding include: lack of significant investments in the energy sector over the past 20 years, backlogs in infrastructure maintenance developments and metropolitan and municipality accounts which are in arrears. In order to increase generation of electricity, two new large coal-fired power stations each in excess of 4 500 MW generation capacity, were commissioned (Medupi and Kusile, which are 56% and 24% complete, respectively). In addition a pumped storage scheme was also commissioned.

The Integrated Resource Plan (DoE, 2011) published in 2011 determines the demand profile for electricity over the next 20 years and details how this demand can be most effectively met from different sources, such as nuclear energy, coal, gas and renewable energies (DoE, 2010). The Integrated Resource Plan was updated in 2013 to incorporate a number of government objectives, and remains under consideration. These objectives included affordable electricity, carbon mitigation, reduced water consumption, localisation and regional development, producing a balanced strategy toward diversified electricity generation sources and gradual decarbonisation of the electricity sector in South Africa (DoE, 2013). The Integrated Resource Plan is currently under review.

1.7.2 Coal

Coal provides over 70% of South Africa's primary energy. The country's coal is nearly all bituminous with very little anthracite. It is generally of low quality with high ash content. Coal reserves in the country are 48 Gt, representing 5.7% of total global reserves. The bulk of South Africa's coal reserves are situated in Witbank, Highveld, Ermelo, South Rand and KwaZulu-Natal (DoE, 2010). About 28% of South Africa's coal is exported mainly through the Richard's Bay Coal Terminal, making South Africa the fourth largest coal exporting country in the world (DoE, n.d.). Coal is an important part of South Africa's energy mix and it will continue to drive economic and social progress of much of the developing world for the foreseeable future. The challenge now is to make the production and use of coal more sustainable.

The Department of Energy has launched a Coal Baseload Independent Power Producer Procurement Programme which aims to procure 2 500 MW of electricity from coal-fired power stations. Individual bids are capped at 600 MW per project. The programme is designed to contribute towards socio-economic development and sustainable growth in South Africa.

1.7.3 Oil and gas

Local refining of crude oil imports contributes 64% to the liquid fuels demand in South Africa (DoE, n.d.). A large portion of liquid fuels are produced in South Africa through the coal-to-liquids and gas-to-liquids processes (DoE, 2010, p. 30). About 36% of the country's liquid fuels demand is met by synthetic fuel production. South Africa produced 24 075 million litres of liquid fuels in 2006 according to the South African Petroleum Industry Association (DoE, n.d.). South Africa typically consumes the following liquid fuels (DoE, 2010, p. 33):

Petrol ~ 47%

Diesel ~ 36%

Paraffin ~ 3%

Jet Fuel ~ 9%

Fuel Oil ~ 2%

Liquefied Petroleum Gas (LPG) ~ 3%

1.7.4 Renewable Energy

Due to South Africa's location, geography and size, multiple renewable energy resources are available as seen in Figure 1.10. South Africa's long coastline provides favourable conditions for wind power and the semi-arid climate and flat terrain receives high irradiation making it ideal for solar power (DoE, 2015). Biomass opportunities are available along the east coast which is tropical and characterised by large wood and sugar plantations (DoE, 2015). Small-scale hydropower is also a possibility.

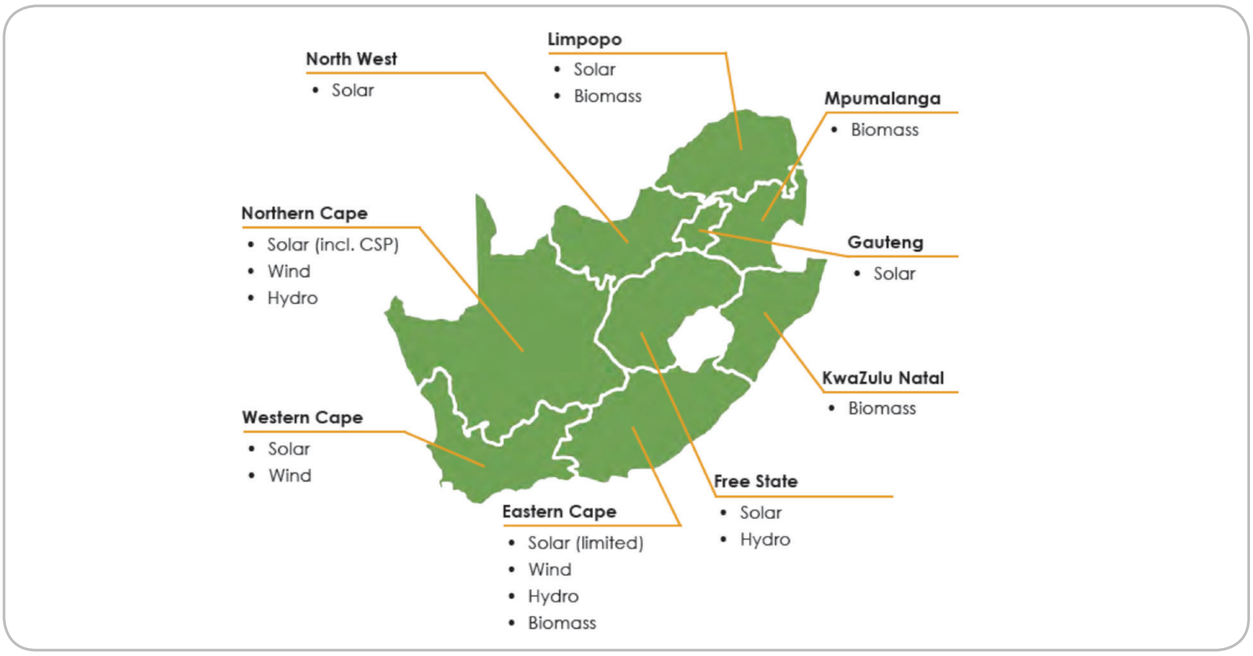

Figure 1.10: Provincial distribution of renewable energy resources across South Africa (DoE, 2015)

Renewable energy producers in South Africa are slowly growing and are being developed under the Department of Energy's Renewable Energy Independent Power Producer Procurement Programme (REI4P). The programme covers renewable energy technologies including solar, wind, biomass, hydro and landfill gas. The programme is based on a competitive bidding format, where prospective power producers submit bids which are adjudicated according to various criteria, price being the most critical. The country's Integrated Resource Plan makes provision for the generation of 17.8 GW of renewable energy by 2030, to be commissioned under the Renewable Energy Independent Power Producer Procurement Programme. Table 1.8 presents the capacity allocations for all the bidding windows from round one to round four (Eberhard, 2014). Preferred bidders under bidding window four were announced on 16 April 2016. Details on installed capacity and implementation of the projects will be further discussed in Chapter 4.

Table 1.8: Capacity allocations per technology over bidding rounds for the Renewable Energy Independent Power Producer Procurement Programme (DoE, 2009)

Technology	Capacity allocated per round (MW)			
	Round 1	Round 2	Round 3	Round 4
Wind	1 850	650	654	590
Solar PV	1 450	450	401	400
Concentrated solar power (CSP)	200	50	200	-
Landfill gas	25	25	25	15
Small hydro	75	75	121	60
Biomass	12.5	12.5	60	40
Biogas	12.5	12.5	12	-
Totals	3 625	1 275	1 473	1 105

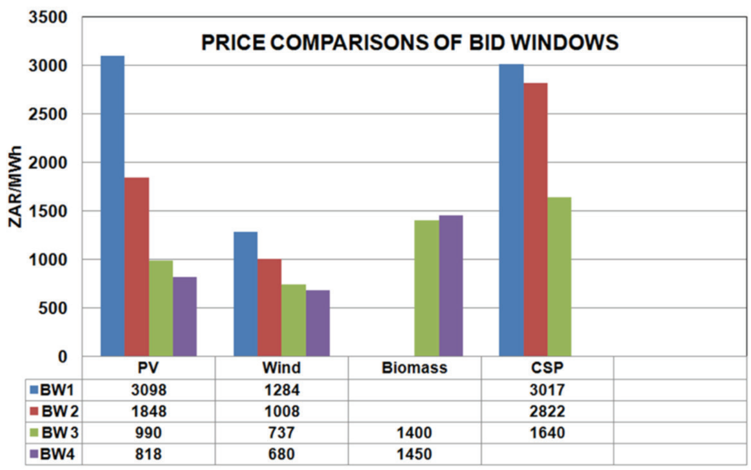

Figure 1.11: Price comparisons of the four bid windows for the Renewable Energy Independent Power Producer Procurement Programme (REI4P)

Source: Department of Energy (prices discounted to a single base year)

The success of the programme can be seen in Figure 1.11, which reveals how the price of renewables has decreased from bid window one to four.

While the majority of households are electrified (77%), South Africa still battles with energy poverty with as much as six million households remaining without electricity (SEA, 2014). The South African government has implemented a number of initiatives and projects aimed at providing non-grid renewable energy alternatives to such households. These include rural energisation, solar water heating systems and energy efficient cooking programmes (DoE, 2015). In 2001, a non-grid electrification programme was introduced which aimed to address electrification backlog in poorer areas. The programme identified solar photovoltaic systems as being the most suitable, temporary alternative to grid electricity. Since inception, the programme has been implemented within Limpopo, KwaZulu-Natal and Eastern Cape, and has supplied approximately 96 000 households with solar home systems. On a national level there has been increased uptake of rooftop PV, particularly in the residential and commercial sectors.

In 2008, the Department of Energy launched the Solar Water Heating Programme with the aim of installing one million solar geysers in homes across the country by 2013. To date the programme has managed to roll out about 424 790 solar geysers.

1.8 Agriculture, Forestry and Fisheries

Agriculture, forestry and fisheries contributed 2.2% (StatsSA, 2015e) towards the GDP in 2015. While this is a small percentage, the sector remains vital to South Africa's socio-economic development (GCIS, 2015) as it contributes significantly to international trade. Figure 1.12 shows the GDP trends for agriculture, forestry and fisheries from 2000 to 2015.

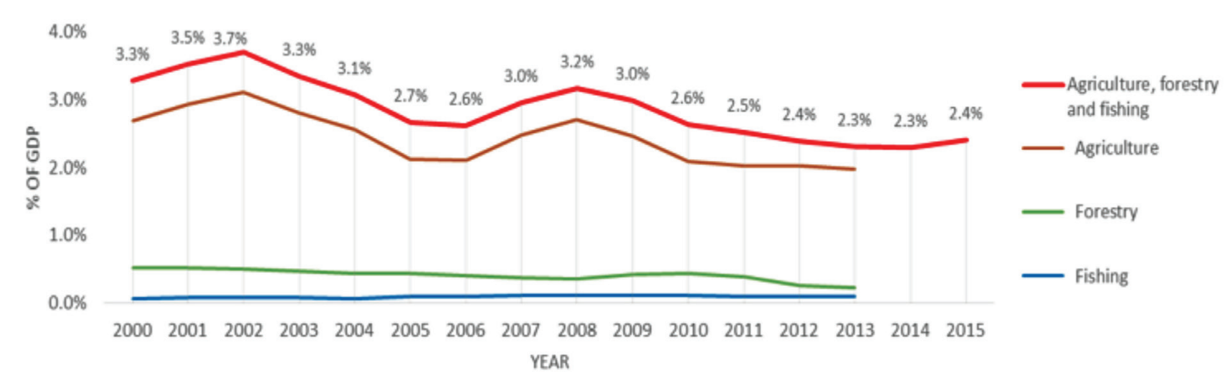

Figure 1.12:Annual percentage contribution of Agriculture, Forestry and Fisheries to the Gross Domestic Product of South Africa (StatsSA, 2015e)

Agriculture:

Maize is the most dominant crop planted in South Africa, followed by wheat and to a lesser extent sugar cane and sunflower seed. The agriculture sector is diverse and comprises mainly of commercial and subsistence farming. Only 14% of South Africa is potentially arable, with one fifth of this land having high agricultural potential (DEA, 2014e). Climate is important in determining potential agricultural activities and suitability across the country. Climate change is expected to have generally adverse impacts on cereal crop production, high value export agricultural production and intensive animal husbandry practices (DEA, 2014e). However, it is likely that climate change will impact positively on tropical crops such as sugarcane, as well as increasing sugarcane pests. While certain crops may be more resilient to climate change, others might be more sensitive. For some crops, climate change impacts can be predicted with more confidence than others (DEA, 2013a).

Climate change impacts on food production, agricultural livelihoods and food security in South Africa are significant national policy concerns. Impacts on food production and food security are linked to future projected water supply constraints. There is evidence that subsistence dry-land farmers are more vulnerable to climate change than commercial farmers. Large-scale irrigated production is likely to be least vulnerable to climate change, upon condition that there is sufficient water supply for irrigation (DAFF, 2013) (Schulze, 2010).

Forestry:

Changes in temperature and rainfall regimes are likely to have a marked impact on the extent and location of land that is climatically suitable for specific genotypes in the forestry sector. Climate also influences the survival and spread of insects and pathogens as well as the susceptibility of forest ecosystems. Variations in temperature and precipitation affect pest production, dispersal and distribution which could negatively impact commercial forests.

South Africa's commercial plantations are grown in KwaZulu-Natal, Mpumalanga and the Eastern Cape provinces with the three main genera being *Pinus, Eucalyptus* and *Acacia*. *Pinus* makes up ~49% of South Africa's commercial forests while *Eucalyptus* makes up ~40%. Climate change could potentially increase the climatically suitable areas inland for *Pinus* and *Eucalyptus*. There are no losses predicted for current suitable areas for *Eucalyptus* (DEA, 2013a). However, coastal areas of the Eastern Cape and parts of eastern Mpumalanga and Limpopo are projected to become less suitable within the next four decades for Pinus (DEA, 2013a). In contrast, drastic shifts in areas climatically suitable for Acacia are expected with current suitable areas being lost. Acacia has proved to be the most drought resistant of the commercial hardwoods grown in South Africa (DEA, 2013a).

Fisheries:

South Africa's fisheries sector is a key contributor to local, national and international food security. Commercial fisheries are concentrated on the western and southern coasts with recreational and subsistence fishing spread along much of the country's coastline (DEA, 2014d). Apart from commercial fisheries, subsistence fishing is also important for coastal community livelihoods and to meet basic needs (DAFF, 2012). Both commercial and subsistence fisheries depend heavily on South Africa's marine resources, which makes the sector more vulnerable to climate change impacts.

Understanding and projecting climate change impacts on marine ecosystems and fisheries can be difficult as there are multiple factors at play. There are complex relationships between species distributions, variations in abundance, and the impacts of over-fishing as well as other stressors (DEA, 2014d). Climate change may affect species differently. For example, some species' ranges may increase with increased sea surface temperature, while other species' ranges may decrease.

It is expected however that accelerated sea level rise, changes in river flows and increased frequency and intensity of coastal storms could pose significant risks to estuarine, inshore and offshore fisheries. The KwaZulu-Natal and west coast estuaries are likely to be most affected in terms of structure and function. Furthermore increased scenarios of extreme rainfall and dry spells, coupled with sea level rise, could cause the loss of estuarine habitats. In contrast, increased summer rainfall could result in some estuaries opening up more frequently with a positive impact on the abundance of some species. Seasonal shifts in rainfall could also confuse behavioural cues at critical life cycle stages for estuarine and marine species, which may affect their numbers.

The Department of Agriculture, Fisheries and Forestry is currently in the process of developing a Climate Change Mitigation and Adaptation Plan for marine fisheries and aquaculture in South Africa. This will ultimately form part of the department's gazetted Climate Change Sector Plan for agriculture, forestry and fisheries.

1.9 Water and Sanitation

South Africa is most likely to experience climate change impacts primarily affecting water resources (DWA, 2013). Due to South Africa's arid to semi-arid climate, less than 9% of annual rainfall ends up in rivers and only about 5% recharges groundwater aquifers (DEA, 2014f). As a result South Africa is classified as a water-stressed country which makes the country even more vulnerable to expected climate change impacts.

Climate change impacts on water in South Africa could exacerbate existing water-related challenges such as access to potable water. Projected impacts are due to changes in rainfall and evaporation rates, further influenced by climate drivers such as wind speed and air temperature as well as soils, geology, land cover and topography across water catchments.

A key impact of climate change will be changes in water runoff. Under a wetter future climate scenario, increased runoff would result in increased flooding, human health risks, ecosystem disturbance and aesthetic impacts. However, under drier future climate scenarios, there would be reduced surface water availability. Reduced water availability would most likely create significant trade-offs in terms of the allocation of water resources between agricultural and urban-industrial water use (DEA, 2013b). Projections for national runoff range from a 20% decrease to a 60% increase based on an unmitigated emissions pathway, which reflects substantial uncertainty in rainfall projections (DEA, 2014f).

In addition to water impacts, climate change will also impact sanitation. In 2013, municipalities increased the supply of sewerage and sanitation services by 6.2%, raising the number of consumer units with access to sanitation facilities from 9.4 million in 2012 to almost 10 million 2013 (StatsSA, 2014). Increased flooding and storms, however, could result in damage to infrastructure and potable water supplies.

As part of the National Water Adaptation process, six hydrological zones were developed for South Africa (Figure 1.13). Each zone reflects boundaries defined by water management areas. Zones are grouped according to their climatic and hydrological characteristics. The hydrological zones have different water use demands due to the socio-economic variations within each zone. As a result each zone is vulnerable to water scarcity in different ways. The zones largely cover a province or a cluster of provinces. The characteristics of each of the zones is described below (DWS, 2014, p. viii):

- **Zone 1** is comprised of the Limpopo, Olifants and Inkomati zones. These zones are a combination of towns and rural settlements, with some commercial agriculture and mining. Water infrastructure in the zone is typically medium dispersed schemes.
- **Zone 2** is comprised of the Pongola-Uzimkulu zone. This is generally a high rainfall region with little irrigation except for the Pongola and upper Thukela areas. Economic activity in this zone is quite diverse comprising of rural subsistence farming, commercial agriculture and industry. Large urbanised areas typically dominate the coastline.
- **Zone 3** comprises solely of the Vaal zone. The zone has extensive urbanisation, mining and industrial activity with large water infrastructure including dams and interbasin transfers to the upper Vaal.
- **Zone 4** is made up of the Orange River system. The Orange system has major water infrastructure in place, with four of the largest eight dams in South Africa located in this zone. Most of the water in this zone (70%) is however transferred to meet demand in other regions. In terms of economic activity, there is extensive livestock farming, with sizeable areas under irrigation downstream of the main storage dams.
- **Zone 5** comprises of the Mzimvubu-Tsitsikamma zone. Mainly livestock farming and subsistence agricul-

ture dominate this zone. Industrial activity is found in the vicinity of East London and Port Elizabeth, which is a major hub for the automotive industry. The major water infrastructure in this zone serves East London and Port Elizabeth. Most of the remaining river systems in the region are small.

- **Zone 6** is made up of the Breede-Gouritz and Berg Olifants zones. This zone has several water schemes to meet the region's water needs.

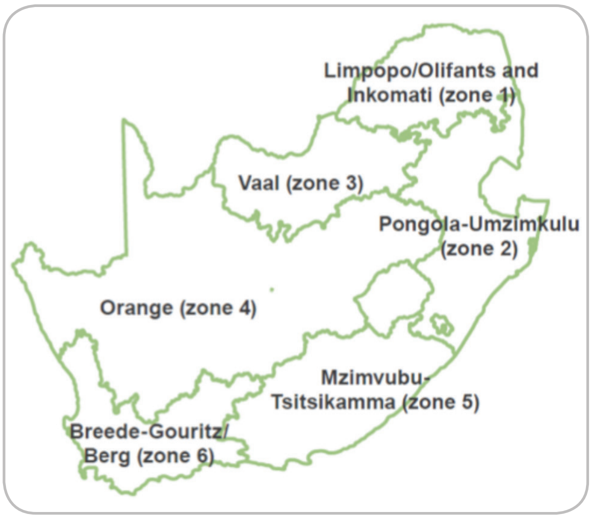

Figure 1.13: South Africa's six hydrological zones (DEA, 2013b, p. 40)

1.10 Institutional Arrangements

Preparation of national communications and biennial update reports is the primary responsibility of the International and Domestic Reporting Unit, which resides within the Department of Environmental Affairs. The organogram outlining the structure of the International and Domestic Reporting Unit institutional is illustrated in Figure 1.14. The green shaded blocks represent units directly involved with developing national communications and biennial update reports.

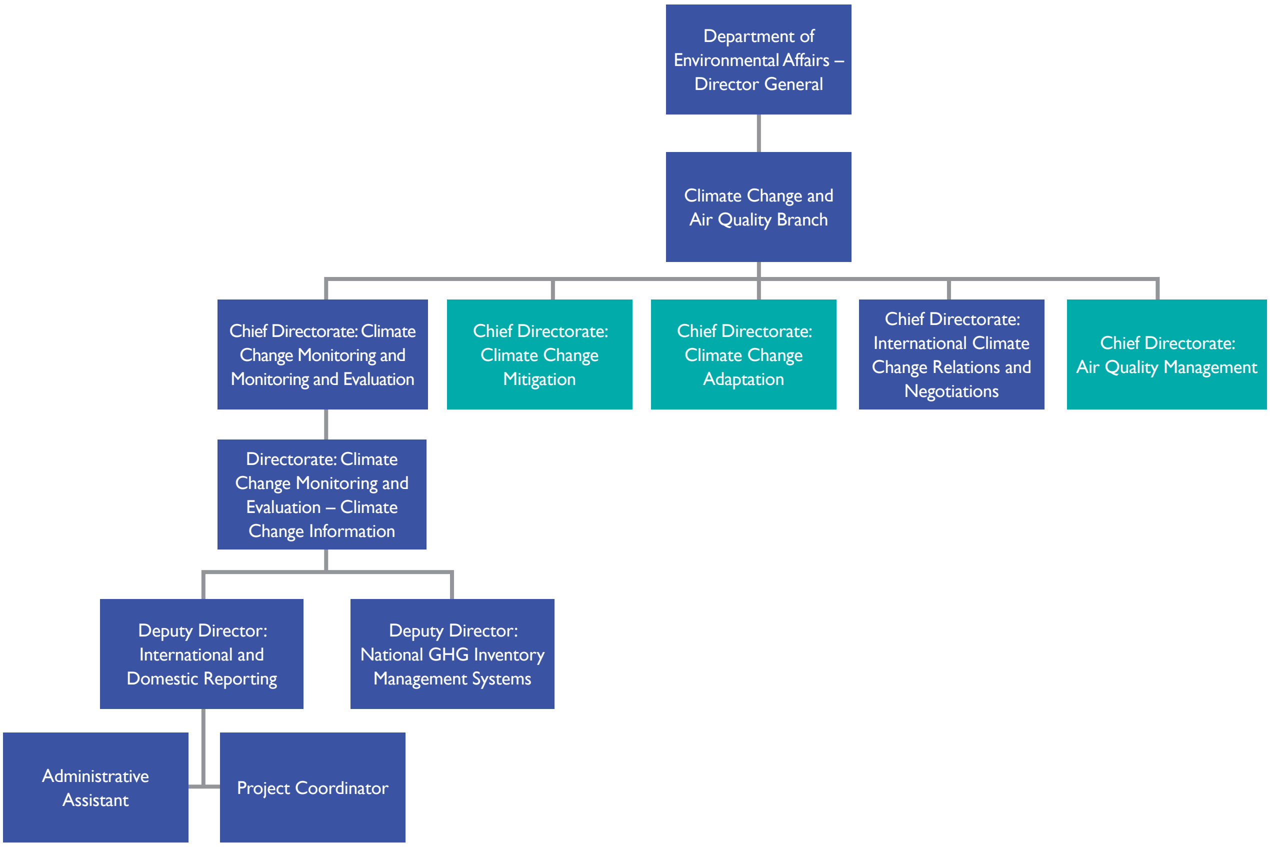

Figure 1.14: Organogram outlining the structure of the International and Domestic Reporting Unit

The drafting of the various chapters of South Africa's Third National Communication was put out on public tender. A number of different service providers were subsequently selected to draft chapters of the Third National Communication.

A standing project steering committee assisted the authors of the national communications (and the biennial update reports) with the provision of required documents and subsequent reviews to ensure policy alignment between Government departments. The project steering committee includes the following:

- Department of Transport;
- Department of Economic Development;
- Department of Human Settlements;
- Department of Agriculture, Forestry and Fisheries;
- Department of Public Enterprise;
- Department of International Relations and Cooperation;
- Department of Rural Development;
- Department of National Treasury;
- Department of Energy;
- The Presidency;
- Department of Science and Technology;
- Department of Trade and Industry;
- Department of Cooperative Governance and Traditional Affairs;
- National Disaster Management Centre;
- Department of Mineral Resources;
- Department of Health;
- Department of Basic Education;
- Department of Water and Sanitation.

The Third National Communication was independently reviewed by the CSIR. The preview process included the incorporation of relevant comments and amendments that were made during the course of compilation process. In addition the document was published for public comment. The final document was sent for parliamentary approval by South Africa's focal point, the Chief Directorate of Climate Change Monitoring and Evaluation. The approved document was then submitted via the focal point to the Convention.

The relevant institutional arrangements necessary to compile a national communication are given below. The Department of Environmental Affairs is responsible for oversight of the national communication. Various other government departments/organisations also provide support and information for use in the report (Figure 1.15).

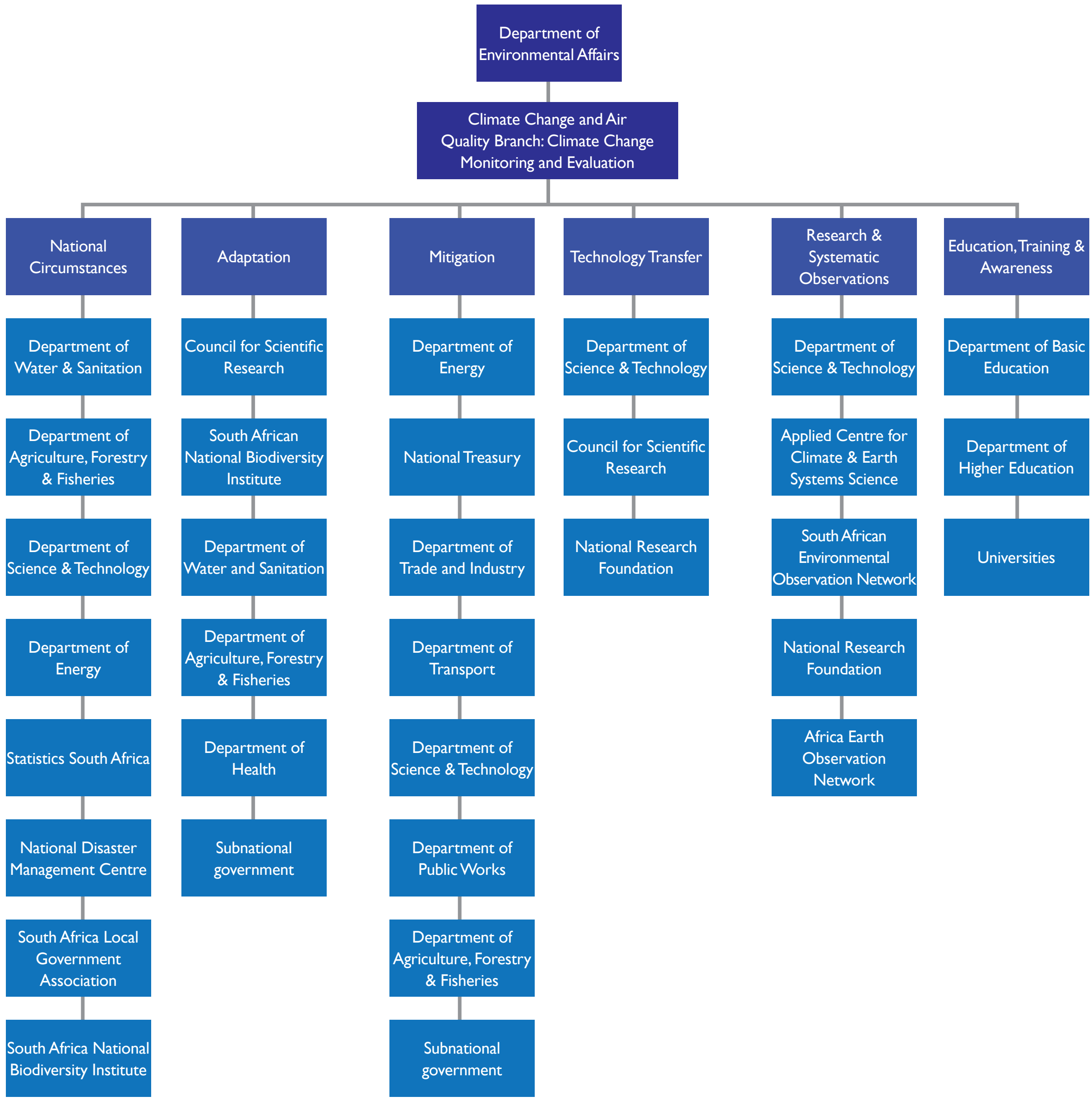

Figure 1.15: Institutional arrangements for preparing National Communications in South Africa

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2 National Greenhouse Gas Inventory

2. National Greenhouse Gas Inventory

This chapter presents an update of South Africa's National Greenhouse Gas (GHG) Inventory, covering the period 2000 – 2012. This inventory was compiled in accordance with the 2006 IPCC Guidelines for National GHG Inventories and covers four sectors, namely:

- Energy;
- Industrial Process and Product Use (IPPU);
- Agriculture, Forestry and Other Land Use (AFOLU); and
- Waste.

A summary of South Africa's 2000 – 2012 GHG emission trends by gas and by sector is presented below. The full GHG Inventory for 2000 – 2012 is available in South Africa's 5th National GHG Inventory and comprehensive information is provided in the GHG National Inventory Report for 2012 (DEA, 2017). The GHGs reported on include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). A number of new developments and improvements have been incorporated into this inventory and the 5th National GHG Inventory has started to apply an uncertainty assessment by sector. This chapter discusses the uncertainties identified in the Energy and IPPU sectors. A summary of each sector is provided, with details of trends, methodologies, data and recalculations performed within each sector.

2.1 Evolution of South Africa's GHG Inventory

As part of our reporting obligations under the UNFCCC, South Africa prepared its first National GHG Inventory for 1990 in 1998. Figure 2.1 shows the evolution of South Africa's National GHG Inventory over the years.

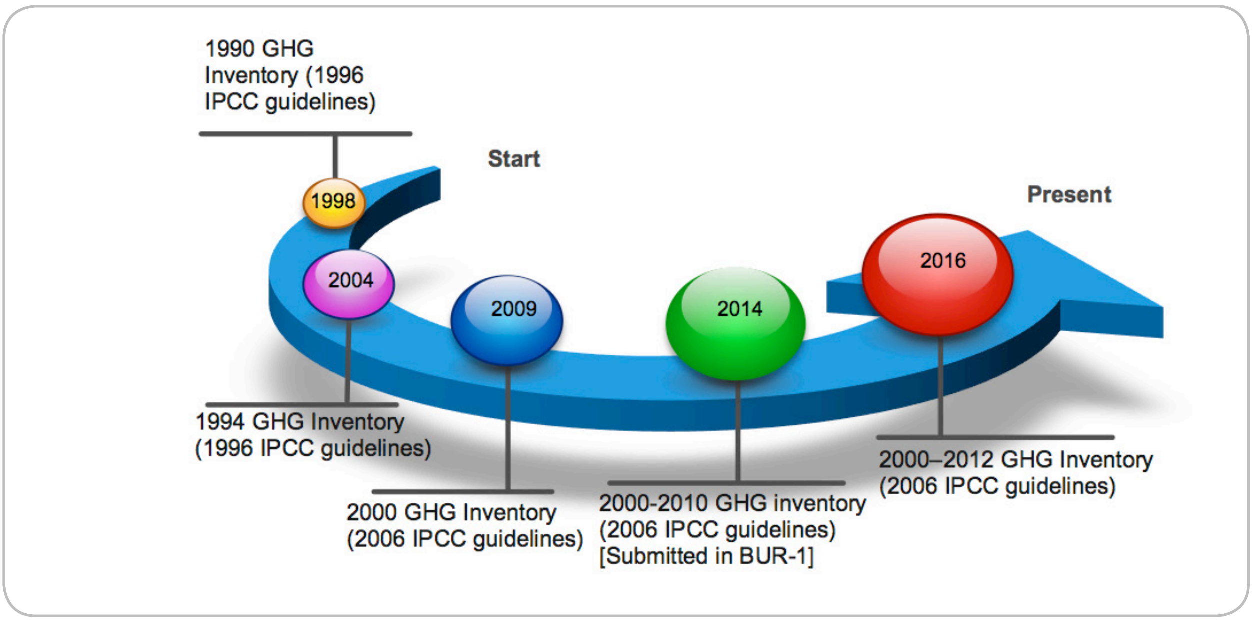


Figure 2.1: The evolution of submitted GHG inventories over the years

The GHG inventories since 2000 have been compiled and updated to provide a more consistent time series, applying the 2006 IPCC guidelines. This allows for a better analysis of the emission trends and recalculations of the time-series whenever improved activity data or emission factors become available. The data from the 1990 and the 1994 GHG Inventories are not included in the trend analysis, as the previous version of the 1996 IPCC guidelines were applied and this hampers data comparability and consistency in reporting over time. The SNC reported on GHG emissions for year 2000, whereas a summary of South Africa's 2000 – 2012 GHG emission trends by gas and by sector is presented in this chapter.

2.2 Institutional Arrangements

The institutional arrangements for compiling the National GHG Inventory were presented in BUR-1 (DEA, 2014) and Figure 2.2 below presents an update of the institutions which contribute to the preparation of the National GHG Inventory. In addition to the roles and responsibilities of the institutions described in BUR-1, Table 2.1 records the roles and responsibilities of those institutions not reported previously.

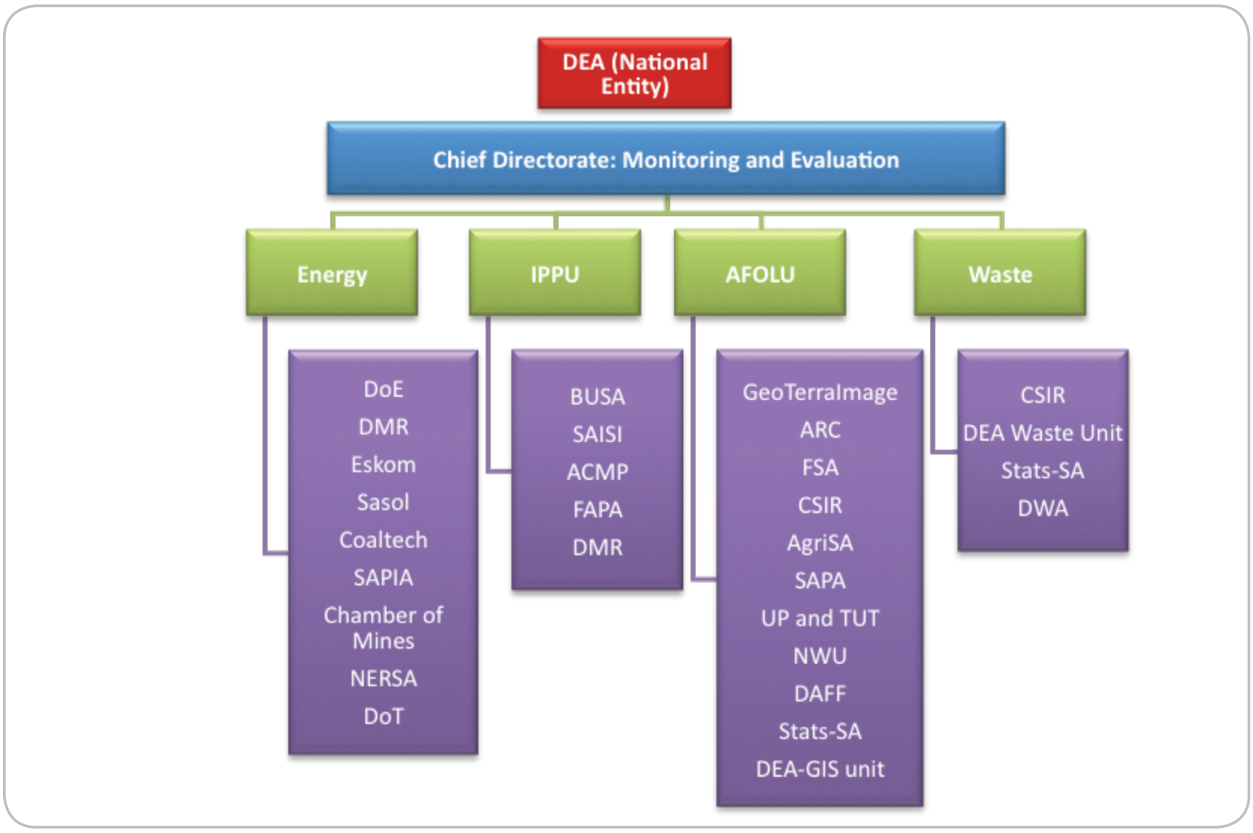


Figure 2.2: Institutional arrangements for national GHG inventory preparation

There is currently no legal mechanism to formalize information flows through this institutional arrangement to ensure consistent and sustainable data input for the GHG inventory. This is currently being addressed though the development of GHG reporting guidelines under the existing National Environmental Management Act: Air Quality (Act No. 39 of 2004, as amended) and the National GHG System described in more detail in Section 2.3 (below). The National Greenhouse Gas Emissions Reporting Regulations were published in April 2017, thereby officially launching the company level GHG reporting program in South Africa.

Table 2.1: Roles and responsibilities for institutions not described in BUR-1

Ministry / Agency	Role
South African Poultry Association (SAPA)	Provides poultry population data
Council for Scientific and Industrial Research (CSIR)	Provides carbon data and technical support when compiling GHG emissions for land
North-West University (NWU)	Provides burnt area data and support for the compilation of the AFOLU sector inventory
Statistics South Africa (Stats-SA)	Provides statistical data
Department of Science and Technology (DST)	Develops various energy programmes and initiatives (renewable energy, energy efficiency, solar and transportation). The HySA Systems is one of three national Competence Centres initiated by the Department of Science and Technology's National Hydrogen and Fuel Cells Technology Flagship Project – also known as Hydrogen South Africa (HySA).
Chamber of Mines	Coordinating the collation and analysis of greenhouse gas emission data for its members[1]
Eskom	Primary Electricity producer in South Africa; Eskom generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa.[2]
SASOL	Primary liquid and gas fuel producer in South Africa. Sasol develops and commercialise technologies, builds and operates world-scale facilities to produce a range of high-value product stream, including liquid fuels, chemicals and low-carbon electricity.[3]
Provincial Environmental Departments	Provinces: provides GHG information on Section 21 Listed Activities regulated in terms of the Air Quality Act; and on point, non-point and area sources of pollution.
Municipalities	Municipalities: provides GHG information on Section 21 Listed Activities regulated in terms of the Air Quality Act; and Metropolitan Municipalities also provides GHG information on point, non-point and area sources of pollution

1. *http://www.chamberofmines.org.za/work/environment*
2. *http://www.eskom.co.za/OurCompany/CompanyInformation/Pages/Company_Information.aspx*
3. *http://www.sasol.com/about-sasol/company-profile/overview*

2.3 Overview of the 2000 – 2012 National GHG Inventory

Since the submission of BUR-1 and the SNC, South Africa's National GHG Inventory has been updated as follows:

1. GHG inventories for the years 2011 and 2012 have been calculated and added to the time-series; and
2. Recalculations for GHG inventories of 2000 – 2010 undertaken due to availability of improved activity data and emission factors. Section 2.3.4 below gives full details of the recalculations. Due to these recalculations, the GHG inventory values for the period 2000 – 2010 differ from the values submitted in BUR-1 for the same period.

This section presents a summary of the latest GHG inventory and the full details are reported in South Africa's 2012 GHG National Inventory Report (DEA, 2017) which accompanies the 5th National GHG Inventory.

South Africa's net GHG emissions for 2012 amounted to 518.3 $GgCO_2e$, which includes the contribution from forestry and other land-use (FOLU), as this sector acts as a carbon sink by absorbing and holding carbon. The gross annual GHG emissions (excluding FOLU emissions) for 2012 totalled 539.1 $GgCO_2e$. Table 2.2 presents South Africa's net National GHG Inventory disaggregated by sector between 2000 and 2012. With the inclusion of FOLU, the energy sector accounted for 78.9% of the net emissions in 2000 and this increased to 82.6% in 2012, amounting to 428.1 $GgCO_2e$ of the 2012 net GHG inventory. This showed a 25% increase in emissions from the energy sector from 2000 to 2012. The GHG emissions from the IPPU, AFOLU and Waste sectors increased collectively by 20.9% from 2000 to 2012; with emissions from the IPPU and Waste sectors showing an increase of 10.6% and 78.5% respectively, while emissions from the AFOLU sector decreased by 32.1% between 2000 and 2012.

Table 2.2 indicates the change of GHG emissions over the period 2000-2012 in total and per key emission category. It highlights that GHG emissions in South Africa have been rising steadily from 434.3 $GgCO_2e$ in 2000 to 518.3 $GgCO_2e$ in 2012, with a significant deceleration taking place between 2007 and 2012. This was mainly due to a deteriorating economy in this period and lower fuel-combustion activities and fugitive emissions as a result.

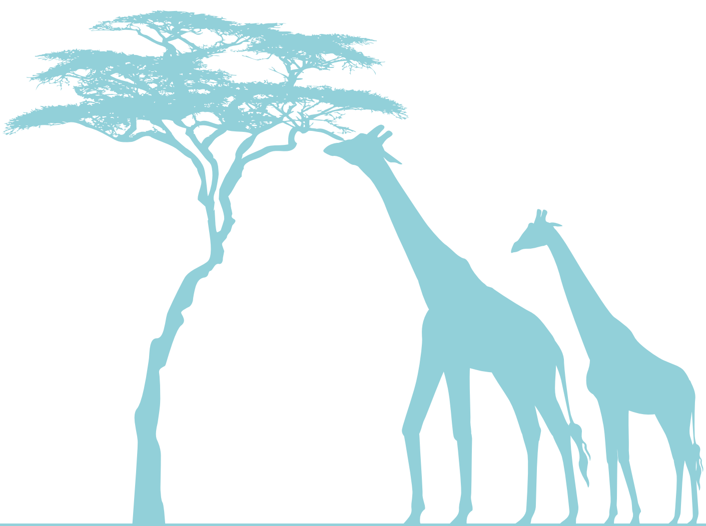
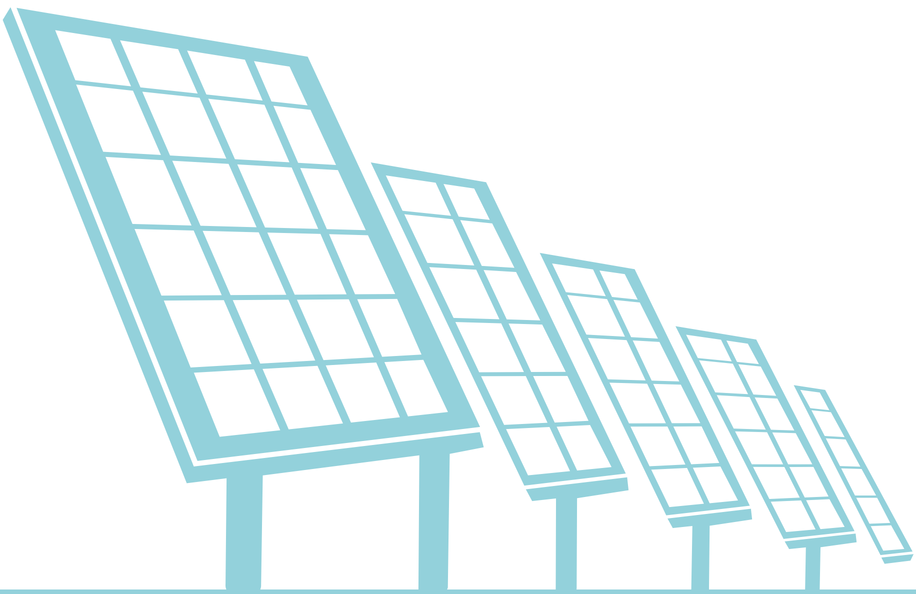


Table 2.2: Trends and levels in net GHG emissions (including FOLU) per sector between 2000 and 2012 (DEA, 2017)

Sector	2000	2001	2002	2003	2004	2005	2006
	$GgCO_2e$						
Energy	342.6	341.3	352.2	375.7	393.6	386.6	393.1
IPPU	33.6	33.6	35.3	34.8	35.3	38.3	39.3
AFOLU	45.9	45.8	44.0	42.3	44.1	44.0	42.0
Waste	12.3	13.2	14.1	14.9	15.8	16.6	17.4
Total	**434.3**	**434.1**	**445.5**	**467.8**	**488.7**	**485.5**	**491.7**
Sector	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Percentage change 2000-2012**
	$GgCO_2e$						
Energy	421.8	413.7	421.8	435.1	415.8	428.1	25.0%
IPPU	37.5	34.9	33.0	35.5	38.9	37.1	10.6%
AFOLU	39.8	47.2	39.0	38.5	38.4	31.1	-32.1%
Waste	18.2	18.9	19.6	20.4	21.2	21.9	78.5%
Total	**517.2**	**514.8**	**513.5**	**529.4**	**514.3**	**518.3**	**19.3%**



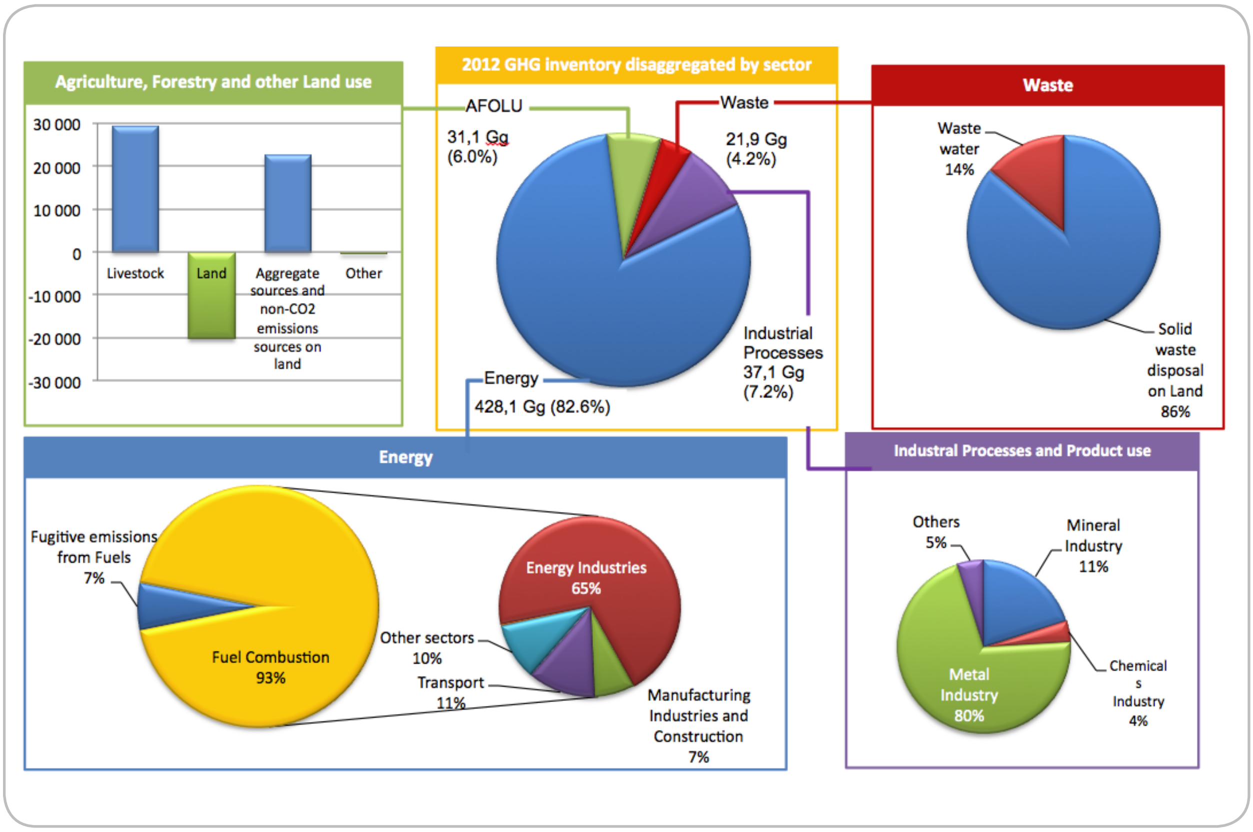


Figure 2.3: South Africa's 2012 National GHG Inventory (net emissions) disaggregated by sector (DEA, 2017)

2.3.1 GHG emission trends and time-series

South Africa's National GHG Inventory time series from 2000 to 2012 is presented graphically in Figure 2.4 (below) and shows a steady increase in trend, with annual declines in absolute emissions of 0.7% between 2004 and 2005 and 1.6% between 2007 and 2008, as well as the highest decrease of 2.7% recorded between 2010 and 2011. These declines are largely attributed to a reduction in fuel combustion activities and fugitive emissions; showing a direct correlation with the decrease in GDP reported for the Mining and Manufacturing sectors over these periods, as shown in Figure 2.3 (above) which depicted South Africa's GDP per sector. Total net GHG emissions trends showed an increase of 16.21% over this period, rising from 434.3 $GgCO_2e$ in 2000 to 518.3 $GgCO_2e$ in 2012 (DEA, 2017).

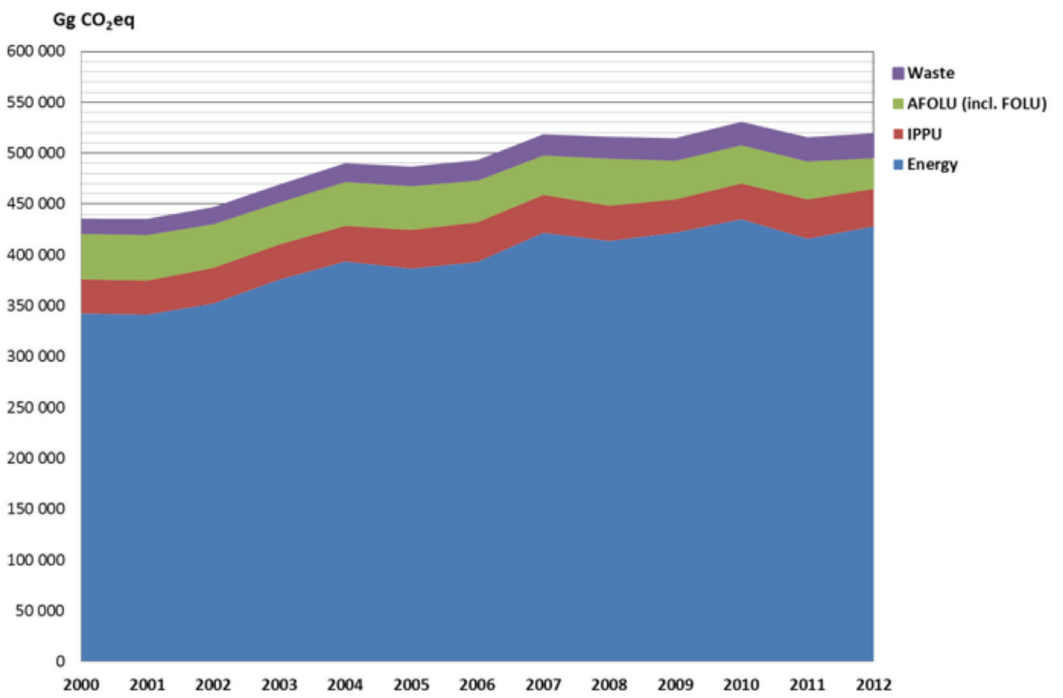


Figure 2.4: South Africa's net GHG inventory time-series 2000-2012, disaggregated by sector (DEA, 2017)

The energy sector contributed 77.3% of the total gross GHG inventory (excluding FOLU emissions) in 2000 and this increased to 79.4% in 2012 (see Figure 2.5 below). There was a general increase in the energy sector contribution; however slight declines were evident in 2001, 2005 and 2006. The AFOLU sector (excluding FOLU emissions) is the second-largest contributor, followed closely by the IPPU sector. The AFOLU sector made up 12.3% of the gross GHG emissions in 2000, which declined to 9.6% in 2012, while in 2000 the IPPU sector contributed 7.6% to the gross GHG emissions, which subsequently declined to 6.9% in 2012. The IPPU sector showed an increase in emissions between 2000 and 2006, followed by a decline between 2007 and 2009 as well as in 2012. The AFOLU sector showed a general decline in GHG emissions, with small annual increases (of less than 5%) in 2002, 2006, 2008, 2010 and 2011. The Waste sector showed a steady increase in its contribution from 2.8% in 2000 to 4.1% in 2012. The inclusion of the FOLU component results in the total net GHG emissions decreasing to 518.3 $GgCO_2e$ in 2012. This also changed the contribution from the Energy, IPPU, AFOLU and Waste sectors to 82.6%, 7.2%, 6.0% and 4.2%, respectively, in 2012 (see Figure 2.6 below).

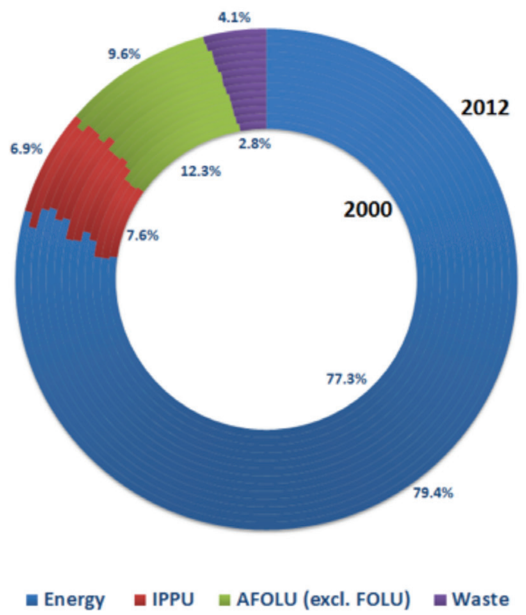


Figure 2.5: Distribution of gross GHG emissions for South Africa (2000 – 2012), disaggregated by sector (DEA, 2017)

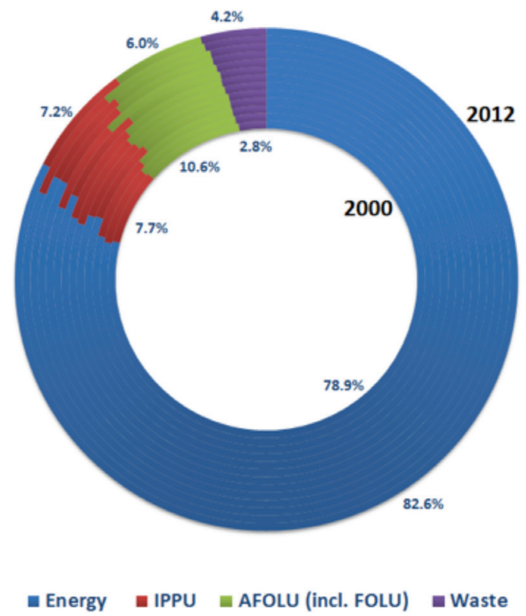


Figure 2.6: Distribution of net GHG emissions for South Africa (2000 – 2012), disaggregated by sector (DEA, 2017)

2.3.2 Overview of greenhouse gas emission estimates and trends

According to the 2012 GHG National Inventory Report (DEA, 2017), South Africa's net GHG emissions in 2012 were predominantly CO_2 (83.7%), followed by CH_4 (10.7%) and N_2O (4.9%), with F-gases contributing less than 1% to the National GHG Inventory. The CO_2 and CH_4 emissions contributing to the net National GHG Inventories (i.e. the inventories which include FOLU contributions) increased by 21.2% and 14.6% respectively for 2000 and 2012, and showed a 23.9% and 15.1% increase respectively in the 2000 and 2012 gross National GHG Inventories (i.e. the inventories excluding the FOLU contribution). N_2O emissions showed a decline of 5.6%, while PFC emissions doubled between 2000 and 2010. HFC emissions (only included from 2005) increased by 65.8% between 2005 and 2012.

2.3.3 Other indicators of South Africa's transition to a lower-carbon economy

South Africa's carbon intensity of the economy has dropped steadily over the past decade and this is largely due to growth in the services and financial sectors, a decline in the manufacturing sector and stagnation in the mining sector (DEA, 2017). The 2008 global economic crisis has had an impact on the carbon-intensity of the national energy supply even though there is generally stagnation elsewhere in the time series due to an unchanged energy supply mix (DEA, 2017). The emissions intensity trend between 2000 and 2012 is shown in Figure 2.7 below.

2.3.4 Recalculations

In the past year, various improvements have been made to the National GHG Inventory due to the incorporation of more detailed activity data and updated emission factors. For the Energy sector, country-specific CO_2 emission factors were incorporated, and these changes led to a 1.5% and 1.6% change to the 2000 and 2010 estimates, as shown in Table 2.3 below (DEA, 2017). This translated to a 1.3% increase in the net national net total for 2010.

The IPPU emissions were recalculated due to updates in the iron and steel production emission factors, updated ferromanganese activity data and updated Ozone Depleting Substances (ODS) and zinc production data (DEA, 2017). The recalculation resulted in a 20% reduction in the GHG emissions from the IPPU sector in 2010 (see Table 2.4 below); mostly because of the adjusted emission factor for the iron and steel production calculations.

Table 2.3: Energy sector GHG emission recalculations for 2000 and 2010

		Initial	Recalculated	% change	% impact on national total (incl. FOLU)
		emissions ($GgCO_2e$)			
Energy	2000	337 381	342 592	1.5%	1.2%
	2010	428 368	435 117	1.6%	1.3%

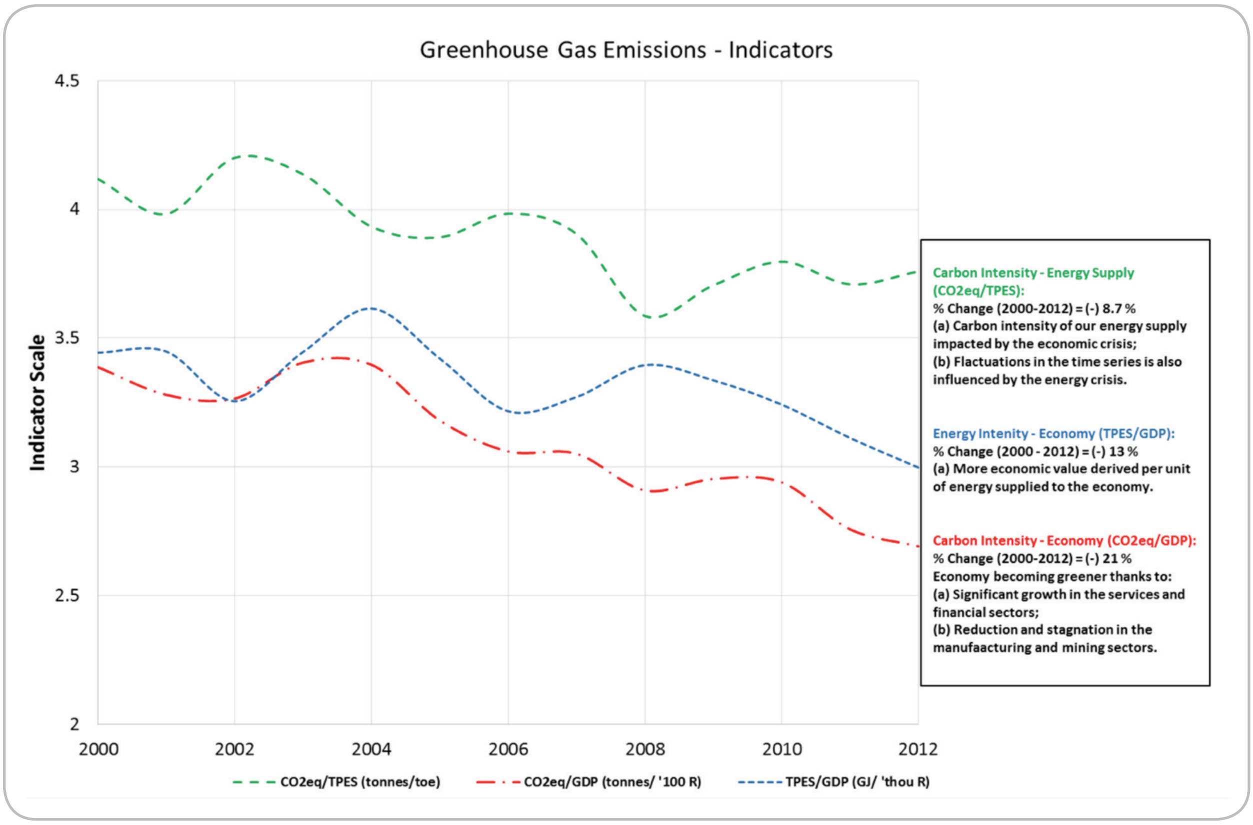


Figure 2.7: South Africa's emissions intensity between 2000 and 2012 (DEA, 2017)

Table 2.4: IPPU sector GHG emission recalculations for 2000 and 2010

		Initial	Recalculated	% change	% impact on national total (incl. FOLU)
		emissions ($GgCO_2e$)			
IPPU	2000	44 907	33 563	-25.3%	-2.6%
	2010	44 350	35 463	-20.0%	-1.7%

The 2012 NIR reports significant updates made in the AFOLU sector calculations (DEA, 2017). In the Agriculture sector, small corrections were made to beef cattle and poultry population and data and emissions from game on privately owned land was included. In the section on Land Use, new land cover maps with higher resolution were introduced, and emissions from 'Dead Organic Matter (DOM) and other lands' were included. The methodology to determine soil carbon was corrected to incorporate soil types and land change over the full 20 years, while data for 'Harvested Wood Products' (HWP) was updated based on the IPCC's revised Supplementary Methods and Good Practice Guidelines (IPCC, 2014). For 'Biomass burning' the burnt area data was intersected with the new land-cover map which led to small changes in emissions from burning biomass. The GHG emissions for the period 2000 to 2012 were recalculated using the updated activity data and emission factors so as to present a more consistent time series.

The recalculations performed for the AFOLU sector had the largest impact on the total emissions (see Table 2.5 below) with a 50.4% and 49.6% increase for 2000 and 2010, respectively. The majority of these changes were due to the availability of updated land change maps and corrected HWP estimates. These increases impacted the national net total by a 3.5% and 2.4% increase in 2000 and 2010, respectively.

Table 2.5: AFOLU sector GHG emissions recalculations for 2000 and 2010

		Initial	Recalculated	% change	% impact on national total (incl. FOLU)
		emissions ($GgCO_2e$)			
Total AFOLU	2000	30 496	45 860	50.4%	3.5%
	2010	25 713	38 456	49.6%	2.4%
3A Livestock	2000	31 118	31 162	0.1%	0.0%
	2010	28 986	30 245	4.3%	0.2%
3B Land	2000	-18 492	-8 517	53.9%	2.3%
	2010	-33 224	-14 876	55.2%	3.5%
3C Aggregated sources and non-CO_2 emissions on land	2000	23 656	23 526	-0.5%	-0.0%
	2010	22 802	23 577	-3.4%	-0.1%
3D Other	2000	-5 785	-312	-94.6%	1.3%
	2010	-6 204	-491	-92.1%	1.1%

The 2012 NIR reports that recalculations of the 2000 GHG emission for the Waste sector led to a reduction of 1.2% of the annual estimates for 2000, but the estimates for 2010 increased by 2.8%, as shown in Table 2.6 below (DEA,2017). These changes were as a result of the availability of updated information and statistics of waste generated and waste disposal.

Table 2.6: Waste sector GHG emissions recalculations for 2000 and 2010

		Initial	Recalculated	% change	% impact on national total (incl. FOLU)
		emissions ($GgCO_2e$)			
Waste	2000	12 433	12 288	-1.2%	-0.03%
	2010	19 806	20 354	2.8%	0.11%

Source specific recalculations were performed for the Waste sector for the period 2000 to 2012 due to the following changes:

- Population statistics for the period 2002-2012 were based on new information available from the 2011 National Census conducted by Stats-SA;
- Percentage of waste generated that is disposed to solid waste disposal sites was reviewed and updated based on the 2012 National Waste Information Baseline Report (NWIBR) (DEA, 2012);
- The waste generation rate for municipal solid waste was reviewed based on new information sourced from the NWIBR. The new waste generation rate is based on provincial weighted average for waste generation rate. This rate was assumed constant for the entire time period; and
- The generation rate for industrial waste was reviewed based on GDP data reported by Stats-SA, as well as industrial waste tonnage rates available from the NWIBR for the year 2011. This rate was assumed constant for the entire time period.

2.3.5 Quality control and Quality Assurance (QA/QC)

Quality controls applied for determining the National GHG Inventory include generic quality checks of the calculations, data processing, completeness and applicable documents. The Quality Assurance was conducted by independent external reviewers, not involved in the compilation of the inventory, to ensure an unbiased review. The external reviewers determined that the results of the annual inventories, emission factors and assumptions applied as well as the methodologies used were reasonable. The independent review process followed is depicted in Figure 2.8 below (DEA, 2017). Furthermore, a public review process was undertaken to supplement the external review, by publishing the draft GHG National Inventory Report in a Government Gazette for stakeholder engagement. Comments received from the public were considered during the independent review process. Findings and recommendations from the independent reviewer were used to refine the 2012 GHG National Inventory Report.

Currently, DEA is preparing a revised 3-year supplementary improvement plan to address recommendations from the independent review process. Some of the current projects listed in the Greenhouse Gas Improvement Programme (GHGIP) are due to findings from a previous review undertaken for the 2000-2010 National GHG Inventory.

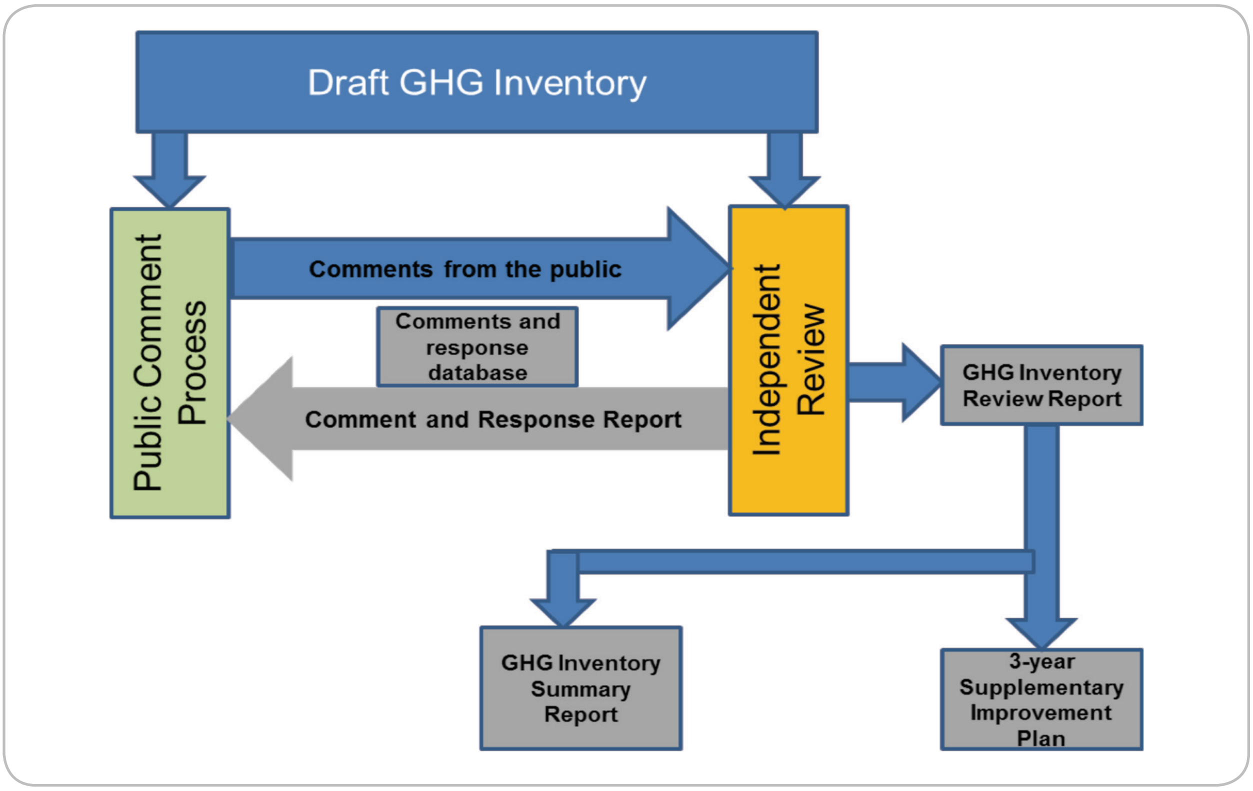


Figure 2.8: The independent review process for the 2000 – 2012 National GHG Inventory (DEA, 2017)

In addition to the 2006 IPCC Guidelines for National GHG Inventories, (IPCC, 2006), South Africa has adopted the internationally accepted validation and verification procedure for GHG assertions for corporate reporting of emissions, which have been adopted locally (SANS:ISO 14064-1), and for emission estimation linked to voluntary market schemes (SANS:ISO 14064-2). A GHG assertion is defined as a declaration or factual and objective statement made by a person or persons responsible for the greenhouse gas inventory and the supporting GHG information. These standards[4] provide for data documentation and audits as part of a quality management system.

In the South African context, QA/QC measures are defined by Part 3 of the South African National Standard for Greenhouse Gases: Specification with guidance for the validation and verification of greenhouse gas assertions (SANS:ISO 14064-3:2006). This standard specifies the requirements for selecting GHG validators/verifiers, establishing the level of assurance, objectives, criteria and scope, determining the validation/verification approach, assessing GHG data, information, information systems and controls, evaluating assertions, and preparing validation/verification statements.

4. All SANS:ISO standards are available on https://store.sabs.co.za/catalogsearch/result/?q=14064

2.4 The GHG Improvement Programme (GHGIP)

South Africa strives to continuously improve its National GHG Inventory. The National Greenhouse Gas Improvement Programme (GHGIP) comprises a series of sector-specific projects that target improvements in activity data collection, country-specific methodologies and emission factors used.

2.4.1 Energy sector

In accordance with the 2006 IPCC Guidelines the energy sector covers two categories, fuel combustion activities and fugitive emissions from fuels. The projects under the energy sector focus on moving to higher tier methodologies which include development of country-specific emission factors and enhancements on bottom-up collection of activity data. Research in the energy sector has focussed on developing country specific emission factors (EFs). GHG emission calculations from the electricity sector improved through the development of country specific EFs for stationary combustion of fuels in the electricity generation sector (DEA, 2016a). This study conducted direct measurements on some boilers at Sasolburg and Secunda coal and gas power plants and applied the Tier 2 and 3 IPCC methodologies to determine EF for these power plants. The outputs of the two methods were compared to provide cross-checks of the calculated EFs. The study also applied Tier 2 IPCC methodology to estimate the country specific EF for electricity produced by Eskom. It recommended that further measurements and calculations be carried out at other plants and that more professionals should be trained in EF determination to maintain continuity.

Other projects that have been completed include the development of country specific EF for coal mining, including emissions from abandoned mines and spontaneous combustion; development of higher tier methodologies to estimate fugitive emissions from processing of fuels through a detailed life-cycle emissions analysis coupled with a material balance approach; and an economy wide fuel consumption survey to determine the split in consumption between the energy carrier and the sectors' demand. Table 2.7 presents some of the projects under implementation as part of the GHGIP.

Table 2.7: GHGIP projects completed for the Energy sector

Project	Objective	Partner	Donor	Outcome	Status	Time-lines
Country-specific CO_2, CH_4 and N_2O emission factors from power generation and stationary combustion	To develop emission factors for stationary combustion using the main electricity producer and other independent power producers as a pilot	Eskom, SASOL	BMUB-GIZ	Emissions from key sectors based on country-specific information (DEA, 2016a)	Completed	2014-2015
Country-specific CH_4 and CO_2 emission factors for coal mining; Emissions from abandoned mines and spontaneous combustion	To develop country-specific emission factors for domestic coal mining	Coaltech		Emissions from coal mining are based on domestically developed methodologies and emission factors	Completed	2011-2014
Bottom-up Gas-to-liquids (GTL) Coal-to-liquids (CTL)	Use of higher-tier methodologies for the estimation of fugitive emissions from processing of fuels	PetroSA, SASOL		Detailed life-cycle emissions analysis coupled with material balance approach	Completed	2013-2015
Economy-wide fuel consumption survey	Analysis of fuel consumption by energy carrier and demand-side sector	GIZ	GIZ	Understanding the split of energy carriers across demand-side sectors (DEA, 2016c)	Completed	2014-2015

GHGIP projects currently underway, through support from donor funding are presented in Table 2.10 below.

2.4.2 Industrial processes and product use (IPPU) sector

The GHGIP projects for the IPPU sector focussed on moving to higher Tier methodologies which includes the development of country-specific emission factors and enhancements on bottom-up collection of activity data. A study is being completed on the implementation of a Tier 3 IPPC method for estimating process emissions from aluminium production. A sector-specific CO_2 EF for ferroalloy production is also being determined currently. A survey on HFC consumption has been commissioned and this aims to assess baseline data on the current use of HFC's in South Africa. Completed GHGIP projects for the IPPU sector, are reflected in Table 2.8.

Table 2.8: GHGIP projects completed for the IPPU sector

Project	Objective	Partner	Outcome	Status	Timelines
Bottom-up methodologies for Aluminium production	Implementation of a tier-3 IPCC methodology for estimation of process emission from aluminium production	BHP Billiton	GHG emission from aluminium production based on plant-specific data	Completed	2011-2014

GHGIP projects currently underway, through support from donor funding are presented in Table 2.10 below.

2.4.3 Agriculture, forestry and other land use (AFOLU) sector

The improvements to GHG inventory data and information for the AFOLU sector mainly involved the use of updated land cover maps to identify the emissions and sinks with consideration of South Africa's circumstances and landscapes. The GHGIP projects in the AFOLU sector focussed on improving activity data collection for the sector. In order to determine the impacts of land use change on the GHG inventory, good land-use change maps at the national level are required. Presently many maps are only available at the provincial level and these are often compiled at different scales, years and make use of different classifications, as the development of maps is often project specific and created on demand. Recently land cover maps, and subsequent land-use change maps, were developed for 2001, 2005 and 2010. These were based on lower resolution MODIS data. Improvements in this sector therefore included the development of a higher resolution national land cover change map (based on Landsat data) for the period 1990 and 2013. The other focus for the GHGIP includes the collection of more detailed data on cropland management.

In addition to the GHGIP, the Tshwane University of Technology (TUT) together with the University of Pretoria (UP) conducted research and measurements to develop country specific EFs for the livestock sub-sector. Country specific EFs for enteric fermentation and manure management for all livestock have been developed (Du Toit et al. (2013a-d); as in (DEA, 2017) and incorporated into the inventory. In addition, UP is currently measuring direct CH_4 and N_2O emissions from manure management on cattle feedlots and dairy and pig farms. There is also a collaborative project between the Paper Manufacturers Association of South Africa (PAMSA), the University of Stellenbosch and the Institute of Commercial Forestry Research (ICFR) on carbon sequestration in plantation forests. This research investigates techniques used to estimate carbon sequestration at the Tier 2 level and provides detailed activity and EF data for plantations. The University of the Witwatersrand is also involved in research determining country specific EFs for the Waste sector. Projects completed under the GHGIP programme for the AFOLU sector are presented in Table 2.9 below:

Table 2.9: GHGIP projects completed for the AFOLU sector

Project	Objective	Donor	Outcome	Status	Timelines
Strategic Climate Policy Fund	Improvement of the Greenhouse Gas Emissions Inventory for the Agricultural Sector	DEA	Planned improvements for livestock production, agricultural soils, and biomass burning (DEA, 2016b).	Complete	2014-2015
National Land-Cover Maps	To develop national land cover maps for two-time steps (1990, 2013)	Department for International Development (DFID) –UK	Emissions and Sinks are estimated based on accurate and consistent land cover data	Completed	2014-2015
Croplands Management survey	The collection of crop management data for various agricultural crops to estimate GHG emissions and sinks at national level	United Nations Environmental Programme (UNEP)	Data available on the application of fertiliser per commodity crop; irrigation practices; application of lime; application of organic matter; management of crop residue; cropping systems; tillage practice and area under cultivation.	Completed	2014-2015
National Climate Change Monitoring and Evaluation system of the AFOLU Sector	A study to inform design, development and implementation of M&E for the AFOLU sector	DEA	AFOLU M&E System for cost effective MRV and annual reporting of AFOLU GHG inventory (DEA, 2015a)	Completed	2014-2015

2.4.4 GHGIP projects under implementation

The Department of Environmental Affairs is implementing five GHGIP projects in the Energy, IPPU and Waste sectors which are donor funded, as presented in Table 2.10.

Table 2.10: GHGIP Project under implementation

Project	Objective	Partner	Donor	Outcome	Status	Timelines
Development of the National GHG Inventory System	The implementation of a national system for the sustainable management of the GHG emissions inventory compilation.	Norwegian Embassy and Norwegian Environmental Agency	Norwegian Embassy and Norwegian Environmental Agency	A national system with elements necessary to compile annual GHG emissions inventories, such as institutional, legal and procedural arrangements.	Under Implementation	2015-2017
Sector-specific CO_2 emission factors for Ferroalloy production – (Ferrochrome)	GHG emissions from ferrochrome production are based on locally derived CO_2 emission factors.	Xstrata (Glencore), United Nations Environmental Programme (UNEP)	United Nations Environmental Programme (UNEP)	Emissions from key sectors based on country-specific information	Under Implementation	2014-2016
Survey on HFC consumption	To collect, summarise and present in a written report all relevant technical, commercial and baseline data on the current use of Hydro fluorocarbons (HFCs)	United Nations Environmental Programme.	United Nations Environmental Programme.	HFC application at a sectoral level	Under implementation	2015-2016
Country-specific CO_2 emission factors for Road transportation	Development of country-specific CO_2, CH_4 and N_2O emission factors	Department of Transport (DOT) and United Nations Environmental Programme.	United Nations Environmental Programme	Road transport related GHG emissions informed that are reflective of national circumstances	Conceptualization	2016-2017
Development of Source Specific Activity Data for the Waste Sector	The improvement in the estimation of GHG emissions from the waste sector.	United Nations Environmental Programme.	United Nations Environmental Programme	Bottom-up country specific information for the estimation of GHG emissions from the waste sector	Under Implementation	2016-2017

As indicated in the table above, these GHGIP projects are all anticipated to be completed by 2017.

2.5 References

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3 Climate Change over South Africa from Trends and Projected Changes to Vulnerability Assessments and the Status Quo of National Adaptation Strategies

3 Climate Change over South Africa from Trends and Projected Changes to Vulnerability Assessments and the Status Quo of National Adaptation Strategies

3.1 Introduction

Climate change is projected to impact drastically on the African continent during the 21st century under low mitigation futures (Niang *et al.*, 2014). Temperatures are projected to rise rapidly, at 1.5 to 2 times the global rate of temperature increase (Engelbrecht *et al.*, 2015; James & Washington, 2013). Moreover, the Southern African region and Mediterranean North Africa are likely to become generally drier under enhanced anthropogenic forcing, whilst East Africa and most of tropical Africa will plausibly become wetter (Christensen *et al.*, 2007; Engelbrecht *et al.*, 2009; James & Washington, 2013; Niang *et al.*, 2014). More uncertainty surrounds the projected climate futures of West Africa and the Sahel, with some climate models projecting wetter conditions and equally credible models projecting drier conditions (e.g. Christensen *et al.*, 2007; Niang *et al.*, 2014). The changing African climate is likely to have a range of impacts across the continent, including impacts on energy demand (in terms of achieving human comfort within buildings and factories), agriculture (e.g. reductions of yield in the maize crop under higher temperatures and reduced soil moisture), livestock production (e.g. higher cattle mortality as a result of oppressive temperatures), water security (through reduced rainfall and enhanced evapotranspiration) (e.g. Engelbrecht *et al.*, 2015; Garland *et al.*, 2015; Thornton *et al.*, 2011) and infrastructure (mostly through the occurrence of more large-scale floods in particular regions).

Climate change is not to take place only through changes in average temperatures and rainfall patterns, but also through changes in the attributes of extreme weather events. Over the southern African region the more frequent occurrence of dry spells and droughts are likely to occur over most of the interior under low mitigation futures (Christensen *et al.*, 2007; Engelbrecht *et al.*, 2009). Cut-off low related flood events are projected to occur less frequently over South Africa (e.g. Engelbrecht *et al.*, 2013) in response to a poleward displacement of the westerly wind regime. Some uncertainty surrounds the landfall of tropical cyclone tracks over southern Africa under climate change, but at least one study is indicative of more frequent landfall and thus more frequent flooding over central and northern Mozambique (Malherbe *et al.*, 2013). Further to the north over Tanzania and Kenya more large-scale flood events may plausibly occur, which in combination with the plausible increase in drought over southern Africa would represent an El Niño – like signature in future African climate. Intense thunderstorms are plausible to occur more frequently over tropical and subtropical Africa in a generally warmer climate (e.g. Engelbrecht *et al.*, 2013). More uncertainty surrounds the climate futures of West Africa, the Sahel and the Horn of Africa, particularly within the context of how climate change may impact on the occurrence of mega-droughts over these regions (Lyon and DeWitt, 2012; Roehrig *et al.*, 2013; Williams *et al.*, 2012).

The findings described above are all based on global climate model (GCM) projections of future climate change, or on the downscaling of these projections over Africa through the use of regional climate models (RCMs). The GCMs analysed in Assessment Report Five (AR5) of the Intergovernmental Panel on Climate Change (IPCC) typically had a horizontal resolution of about 200 km. RCMs have typically been applied over parts of the African continent at a resolution of about 50 km in the horizontal, and more recently over the entire continent at a resolution of about 50 km, through the endeavours of the Coordinated Regional Downscaling Experiment (CORDEX) of the World Climate Research Programme (WCRP).

Since the Second National Communication (SNC), updated analysis of observed trends in climate in South Africa and significantly enhanced projections of regional climate change, obtained in South Africa and through the international Coordinated Regional Downscaling Experiment (CORDEX) have served to fill some of the gaps in our understanding of climate change in South Africa. Moreover, the National Climate Change Response Plan (NCCRP) in 2011 and the conclusion of Phase 2 of the Long Term Adaptation Scenarios (LTAS) in 2014 have been amongst the key milestones since the SNC with respect to the understanding climate change impacts, vulnerability and adaptation in South Africa.

This chapter uses comprehensive observed data sets of SAWS, the custodian of observed climate data in South Africa, to document the historical trends in the temperature and rainfall over South Africa for the period of 1921 – 2015. A review of trends in sea-level along the South African coast is also presented. The fine-scale projections of future climate change generated by the University of Cape Town (UCT) and the Council for Scientific and Industrial Research (CSIR) for the LTAS (2013) report have also been significantly extended over the last four years. These projections are used as a baseline to describe the projected climate futures over southern Africa in this communication, with the findings interpreted within the context of AR5 of the IPCC.

Following on the discussions of observed trends in climate and projections of future climate change in South Africa, a review of the most significant climate change risks and vulnerabilities for the sectors of agriculture and forestry, water resources, terrestrial ecosystems, the coastal zone, health, urban and rural settlements and disaster risk management is presented in this chapter. This is followed by a summary of the progress made toward developing a National Adaptation Plan for the country.

3.2 Observed Trends in Climate Over South Africa

3.2.1 Introduction: Trends in southern African and African climate

Studies of historical climate trends have been steadily increasing during the last decade given the increasing concerns about anthropogenically induced global warming and climate change. For the African continent, the studies of Engelbrecht *et al.* (2015) and Jones *et al.* (2012) are indicative of drastic increases in surface temperature occurring over the last five decades. In the African subtropics, temperatures are increasing at a rate of about twice the global rate of temperature increase. For South Africa, the most noteworthy recent investigations of trends in temperature are those of Kruger (2010), Kruger & Nxumalo (2016), Kruger & Sekele (2012), and MacKellar *et al.* (2014). These studies are indicative of wide-spread and statistically significant temperature increases occurring across South Africa over the last five decades (and longer). The strongest warming has been observed in the west over the Western Cape and Northern Cape, and in the north-eastern provinces of Limpopo and Mpumalanga, extending southwards to the coastal areas of KwaZulu-Natal. Moreover, increases have not been observed only in the annual and seasonal averages of minimum and maximum temperature, but also in their extremes. In particular, warm extremes exhibit strong increasing trends, whilst cold nights are decreasing across the country.

The most noteworthy studies on historical trends in rainfall over South Africa are those of Kruger (2006) and MacKellar *et al.* (2014). Whilst the study of Kruger (2006) spanned the period 1910 – 2004, Mackellar *et al.* (2014) used a larger number of stations spanning the more recent period of 1961-2010. Both these studies are indicative of statistically positive trends over parts of the central interior of South Africa, with statistically negative trends largely confined to the northeastern parts of Limpopo and Mpumalanga in the northeast and the winter rainfall region in the southwest. Over most of the country, however, recorded trends in rainfall are largely statistically insignificant, and trends are also small in magnitude over the entire country (in the order of 10 mm/century, or smaller).

The updated analysis of trends in South African temperatures presented in this chapter of the Third National Communication (TNC) builds in particular on the studies of Kruger & Sekele (2012) and Mackellar *et al.* (2014). The study of Mackellar *et al.* (2014) was commissioned by the Department of Environmental Affairs (DEA) LTAS report on climate trends and projections in South African climate (DEA, 2013). One of the shortcomings of the results included in the LTAS (2013) report, and in fact most research initiatives on long-term climate trends, is the relatively short time periods of analysis relative to the cyclical behaviour inherent to regional climate. This could have a significant effect on the eventual trend results obtained, and in particular on the rainfall trends analysis. Both the studies of Kruger & Sekele (2012) and MacKellar *et al.* (2014) focussed on periods of about five decades starting in the early 1960s, in which exist four clear cycles of wet-dry conditions (with plausibly associated temperature cycles). This makes linear trend analysis somewhat susceptible to the specific time window analysed (Kruger, 1999). A further shortcoming of the LTAS (2013) analysis is the absence of data homogenisation for the case of the temperature time-series used. Trend analysis based on such data sets may produce artificial trends produced by shifts in station location, or changes in instrumentation. Limiting the analysis to stations with homogeneous time-series greatly reduce the number of stations available for analysis, however.

In the TNC a two-prong approach is therefore followed, towards obtaining defensible insights into the observed trends in climate over South Africa. Firstly, building on the work of Kruger (2006) and Kruger & Sekele (2012), a carefully constructed analysis of longer term station time-series data was performed. Secondly, the analysis of MacKellar (2014) was updated with the most recent observations to obtain a spatial view of South African temperature and rainfall trends over the period 1960-2015. For the case of temperature, it was possible to construct time-series data with the desired property of temperature homogeneity for the period 1931-2015 (Kruger & Nxumalo, 2016). In the case of the time-series analysis of rainfall, although the construction of homogeneous time-series data was not feasible, the analysis was performed for the extended period 1921-2015 (rainfall). The latter analysis is thought to be more reliable in detecting long-term trends amidst the pronounced inter-annual and decadal variability exhibited by rainfall patterns over South Africa.

3.2.2 Observed data and extreme event indices

A total of 27 weather stations were available for temperature trends analysis spanning the period 1931-2015, whilst 60 stations were used for the rainfall trend analysis spanning the period 1921-2015.

Apart from the trends in the annual mean minimum, maximum and average temperatures, and average diurnal temperature range presented in this report, the analyses also includes the determination of trends in extreme temperatures, of which the indices considered are based on those developed by the World Meteorological Organization (WMO) Expert Team on Climate Change Detection and Indices (ETCCDI) (Wang and Feng, 2013). These are presented in Table 3.1. The base period was selected as 1981 – 2010, as applicable to the six percentile-based indices.

Apart from the trends in the annual rainfall totals, long-term changes in rainfall can manifest in changes in rainfall extremes. Therefore, while general trends in rainfall are analysed, an extreme rainfall trend analysis is also performed, based on rainfall extreme indices developed by the WMO ETCCDI. These are presented in Table 3.2. The base period, from which the annual index values of all indices are determined (except the annual maxima and minima) was selected as 1981 – 2010, which can be considered to be the present general norm for similar trend studies.

Table 3.1: ETCCDI extreme temperature indices utilized for the TNC

Index	Definition	Units	Description
TX90P	Annual number of days when TX > 90th percentile	days	Annual number of hot days
TX10P	Annual number of days when TX < 10th percentile	days	Annual number of cool days
TXx	Annual maximum value of TX	°C	Annual daytime hottest temperature
TXn	Annual minimum value of TX	°C	Annual daytime coolest temperature
WSDI	Annual number of days with at least 6 consecutive days when TX > 90th percentile	days	Annual longest hot spell
TNx	Annual maximum value of TN	°C	Annual night time warmest temperature
TNn	Annual minimum value of TN	°C	Annual night time coldest temperature
TN90P	Annual number of days when TN > 90th percentile	days	Annual number of warm nights
TN10P	Annual number of days when TN < 10th percentile	days	Annual number of cold nights
CSDI	Annual number of days with at least 6 consecutive days when TN < 10th percentile	days	Annual longest cold spell

Table 3.2: ETCCDI extreme rainfall indices utilized for the TNC

Index	Definition	Units	Description
prcptot	Annual total precipitation when daily precipitation ≥1 mm	mm	Annual total precipitation in wet days
r95p	Annual total precipitation from daily precipitation > 95th percentile	mm	Annual total precipitation from high daily rainfall
r99p	Annual total precipitation from daily precipitation > 99th percentile	mm	Annual total precipitation from very high daily rainfall
rx1day	Annual maximum 1-day precipitation	mm	Highest daily rainfall per year
r10mm	Annual count of days when precipitation ≥ 10mm	days	Annual number of days with moderate rainfall
r20mm	Annual count of days when precipitation ≥ 20mm	days	Annual number of days with moderate to high rainfall
r25mm	Annual count of days when precipitation ≥ 25mm	days	Annual number of days with high rainfall
SDII	Annual mean of daily precipitation intensity	mm	Annual mean amount of daily rainfall, indicating mean daily rainfall intensity
CWD	Maximum number of consecutive days with precipitation ≥ 1mm	days	Annual maximum length of wet spell
CDD	Maximum number of consecutive days with precipitation < 1mm	days	Annual maximum length of dry spell

3.2.3 A spatial analysis of temperature trends over South Africa

3.2.3.1 Average temperature

For annual mean temperature over the period 1931-2015 for the homogeneous time-series (Figure 3.1) the most important feature is a significant warming trend exhibited by the vast majority of stations, consistent with earlier studies (Engelbrecht *et al.*, 2015; Kruger, 2010; Kruger & Sekele, 2012; MacKellar *et al.*, 2014).

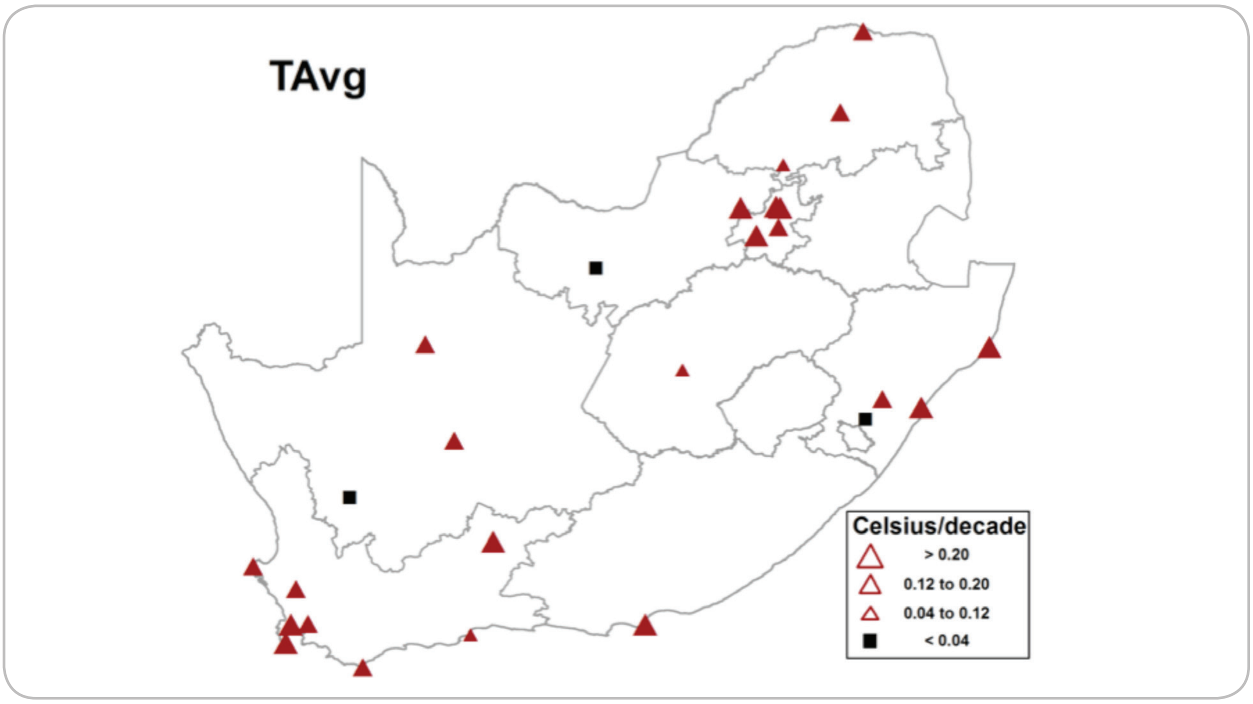


Figure 3.1: Linear trends in annual average temperatures (1931-2015). Filled triangles indicate significance of trend at the 95% confidence level (Kruger & Nxumalo, 2016)

Some of the stations show trends in excess of 2 °C per century, significantly higher than the mean global warming trend, which is in the region of 1 °C per century. Consistent with the analysis of temperature extremes as presented by Kruger & Sekele (2012), the largest warming trends are found to be occurring over the drier western parts of the country (Northern Cape and Western Cape) and in the northeast (Limpopo and Mpumalanga, extending southwards to the east coast of KwaZulu-Natal). The relatively strong warming over Gauteng province is also noteworthy, and it may be postulated that an increasing heat island effect could have contributed to the warming, due to continuous urbanization of the province.

3.2.3.2 Minimum and maximum temperature

The results for maximum temperatures reflect approximately the same tendencies as presented in the LTAS (2013) report. While stations in the Western Cape, east coast of KwaZulu-Natal and Gauteng exhibit strong increases in annual maximum temperatures, there are stations over the central interior showing relatively small and even statistically insignificant trends (see Appendix B). Minimum temperatures have not been found to exhibit negative trends over the central interior of South Africa, contrary to the findings of previous studies (Kruger & Sekele, 2012; DEA, 2013; MacKellar *et al.*, 2014). This may be attributed to the longer period utilized in the analysis, as well as the homogenisation procedure applied to the station data. Due to the different trends in the annual maximum and minimum temperatures it is to be expected that there should be spatial variations in the trends for the diurnal temperature range (DTR). While most stations show decreases in DTR (indicating that the minimum temperature trends are more positive than the maximum temperatures for most stations) there are some regional contradictions in the results (see Appendix B). This may be an indication of localized influences that play a role in urban areas, e.g. in Gauteng and the southwestern Cape.

3.2.3.3 Warm and cold nights

The trends in the annual number of warm and cold nights, as defined by the 10th and 90th percentiles (TN90P and TN10P) respectively of daily minimum temperatures during the baseline period, are presented in Figure 3.2. For warm nights there are mostly relatively small and non-significant trends over the western parts, while the remainder of the country significantly positive trends, strongest along the coast and Gauteng province, can be detected. For most of the country significant decreases are evident in cold nights which, in absolute terms, are generally stronger than the increases in warm nights. While there were very small insignificant trends for most stations in the interior with regards to warm nights, most stations in this region showed statistically significant decreases in cold nights, although the magnitudes of change are relatively small.

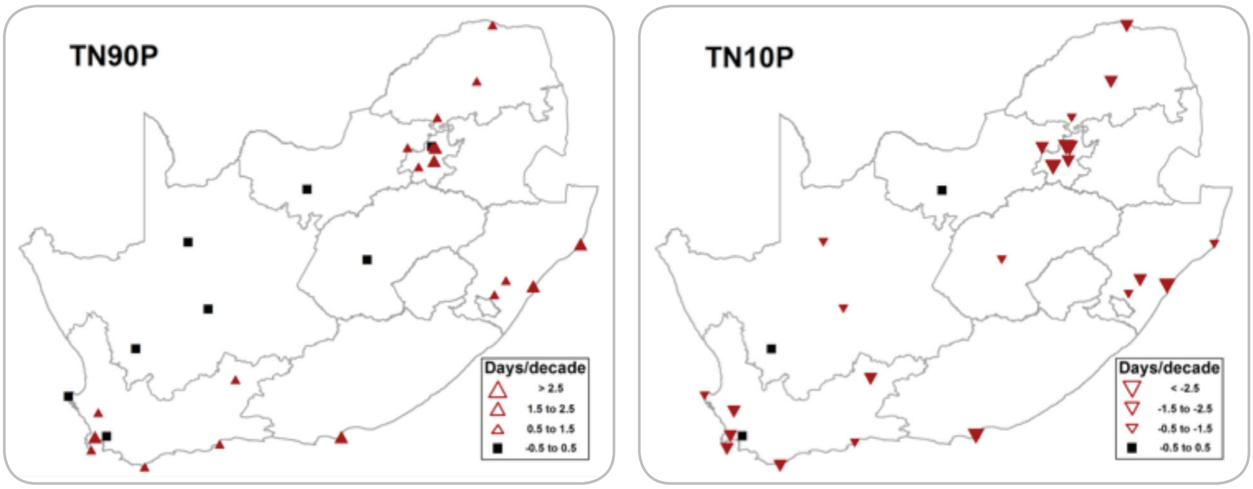


Figure 3.2: Linear trends in annual number of warm nights (TN90P) and cold nights (TN10P) over the period 1931-2015. Filled symbols indicate significance of the trend at the 95% confidence level (Kruger & Nxumalo, 2016)

3.2.3.4 Hot and cool days

To identify decadal trends in the annual number of hot and cool days, indicated by TX90P and TX10P respectively, threshold values were calculated from daily maximum temperature values as recorded over the baseline period. In contrast to the results for warm and cool nights (previous section), the results here are spatially less coherent and also smaller in absolute magnitude (see Appendix B). Notwithstanding, the results still show trends that are consistent with widespread warming of the country. Both of the results of TN10P (previous section) and TX90P indicate that the use of longer time series with homogenisation removes the cooling trends which was evident in previous analyses where some stations in the central interior showed significant increases in cold nights and decreases in hot days (DEA, 2013).

3.2.3.5 Warm and cold spells

The trends in the annual maximum lengths of hot and cold spells, indicated by WSDI and CSDI respectively indicate that it is only in the western parts of the interior where significant increases in warm spells are evident (see Appendix B). In contrast to warm spells, cold spells have decreased significantly for most stations.

3.2.4 A spatial analysis of rainfall trends over South Africa

3.2.4.1 Annual rainfall totals

The results in the trends of annual rainfall for individual rainfall stations are presented in Figure 3.3, for case of the SAWS analysis performed for the period 1921-2015. The most evident result is a statistically positive trend in annual rainfall totals over the central southern interior. Statistically significant negative trends in rainfall have been recorded over the northern parts of the Limpopo Province. Otherwise, the recorded trends in annual average rainfall totals are largely statistically insignificant over the remainder of the country. While for most seasons there are no large-scale spatial coherence in statistically significant trends, it is clear that the positive trends in annual rainfall totals over the southern interior is reflected mostly in the summer rainfall trends, which is the main rainfall season for this particular region (see Appendix B). The decreasing trends in annual rainfall over Limpopo, on the other hand, seem to be largely the result of decreasing rainfall trends in autumn.

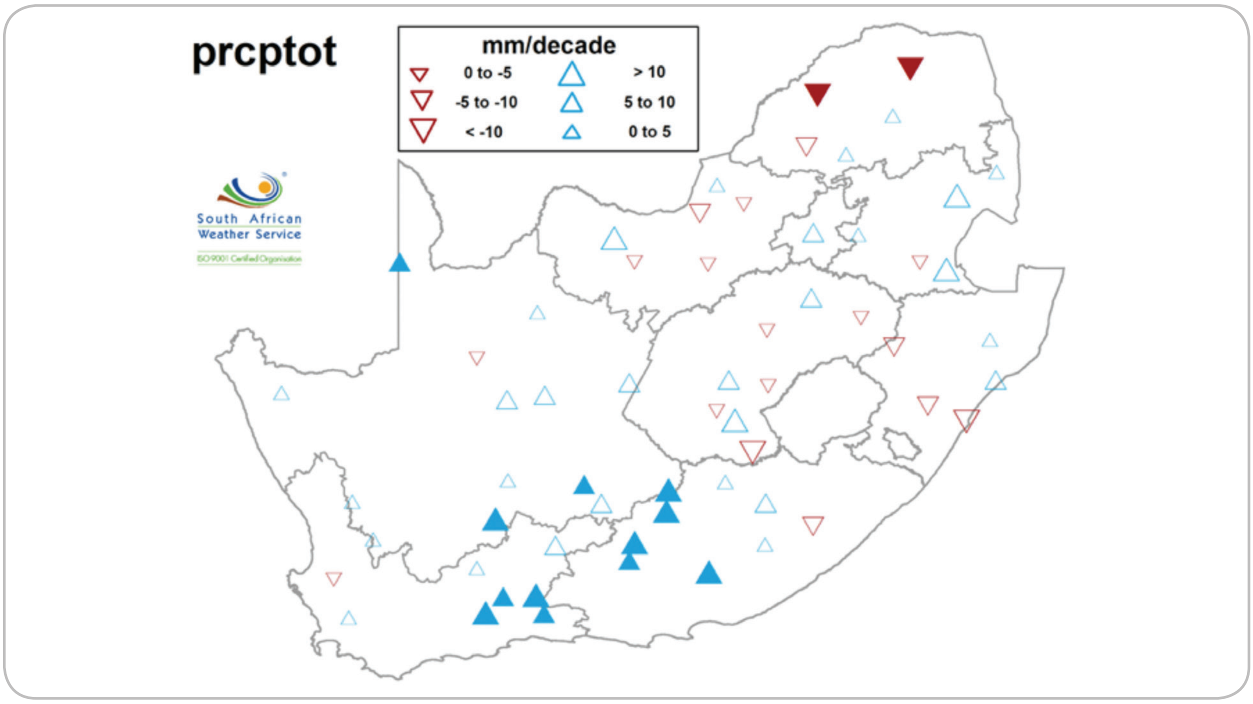


Figure 3.3: Trends in total annual rainfall for individual stations for the period 1921 – 2015. Symbology is indicated in the figure, and shaded symbols indicate significant trends at the 95% confidence level

3.2.4.2 Annual total precipitation from daily precipitation > 95th percentile

Trends in rainfall extremes have the strongest presence in the ETCCDI r95p and r99p indices, and to a lesser degree in the r10mm, r20mm, r25mm and rx1day indices (all these thresholds were calculated relative to the baseline period; see Appendix B for the full set of results). The r95p and r99p indices measure the total rainfall per year with rainfall above the 95th and 99th percentile daily rainfall totals respectively. Both indices calculated for the SAWS data spanning the period 1921-2015 indicate that there have been significant increases occurring in very high daily rainfall totals in the central southern interior and adjacent coastal regions (Figure 3.4), extending westwards to the eastern part of the Western Cape. In the opposite side of the country in the far north-east, these indices indicate decreases. Except for these decreases recorded over parts of Limpopo for r95p, almost all stations are reporting increases in the metric, although these increases are statistically insignificant at most locations.

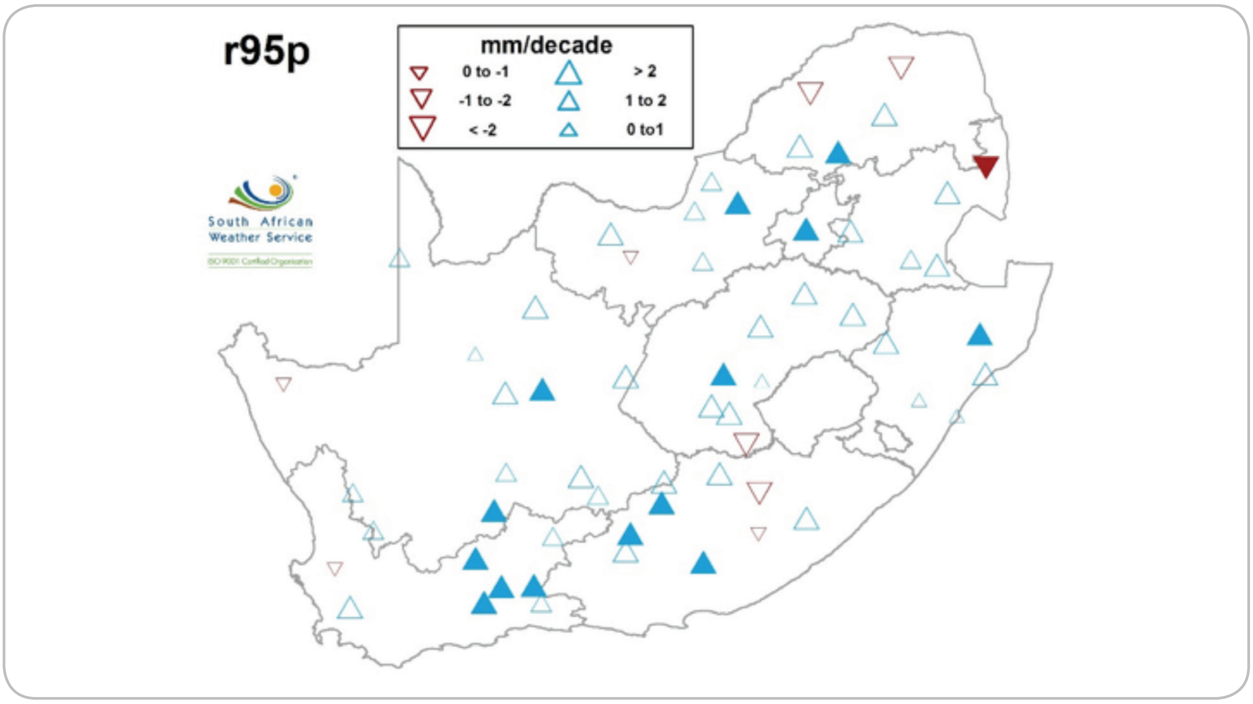


Figure 3.4: Trends in the 95th percentile of precipitation (1921-2015). Shaded symbols indicate significant trends at the 5% level

3.2.4.3 Annual total precipitation from daily precipitation > 99th percentile

Most weather stations considered in the SAWS analysis for 1921-2015 are reporting positive trends in the number of days per year experiencing rainfall above the 99th percentile as determined by the baseline period thresholds. However, these trends are generally not statistically significant, except for a cluster of stations over and to the north of Gauteng (see Appendix B).

3.2.4.4 Annual maximum 1-day precipitation

The rx1day index indicates whether there are trends in the annual maximum of daily rainfall amounts. For the SAWS analysis performed for the period 1921-2015 the results are similar to that obtained for r95p and r99p, in that statistically significant increases are found over the southern interior (see Appendix B). Although the majority of stations are reporting statistically insignificant trends in this metric in the case of the SAWS-analysis, almost all stations are reporting positive trends, consistent with the analysis of the extended LTAS (2013) data set (see Appendix B).

3.2.4.5 Annual count of days when precipitation ≥ 10 mm, ≥ 20 mm and ≥ 25 mm

Analysis of the SAWS data for the period 1921-2015 reveals that statistically significant increases have occurred over the southern and central interior in the number of days experiencing rainfall above the 10 mm, 20 mm and 25 mm thresholds (see Appendix B). A seasonal analysis for the case of the 20 mm threshold reveals that these changes in the annual number of events are largely driven by increases occurring during the summer season.

3.2.4.6 Simple Daily Intensity Index, annual mean of daily precipitation intensity

The SDII index indicates whether there are trends in the average amount of rainfall that is received on a day with rainfall. Significant increases might indicate that the risks of high rainfall intensity became more prevalent, which in turn indicates a higher probability of related disasters such as flash floods more likely. General increases occurred in the daily intensity of rainfall in the central and southern interior and as far north as the North-West, Gauteng and eastern Free State provinces (see Appendix B). Decreases are evident in the eastern parts of the country, according to the SAWS analysis for 1921-2015.

3.2.4.7 Annual maximum length of wet spell, maximum number of consecutive days with precipitation ≥ 1mm

In the south-western Cape the longest annual wet spell usually occurs during winter, while in the remainder of the country it usually occurs in summer. Trends in CWD show predominantly a decrease in the largest part of the north-eastern half of the country, with some stations indicating statistically significant decreases in excess of 0.2 days per decade (see Appendix B). This result corresponds to the decrease of rainfall observed in some of the eastern parts of the country. For the south-western half of the country the trends are mostly non-significant, except for three stations in the Eastern Cape interior, which show significantly positive trends between 0.1 and 0.2 days per decade. The rx5day index determines the highest annual amount of rainfall received in a continuous five day episode, which provides an indication of the trend in the intensity of continuous rainfall episodes. The trend results indicate that the maximum annual amount of continuous rainfall in a five-day episode has increased in parts of the southern interior. Most stations in the country show increases, although not statistically significant. Significant changes elsewhere are isolated and therefore no conclusions can be made thereof in a regional sense.

3.2.4.8 Annual maximum length of dry spell, maximum number of consecutive days with precipitation < 1mm

The Continuous Dry Days (CDD) index defines the length of the longest annual period in days with no significant rain, which indicates that this period should fall in the winter months over most of the country, but in the summer months over the south-west where most rainfall is received during winter. While most of the north-eastern half of the country recorded a decrease in the longest annual period of wet days, and the south-western half mostly an increase, the opposite applies for the annual maximum period of dry days (see Appendix B). However, it is mostly the stations along the escarpment which show significant decreases in CDD. This could indicate that there might be a historical long-term increase in the annual period when there is sufficient influx of moisture from the ocean over the adjacent interior to produce rainfall along the escarpment, which is the main source of rainfall for these areas.

3.2.5 Observed trends in sea-level along the South African coastline

3.2.5.1 Rate of sea level rise

Limited research has been undertaken in South Africa regarding sea-level rise (SLR). Some literature regarding the topic may be found in Brundrit (1984, 1995), Hughes *et al.* (1991), Mather (2008), Mather *et al.* (2009) and Mather & Stretch (2012). Climate change and its potential impacts on the South African coastal domain may be found in studies performed by Brundrit (2008), Cartwright (2008), Cooper (1991, 1993, 1995a, 1995b, 2001), Fairhurst (2008); Mather (2012), Midgley *et al.* (2005), Theron (1994, 2007, 2011) and Theron *et al.* (2016). Relative sea-level rise is a local phenomenon and the study presented by (Mather, *et al.*, 2009) for South Africa and Namibia took into account the vertical local movements of the earth's crust as well as the recorded changes in atmospheric or barometric pressure. The results of their study showed that the western, southern and eastern coasts of South Africa can expect different rates of relative sea-level rise. Both crust movements and barometric pressure varied around the southern tip of Africa resulting in a varying relative sea level rise of (based on intermitted data from 1959 to 2006):

- +1.87 mm/year for the South African west coast,
- +1.48 mm/year for the South African south coast and
- +2.74 mm/year for the South African east coast.

3.2.6 Provincial trends regarding climate

3.2.6.1 Northern Cape

The Northern Cape has been experiencing strong temperature increases of 1.5 - 2 °C per century as recorded over the 1931-2015 period. Extreme warm events have also been increasing across the province, and particularly so over the northern interior. Here hot days have been increasing in frequency of occurrence, at a rate of about 2 days/decade. Annual rainfall totals show statistically significant increases over the southeastern interior parts of the province (at a rate of about 5 mm/decade), with associated increases in extreme daily rainfall events (rate of increase is about 2 days/decade in days with rainfall above the 90th percentile threshold). The rate of sea-level rise along the Northern Cape coast has been measured over the last five decades to be in the order of 20 cm/century.

3.2.6.2 Western Cape

The Western Cape has been experiencing a drastic rate of temperature increase of more than 2 °C per century at some locations, as recorded over the 1931-2015 period. Extreme warm events have also been increasing during this period, for example hot days have been increasing at a rate of about 1 day per decade. Annual rainfall totals show statistically significant increases over the eastern interior parts of the province over the last few decades, with the rate of increase as high as 10 mm/decade. Associated increases in the number of days with extreme rainfall (daily rainfall above the 90th percentile threshold) have also occurred, at a rate of about 2 days per decade. The rate of sea-level rise along the Western Cape coast has been measured over the last five decades to be in the order of 20 cm/century along the west coast and 15 cm/century along the south coast.

3.2.6.3 Eastern Cape

Over the Eastern Cape a lack of long-term homogeneous time series data prevents an extensive analysis of temperature trends as well as trends in extreme temperature events to be performed. There is some evidence though, that strong temperature increases of about 2 °C per century has occurred over the western interior of the province over the 1931-2015 period. Annual rainfall totals show statistically significant increases over the western interior parts of the province (rate of increase about 10 mm/year), with associated increases in extreme daily rainfall events (rate of increase about 2 days/decade). The rate of sea-level rise along the Eastern Cape coast has been measured over the last five decades to be in the order of 15 cm/century along the Cape south coast region (in the west), and somewhat larger towards the east.

3.2.6.4 KwaZulu-Natal

KwaZulu-Natal has experienced drastic warming over the 1931-2015 period, with stations along the coast reporting temperature increases of more than 2 °C/century. Hot days have been increasing at a rate of about 0.5 days per decade. There is no clear evidence of statistically significant changes in annual precipitation totals or daily rainfall extremes. The rate of sea-level rise along the KwaZulu-Natal coast has over the last five decades been measured to be in the order of 30 cm/century.

3.2.6.5 Mpumalanga

A lack of stations with sufficiently long homogeneous temperature records complicate the identification of temperature trends over Mpumalanga. It is plausible though that the trends are strong, given the drastic temperature increases recorded over Gauteng to the west, Limpopo to the north and KwaZulu-Natal to the south. There is no evidence of statistically significant trends in annual rainfall or extreme daily precipitation events, but there are indications of spatially coherent increases in rainfall over the Highveld areas in the west and decreases over the Lowveld areas in the east.

3.2.6.6 Limpopo

Strong warming of more than 1 °C per century has been recorded for the province over the period 1931-2015, with the number of hot days increasing by about 1 day/decade over the same period. Stations in the northern parts of the province have also recorded statistically significant decreases in annual precipitation (at a rate of more than 10 mm/decade), but with no statistically significant increases in extreme daily rainfall events that can be discerned.

3.2.6.7 Gauteng

Drastic temperature increases of more than 2 °C/century have been recorded in Gauteng over the period 1931-2015. The number of hot days has been increasing over the same period at a rate of about 1 day/decade. Annual rainfall totals at stations in the province do not exhibit statistically significant trends, but there is evidence of increases in the occurrence of extreme daily rainfall events (rate of increase as high as 2 days per decade).

3.2.6.8 Free State

The analysis of temperature trends over the Free State is hampered by a lack of station data with sufficiently long and homogeneous records. There is evidence though that the warming that is occurring is statistically significant but less in magnitude than over the Northern Cape to the west and Gauteng to the north. Rainfall stations did not report statistically significant increases in annual precipitation totals or extreme precipitation events over the period 1931-2015, although a spatially coherent pattern of extreme daily precipitation increases is present over the province.

3.2.6.9 North West

A lack of stations with sufficiently long homogeneous temperature records complicate the identification of temperature trends over North West. It is plausible though that the trends are strong given the drastic temperature increases recorded over the Northern Cape to the west, Botswana to the north and Gauteng to the east. There is no evidence of systematic changes in annual rainfall totals, but some evidence of an increase in extreme daily rainfall events.

3.2.7 Conclusions

South Africa has been warming significantly over the period 1931-2015. Over the western parts of the country including much of the Western and Northern Cape, and also in the east over Gauteng, Limpopo and the east coast of KwaZulu-Natal, the observed rate of warming has been 2 °C/century or even higher – more than twice the global rate of temperature increase. Associated increases in extreme maximum temperature events have occurred, but with a decrease in cold nights over most of the country. There is strong evidence of statistically significant increases in rainfall occurring over the southern interior regions over the period 1921-2015, extending from the western interior of the Eastern Cape and eastern interior of the Western Cape northwards into the central interior region of the Northern Cape. Extreme daily rainfall events have increased over these same areas, with these increases also being statistically significant and extending northwards into North West, the Free State and Gauteng. Over Limpopo there is strong evidence of statistically significant decreases in annual rainfall totals.

3.3 Projected Climate Change Futures for South Africa

3.3.1 Introduction: Plausible climate futures for Southern African

Both AR4 and AR5 of the IPCC have concluded that the southern African region is likely to become generally drier under low mitigation climate change futures (Christensen *et al.*, 2007; Niang et al, 2014). Over the eastern escarpment areas of South Africa the climate change signal of the GCM projections described in AR4 and AR5 exhibit some uncertainty though, with some projections indicative of rainfall increases and others indicative of rainfall decreases. Over the winter rainfall of the southwestern Cape, on the other hand, the projections of rainfall decreases are particularly robust. The relatively low resolution of the GCMs that participated in AR4 and AR5 and the associated Coupled Model Intercomparison Project Phases Three and Five (CMIP3 and CMIP5) limits the application of these models in climate change impact studies, however. At the time of the SNC, only a limited number of regional climate modelling studies were available for analysis, with both statistical downscaling (Hewitson and Crane, 2006) and dynamic downscaling capabilities (Engelbrecht *et al.*, 2009) very much under development at the time in the country. More extensive ensembles of regional projections of future climate change have since been developed over southern Africa, however, not least because of the research coordinated through LTAS (DEA, 2013; Engelbrecht *et al.*, 2015). Another important development since the SNC is that more research has been focussed on a process-based understanding of climate change over southern Africa. For example, the projected decreases in rainfall over the southwestern Cape has been linked to a poleward displace met of cold fronts (Engelbrecht *et al.*, 2009; 2013), whilst the plausible increase in rainfall over the central interior regions of South Africa has been linked to a deepening of the heat low over the western interior and a strengthening of mid-level highs (Engelbrecht *et al.*, 2009). Further to the north, increasing rainfall over central to northern Mozambique under low mitigation have been linked to the more frequent landfall of tropical lows and cyclones (Malherbe *et al.*, 2013).

In this section, the most recent projections of future climate change obtained for South Africa are reviewed. The baseline of the discussion is the GCM projections of AR5 of the IPCC and their downscalings to Africa and South Africa obtained through both statistical and dynamic methodologies. The projections are discussed for both low mitigation (RCP8.5) and high mitigation (RCP4.5) futures, and for near-future (2016-2035), mid-future (2040-2060) and far-future (2080-2099) time-slabs. The discussion focusses not only on the projected changes in average temperatures and rainfall totals, but also in the futures of extreme weather events under climate change.

3.3.2 Methodology

The starting point of the analysis of future climate change over South Africa as described in the TNC, are the projections of the Coupled Global Climate Models (CGCMs) of CMIP5 and AR5 of the IPCC. These projections are used to inform on the uncertainty range of the large-scale climate change futures over the southern African region. However, the resolution of the CMIP5 CGCMs is relatively low, in the order of 200 km in the horizontal. These resolutions are too course for the projections to directly find impact in climate change impact studies at municipal and provincial scales. Downscaling methodologies are therefore needed, to obtain projections of future climate change of sufficient detail to aid climate change impacts studies and the formulation of adaptation strategies at the provincial and local scales. In LTAS, and subsequently in the TNC, the most extensive sets of regional downscalings ever obtained in South Africa were used for this purpose. These were obtained using both dynamical and statistical downscaling procedures.

At the CSIR, a dynamic regional climate model CCAM (conformal-cubic atmospheric model) (McGregor, 2005) of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to downscale CMIP5 CGCM projections to 50 km resolution over Africa. These downscalings were performed for the period 1960-2099, and for both Representative Concentration Pathway 8.5 (RCP8.5) and Representative Concentration Pathway 4.5 (RCP4.5) of AR5 of the IPCC. These represent low and modest-high mitigation pathways, respectively. The CGCMs downscaled are the Australian Community Climate and Earth System Simulator (ACCESS1-0); the Geophysical Fluid Dynamics Laboratory Coupled Model (GFDL-CM3); the National Centre for Meteorological Research Coupled Global Climate Model, version 5 (CNRM-CM5); the Max Planck Institute Coupled Earth System Model (MPI-ESM-LR); the Norwegian Earth System Model (NorESM1-M) and the Community Climate System Model (CCSM4). The simulations were performed on supercomputers of the CSIRO and on the Centre for High Performance Computing (CHPC) of the Meraka Institute of the CSIR in South Africa. The CCAM regional climate model has a long track-record of being applied over southern Africa and has been shown to represent many aspects of present-day climate over the region realistically (e.g. Engelbrecht *et al.*, 2009; Engelbrecht et al 2015). At CSAG statistical downscalings of future climate change over South Africa were performed, using a methodology based on that of Hewitson and Crane (2006). These downscalings were also generated for the period 1960-2099, and for RCP4.5 and RCP8.5. A total of eleven CGCMs of CMIP5 were downscaled.

Although the CSIR dynamic downscalings and CSAG statistical downscalings represent the largest ensemble of downscalings analysed to date over southern Africa, it should be noted that the resulting set of projections sample only a subset of the larger set of CGCM projections obtained for the southern African region. That is, the downscalings may not represent the full uncertainty range of climate change over the region, as represented in the GCM projections. For this reason, the TNC also considers the projections of a larger set of fourteen CGCM projections analysed over southern Africa. Moreover, the results obtained are interpreted against the background of the full set of AR5/CMIP5 CGCM projections for Africa, as described in AR5 of the IPCC (Niang *et al.*, 2014). It may be noted that the analysis presented in the TNC represents a step-up over the SNC, when only a single dynamically derived downscaling and a small set of statistical downscalings were available for reanalysis. In the future, towards the Fourth National Communication, even larger sets of regional projections will be available from local and international downscaling efforts, including CORDEX.

3.3.3 Projected temperature futures for South Africa

3.3.3.1 Average temperature

The projections from the CMIP5 GCMs and statistical and dynamic downscaling techniques under RCP4.5 show similar patterns of warming across southern Africa with the strongest warming projected for the interior regions and the weakest warming along the coastal areas (see Appendix B). Most of the projections are indicative of the western and central interior regions of South Africa warming the most. For the near-future period warming is projected to be between 0.5 to 1 °C at most locations (relatively to the baseline period of 1971-2000), in some of the projections reaching values as high as 2 °C over parts of the western interior of South Africa extending into Botswana (see Appendix B). Some of the statistical downscalings are more conservative compared to the forcing GCM projections and dynamic downscalings, projecting temperature increases of less than 0.5°C for the near-future period (see Appendix B). The dynamic downscalings on the other hand, are indicative of relatively large increases of 1-2 °C over much of the interior, with one downscalings indicative of temperature increases as large as 2.5°C over parts of the central interior, including the Free State and North West provinces (see Appendix B).

A somewhat larger degree of heterogeneity exists in the projections for the mid-future period 2040-2060 under RCP4.5, but the western interior regions of southern Africa are projected to warm most in almost all the projections, with the magnitude of temperature increases ranging between 2 and 3 °C in most projections (see Appendix B). There is a single dynamic downscaling in which the warming reaches 3.5 °C over the western to central interior by the mid-future. Warming continues deeper into the 21st century, reaching values of 3-4 °C over the western interior regions for the period 2080-2099 in most of the model projections (see Appendix B). A minority of projections are indicative of temperature increases exceeding 4 °C over the western and central subtropical interior regions by the far-future period of 2080-2099 (see Appendix B).

The projections under RCP8.5 show close correspondence to the projections under RCP4.5 for the near-future period of 2016-2035. Warming that is projected to range between 0.5 to 1 °C at most locations reaching values as high as 2 °C over parts of the western interior of South Africa (see Appendix B). The dynamic downscalings are indicative of relatively large increases of 1-2 °C over much of the interior, with one downscalings indicative of temperature increases as large as 2.5°C over parts of the central interior, including the Free State and North West provinces (see Appendix B). However, for the mid-future period of 2046-2065 the projected warming is significantly stronger under RCP8.5, ranging from 3-4 °C over the western and central interior, and exceeding 4 °C over some of the western parts. For the far-future period of 2080-2099 drastic warming of more than 4 °C is projected for entire southern African region, with the exception of the southern and eastern coastal regions of South Africa (Figures 3.5 and 3.6). Warming of more than 6 °C is projected for parts of the western interior by some of the downscalings for the far-future under RCP8.5.

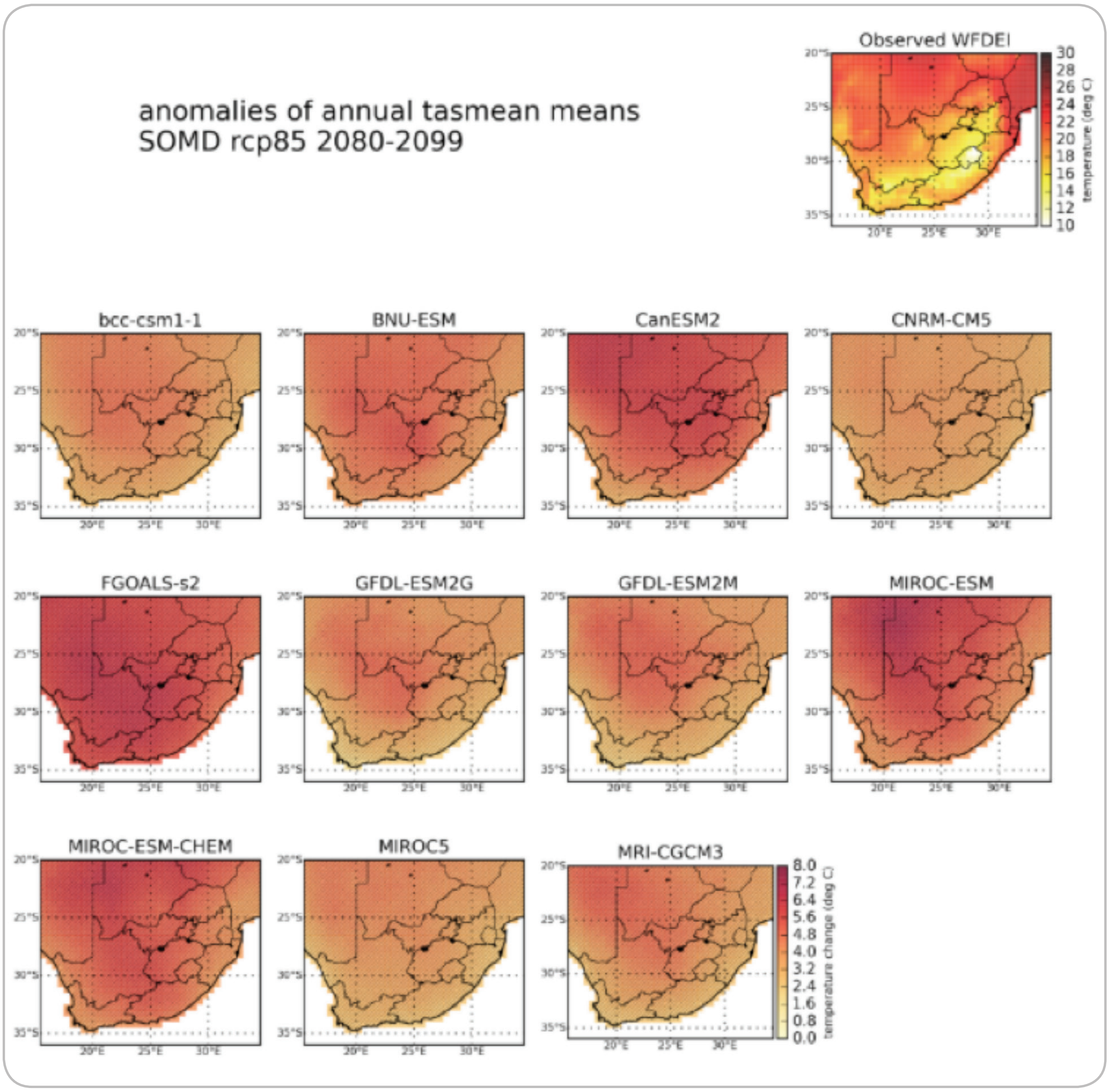


Figure 3.5: Downscaled projected changes in annual mean temperature (°C) under RCP 8.5 for the 2080-2099 period

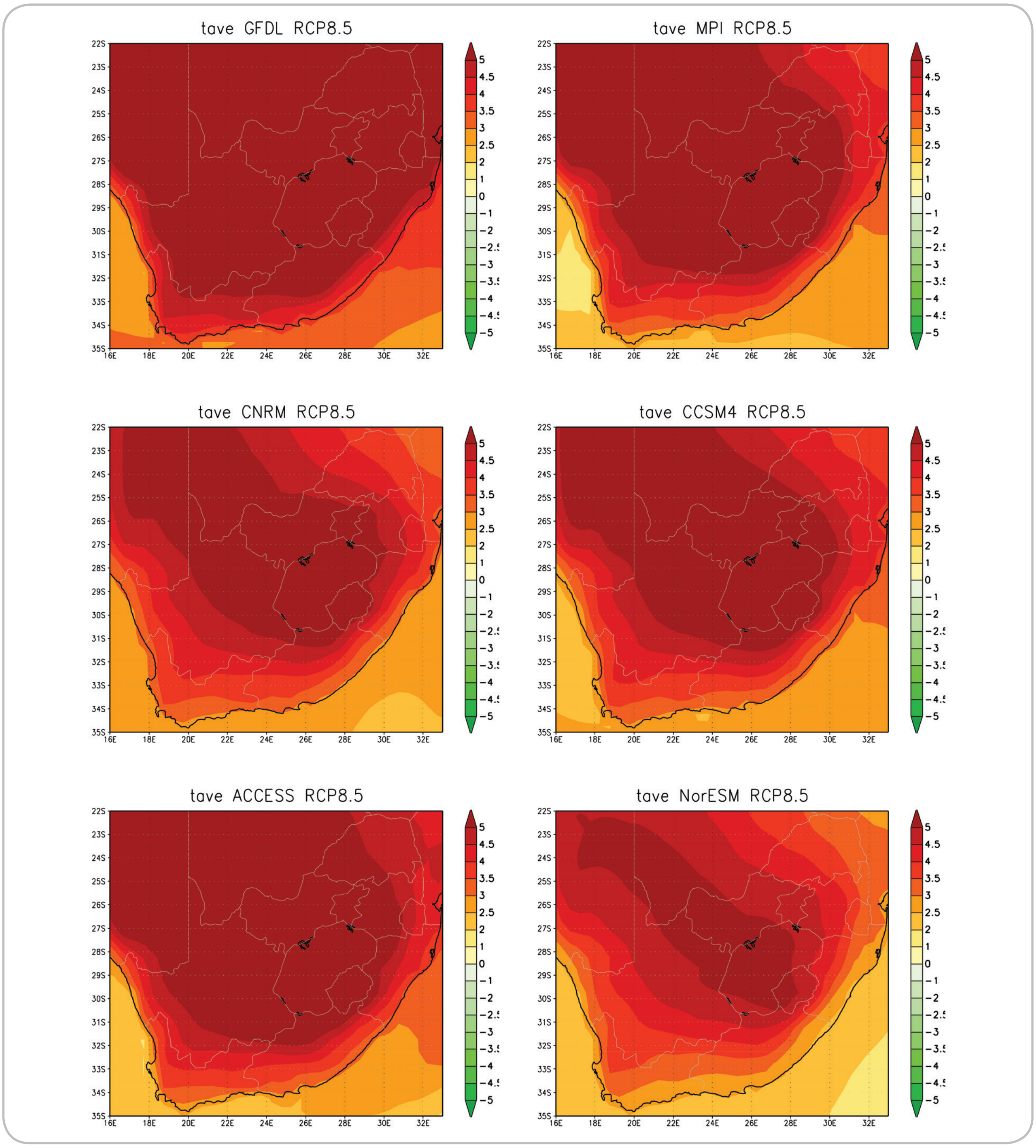
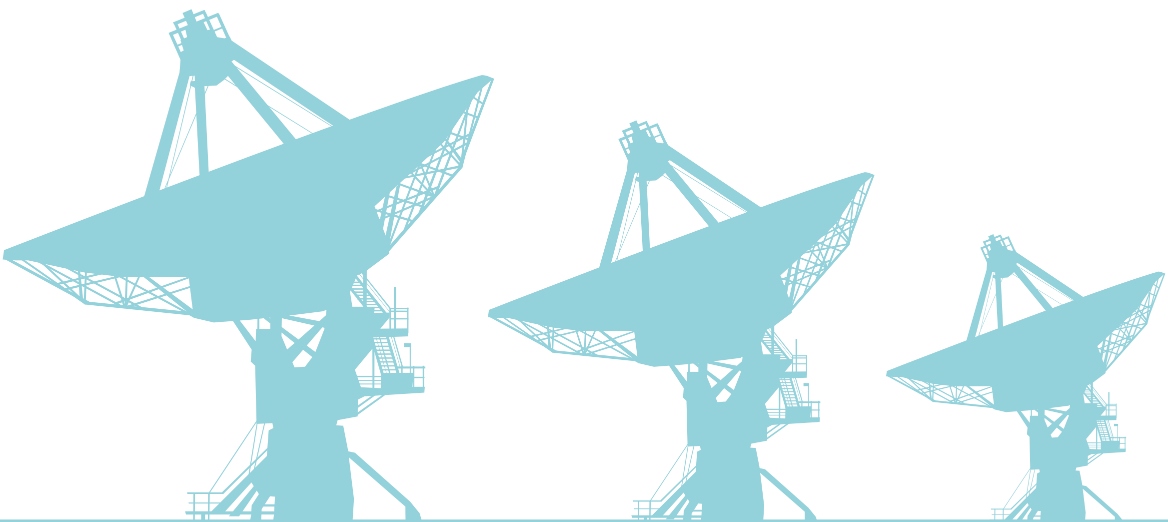


Figure 3.6: CCAM dynamically downscaled projected changes in annual mean temperature (°C) under RCP 8.5 for the 2081-2099 period

3.3.3.2 Very hot days

One of the most problematic consequences of increasing mean temperatures is an increase in the number of very hot days (here defined as days when the maximum temperature exceeds 35 °C) with serious societal consequences including for health (Kovats, 2008; Campbell, 2007), energy demand (Isaac, 2009) and agriculture (Schlenker, 2010). Projected changes in very-hot day statistics for the near-future (2016-2035) compared to the present-day baseline period are largely insignificant along the coastal areas and eastern interior, but for the Northern Cape, North West and Limpopo projected increases range between 20 and 40 days per year (see Appendix B). Very similar changes are projected for the near-future under RCP4.5 and RCP8.5. Over the western interior regions increases in the annual number of very hot days are projected to range between 40 and 80 by the mid-future period of 2046-2065 (see Appendix B). Under RCP8.5 by the far-future, increases of 80 very hot days per year are projected over almost the entire southern African interior, with increases of more than 120 days per year that can plausibly occur over the western interior (Figures 3.7 and 3.8). Considering that for the Northern Cape, currently only around 60 days per year exceed this threshold, such large changes would have severe consequences in many sectors. Even under the more conservative RCP4.5 scenario, increases as high as 80 days per year are projected by some models by the end of the century over much of the western interior (see Appendix B). It is clear that for sectors currently sensitive to extreme temperatures, exposure to such events will most certainly pose a serious risk in the future, even under modest-high mitigation.



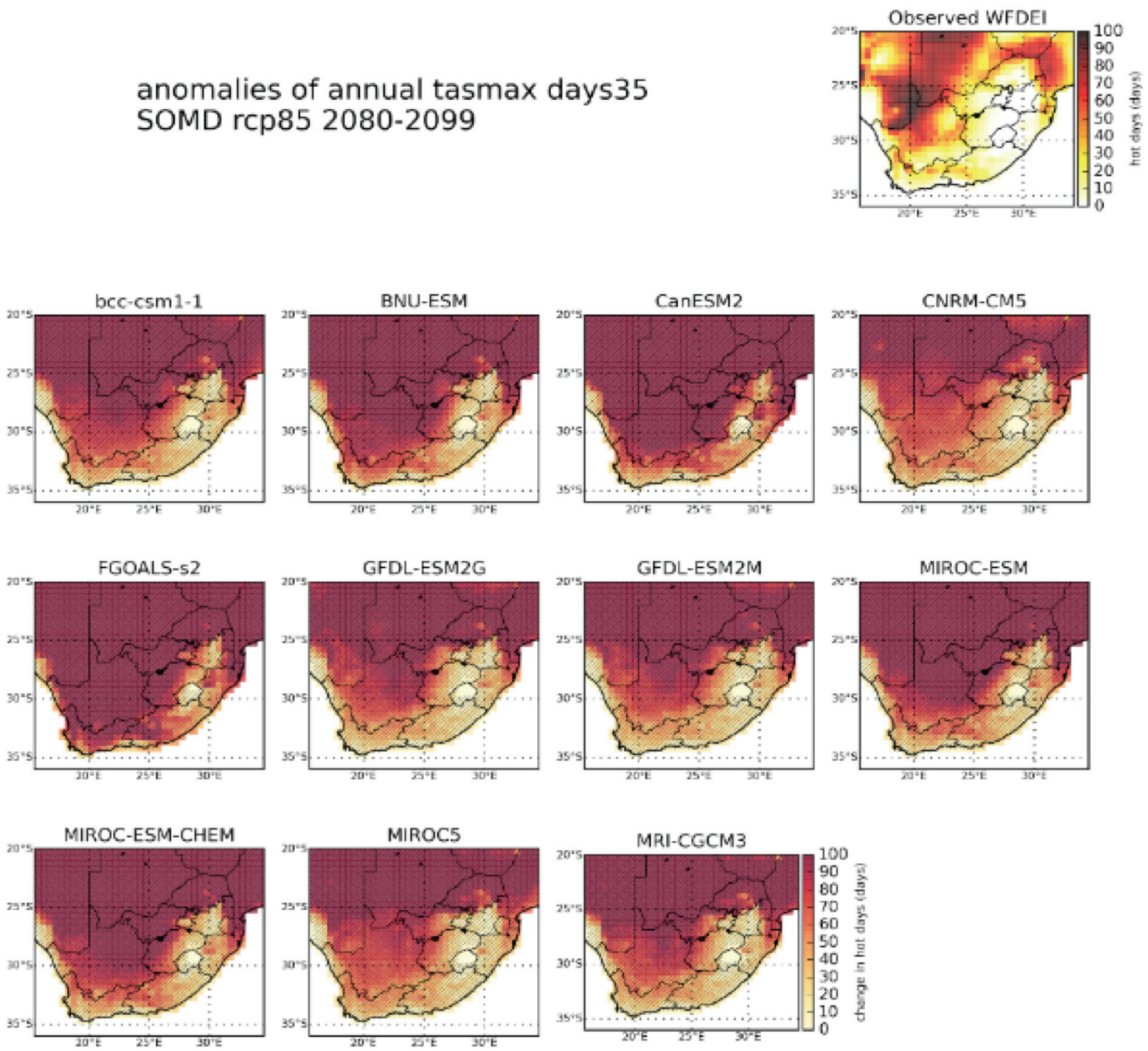


Figure 3.7: Statistically downscaled changes in the number of very hot days under RCP8.5 for the 2080-2099 period

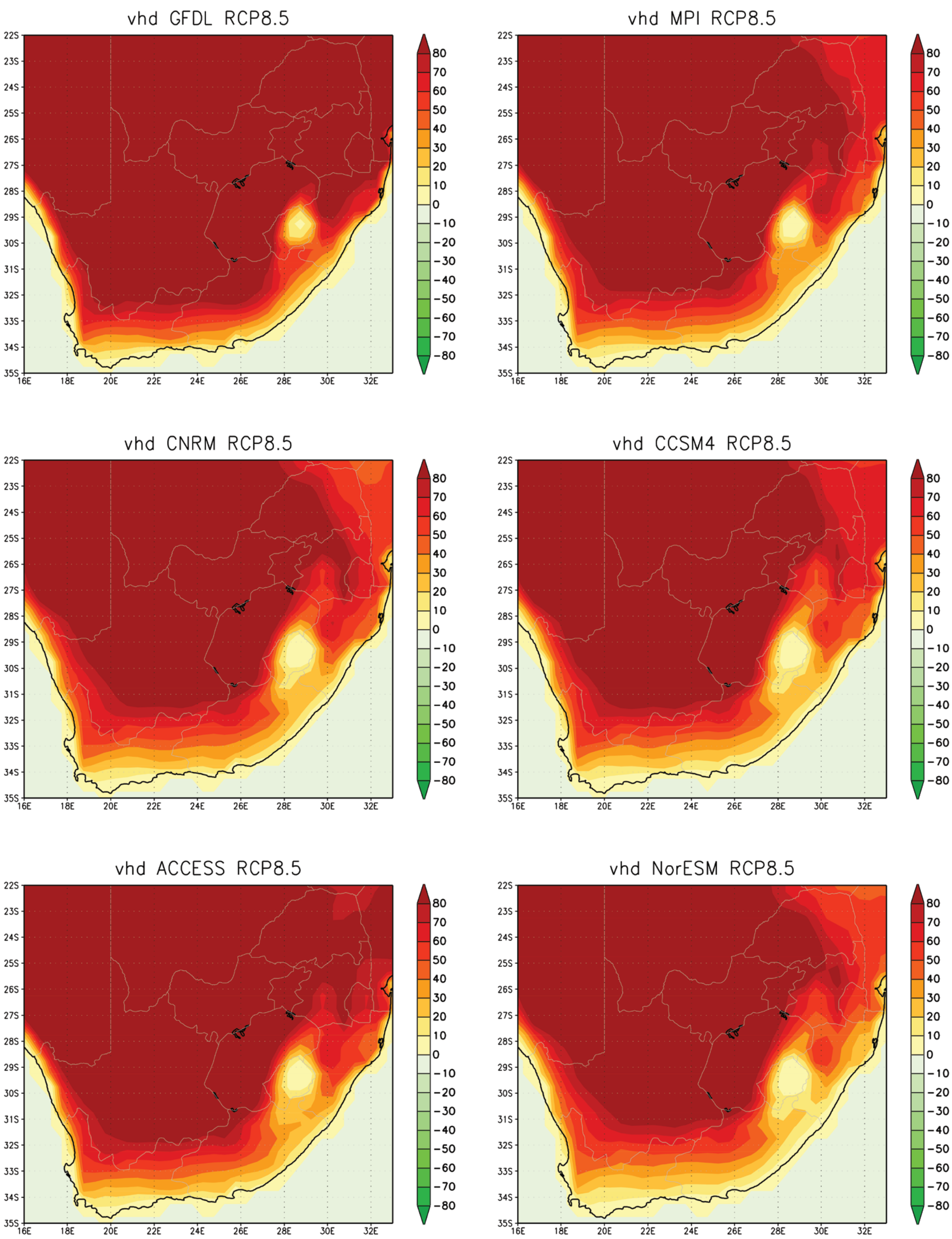


Figure 3.8: Dynamically downscaled changes in the number of very hot days under RCP8.5 for the 2080-2099 period

3.3.4 Projected rainfall futures for South Africa

3.3.4.1 Rainfall totals

Projected changes in rainfall totals and other statistics derived from GCMs need to be treated with some caution. GCMs necessarily simplify various aspects of the climate system including topographic effects, convective rainfall dynamical processes and cloud microphysics, which are all critically important for the production of rainfall. As a result, GCMs typically do not capture local or regional scale rainfall patterns and often have significant biases (too much rainfall or too little rainfall) relative to observations. However, GCMs are able to capture large scale shifts in circulation features such as the Hadley circulation, or the positioning of the southern hemisphere jet stream. In many cases GCMs agree on shifts in these large scale processes into the future (e.g. Barnes 2013). It is therefore important to (a) focus on large scale shifts in rainfall produced by GCMs, rather than focus on local scale changes which are likely poorly represented in the models, and (b) to explore downscaling approaches to gain insights into local scale precipitation changes as a result of large scale circulations changes. This is exactly the strategy followed in the TNC analysis of the plausible rainfall futures for South Africa.

For the near-future (2016-2035) period, regardless of RCP, the GCM projections and their statistical and dynamical downscalings show mixed but relatively weak and not statistically significant messages of change in annual total rainfall across the country (see Appendix B). Towards the mid-future period (2046-2065) in both RCPs most GCM projections and dynamic downscalings are indicative of significant changes with the majority of projections showing decreased rainfall under particularly RCP8.5 (Appendix B). However, the statistically downscaled projections show a much more even split between increasing and decreasing rainfall compared to the driving CMIP5 GCM projections, even under RCP8.5 (see Appendix B). Towards the far-future period the majority of GCM projections, CCAM dynamic downscalings and the statistical downscalings are showing significant drying over most of southern Africa under RCP8.5 (Figures 3.9 and 3.10, also see Appendix B). Under RCP 4.5 some models continue to show increased rainfall through to the end of century (see Appendix B). Generally, the projections are indicative of a southern African region that will not only be drastically warmer under low mitigation futures in the far-future, but also generally drier.

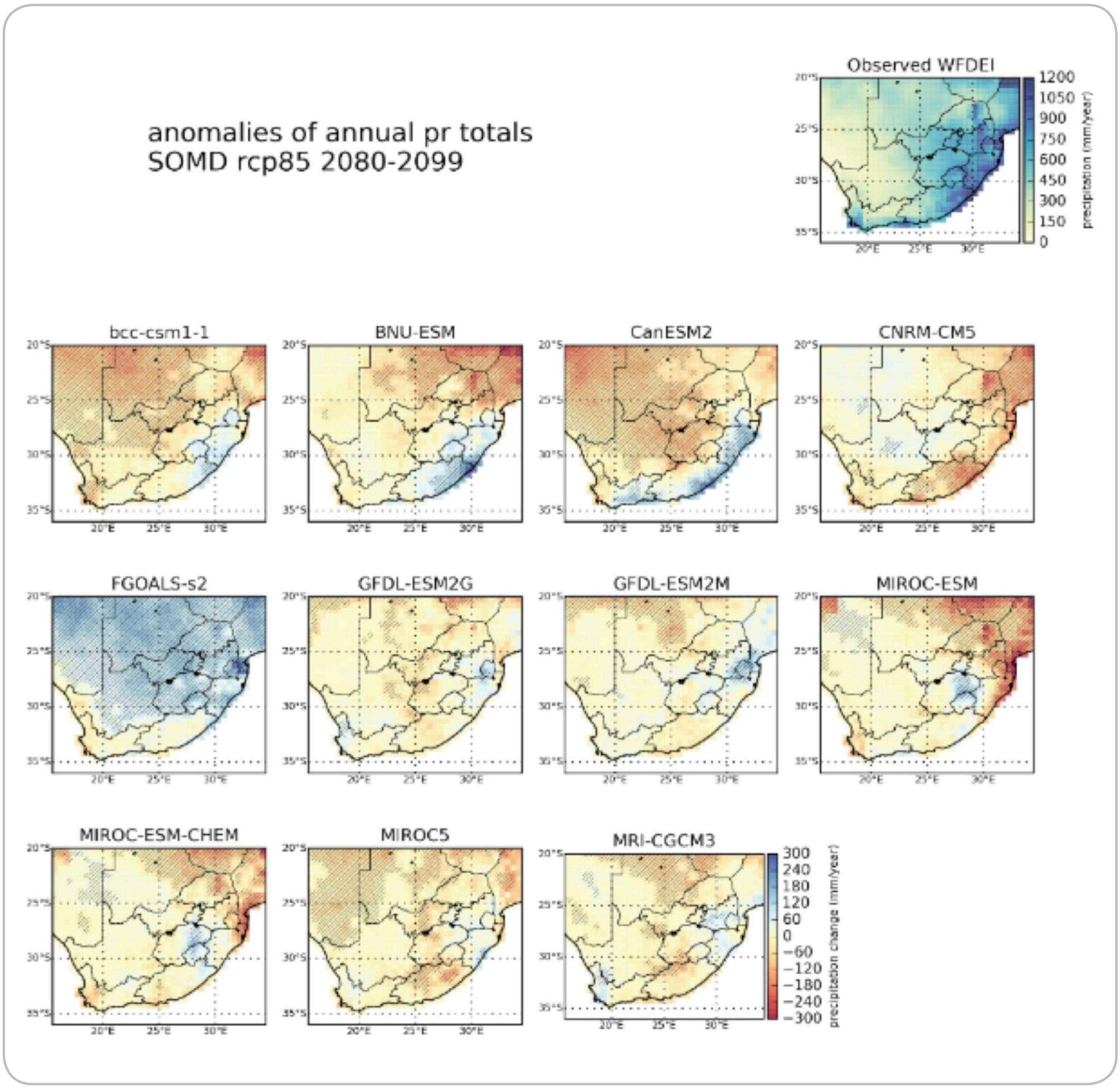


Figure 3.9: Statistically-downscaled projected changes in annual total rainfall (mm) under the RCP 8.5 pathway for the 2080-2099 period

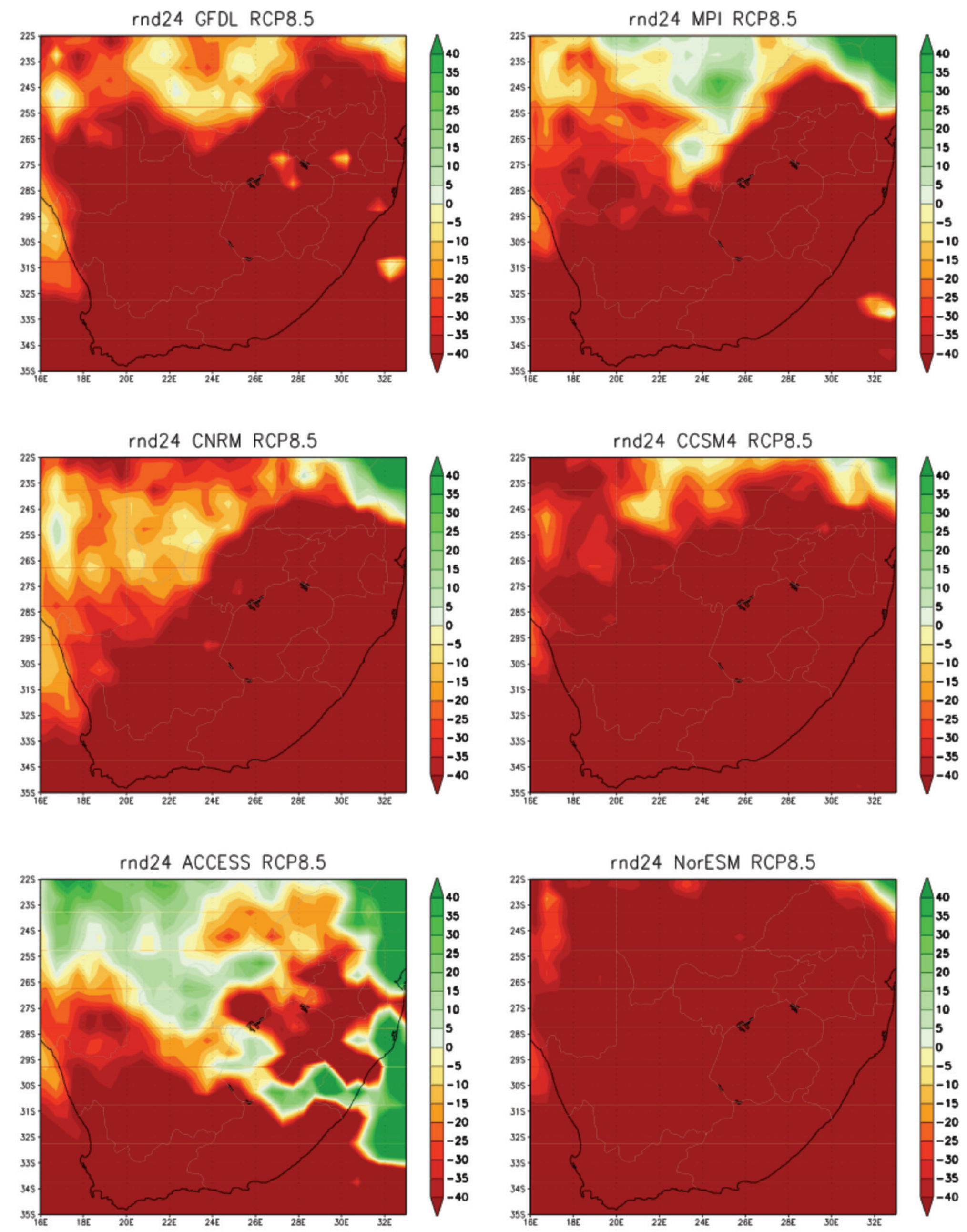


Figure 3.10: CCAM dynamically downscaled projected changes in annual total rainfall (mm) under the RCP 8.5 pathway for the 2080-2099 period

3.3.5 Projected changes in sea-level along the South African coastline

3.3.5.1 Background

The frequency and intensity of extreme weather events will plausibly increase during the 21st century under enhanced anthropogenic forcing (IPCC 2007). This includes plausible decreases in the return period of extreme storm surges (high sea-level events), which may well be as large as an order of magnitude by the end of the century (IPCC, 2013). Surge events (and associated storms) are region specific, however, and as a consequence the projections of detailed regional changes are of relatively low confidence (IPCC, 2013). In South Africa, increases in either intensity or frequency, or changes in seasonality have been reported at a local scale for certain coastal areas (Guastella and Rossouw 2012, Harris 2010) - although for periods of insufficient length to deduce whether these changes can be attributed to systematic climate change (as opposed to natural variability). Other short-term and local evidence of changing storminess can be found in the fishery sector: climate change can potentially influence fisheries though alterations in temperature, oxygen, coastal upwelling, currents and biological and ecological changes. Moreover, increases in the number of days with adverse weather conditions will negatively affect the number of days fishermen can go out to sea. Such changes have indeed been observed for the South African south coast in recent years, as reported by CCAMPF (2016). The number of fishing days for small-craft fisheries has dropped significantly due to an increase in the amount of days with strong wind events. Small-scale fisheries that operate from the shore or from small, relatively unprotected harbours or slipways are most vulnerable to this increase of storminess days (CCAMPF, 2016). It is unlikely though that this phenomena is due to long-term climate change effects - rather it is the outcome of natural climate variability. Nevertheless, the long term monitoring of these types of impacts might play a valuable role in understanding and mitigating climate change effects on the daily lives of people living in the coastal zone.

Generally, increases in sea-level rise alone may greatly increase the impacts of extreme sea-storm events (Theron 2007). The regional variation in the global wave climate was demonstrated by Mori *et al.* (2010), who, in simulating future trends, predicted that mean wave height might generally increase in the regions of the mid-latitudes (both hemispheres) and the Antarctic ocean, while decreasing towards the equator. Wang *et al.* (2004), Komar and Allan (2008) and Ruggerio *et al.* (2010) provide further evidence of a general wave height increase and increasing storm intensities in the Northern Hemisphere. Such changes in the regional ocean climates are expected to have significant impacts on local coastal areas. It is therefore important to also investigate possible future climatic changes off the southern African coastline as well as the expected associated impacts. As can be anticipated, a more severe wave climate (or related oceanic wind climate) will result in more storm related erosion (episodic erosion), potentially more coastal sediment transport, and greater coastal impacts.

3.3.5.2 Climate change projections

Wave climate is largely determined by ocean winds (velocity, duration, fetch, occurrence, decay, etc.). Projections of changes in the regional wind regimes off the southern African coast are lacking however – or at least, the analysis of extensive ensembles of projected changes is lacking. An example of such projections can be obtained from the ensemble of dynamic downscalings analysed in the TNC. No quantitative studies have to date been performed, where dynamic climate model projections have been linked to quantitative wave modelling, This represents a gap in southern African climate change impacts assessments, and an area of future work. To gain some quantitative understanding of climate change impacts on coastal processes and to enable an assessment of the potential impacts of stronger winds, a relatively modest increase of 10% could be assumed. Thus, a modest 10% increase in wind speed, implies a 12% increase in wind stress, a 26% increase in wave height, and as much as an 80% increase in wave power (Theron, 2007). This means that a modest 10% increase in wind speed could also result in a potentially significant increase in coastal sediment transport rates and consequently impact on estuarine mouth regimes. The dynamic processes in the ocean, and especially on the coast, are thus mostly a non-linear system and small changes in the atmospherics could have a drastic effect on our coast. It should be noted however, that many of the regional changes in circulation over southern Africa argue for the decreasing impact of severe storm events along the South African coastline: the westerly wind regime and cold fronts are projected to be displaced polewards (Christensen *et al.*, 2007; Engelbrecht *et al.*, 2009), implying a poleward displacement of the swell and wind waves these systems generate. Moreover, this poleward displacement of frontal systems will plausibly be associated with a strengthening of the subtropical high-pressure belt over southern Africa. Consequences of these changes may include the decreasing occurrence of cut-off lows (Engelbrecht *et al.*, 2013) and equatorward displacement of land-falling tropical cyclone tracks (Malherbe *et al.*, 2013). However, it should be noted that these are the only studies that have to date explored changes in synoptic-scale weather systems important to the generation of damaging wind and wave events along the South African coastline – more work is needed towards quantifying the impact of these weather systems under climate change.

3.3.6 Narratives of climate change for South Africa and its provinces

3.3.6.1 Northern Cape

The Northern Cape is the driest province in South Africa, with some areas receiving less than 70 mm/year on average. The north western parts of the province are arid and experience very infrequent rainfall events produced either by the passage of rare cold fronts in winter or occasional convective rainfall during summer. The south western parts experience infrequent winter rainfall, while the eastern two thirds of the province experience summer rainfall associated with local or large scale convective rainfall systems. The south and west of the province experience low rainfall during winter. The eastern part of the province responds partly to ENSO oscillations while the south and western areas having very weak, if any, association with ENSO.

The northern parts of the province also experience some of the highest maximum temperatures in the country, with places like Upington experiencing average daytime temperatures in summer of over 32 °C and more than 30% of days in January exceed 36 °C. However, typical of many arid and semi-arid inland locations, winter night time temperatures can regularly drop below 0 °C. The western coastline is very dry, and the northern extremes transition into coastal desert. In these areas coastal marine fog forms an important source of water for ecosystems.

Historical trends show no detectable trend in annual rainfall totals over the past 50 years, though there are some weak indications of increases in number of wet days. Daily maximum temperatures have been increasingly steadily and more rapidly than night time minimum temperatures, with a resultant increase in the day/night temperature differences.

Narrative 1: A hotter drier future

In this narrative for the Northern Cape the province continues to experience cycles of dry years and wet years, with dry years typically associated with higher temperatures. The spatial size of the province and north-east, south-west climate gradient means that it is not uncommon for the north and east of the province to be experiencing dry conditions while the south and west are not, and vice versa. The province experiences more rapid warming than the most of the rest of the country, particular in the northern and eastern interior. This means that temperatures in the province will reach 2 °C warmer than the recent past by between 2040 and 2060. This has important impacts on hot spells, with days exceeding 36 °C reaching 20-30 days a month in the north of the province in summer. The most rapid warming is experienced in the months before the summer rainfall begins.

Retreating cold fronts as a result of a southerly shift in the mid-latitude jet-stream means that the frequency of frontal winter rainfall events in the south west of the province decrease, resulting in lower annual rainfall totals. To the east of the province, increased subsidence, caused by more intense subtropical high pressure systems, suppresses convective rainfall processes reducing summer rainfall. However, more intense heating and increased atmospheric humidity under a warmer climate produces more intense rainfall events when they do occur, causing localised flooding and infrastructure damage.

Reduced rainfall together with substantially higher temperatures combine to increase evaporation, which places strain on natural environments as well as dams for irrigation and human consumption. Ground water is an important source of water in the west of the province, and reduced rainfall begins to reduce ground water recharge rates reducing well point yields. While the province does not contain many large cities, urbanisation places increased strain on existing water sources. Natural eco-systems are the foundation of much tourism in the province, and as these are placed under strain tourism is forced to adapt.

Narrative 2: A hotter, mixed rainfall future

In this narrative for the Northern Cape the province continues to experience cycles of dry years and wet years, with dry years typically associated with higher temperatures. The spatial size of the province and north-east, south-west climate gradient means that it is not uncommon for the north and east of the province to be experiencing dry conditions while the south and west are not, and vice versa. The province experiences more rapid warming than most of the rest of the country, particularly in the northern and eastern interior. This means that temperatures in the province will reach 2 °C warmer than the recent past by between 2040 and 2060. This has important impacts on hot spells, with days exceeding 36 °C reaching 20-30 days a month in the north of the province in summer. Most rapid warming is experienced in the months before the summer rainfall begins.

Retreating cold fronts as a result of a southerly shift in the mid-latitude jet-stream means that the frequency of frontal winter rainfall events in the south west of the province decreases, resulting in lower annual rainfall totals. To the east of the province, an intensified heat low combined with increased atmospheric moisture and moisture transport into the interior results in increased summer rainfall. These same dynamics of heating and increased moisture produces more intense rainfall events when they do occur, causing localised flooding and infrastructure damage.

Reduced rainfall in the south and east together with substantially higher temperatures combine to increase evaporation, which places strain on natural environments as well as dams for irrigation and human consumption. Groundwater is an important source of water in the west of the province, and reduced rainfall begins to reduce groundwater recharge rates reducing well point yields.

While the province does not contain many large cities, urbanisation places increased strain on existing water sources. Natural ecosystems are the foundation of much tourism in the province, and as these are placed under strain by increasing temperatures and rainfall changes, tourism is forced to adapt.

3.3.6.2 Western Cape

The Western Cape, dominated by ocean, mountains and plains (coastal and inland), has a very diverse climate. Locations such as Bethlehem in the Hottentots Holland mountains experience some of the highest annual rainfall totals in the country (1500 mm/year), whereas Laingsberg only receives around 120 mm/year. Temperatures also range widely from cool coastal mountains often covered by low orographic cloud where even in summer temperature rarely exceed 25 °C, through to semi-arid Karoo valleys where summer temperatures can average 35 °C.

Rainfall in the coastal regions and coastal mountains is largely produced by cold fronts generated in the mid-latitudes that bring cold weather and rainfall to the province. Cold fronts interact with the mountains such that far more rainfall falls in the mountains than on the coastal plains. The mountains also impede the inland progression of cold fronts and so produce a rain shadow inland marked by much lower rainfall. These inland areas of the province actually experience summer rainfall resulting from strong surface heating and thunderstorm type weather, similar to the rest of the summer rainfall regions in South Africa. However, strong cold fronts can sweep inland bringing cold weather and rainfall or even snow. While this is more common in winter, strong cold fronts have been experienced during summer.

Southerly winds transporting relatively moist but cool air from the southern oceans to the Western Cape are also key to the province's climate. There is some evidence that the very common orographic clouds that cloak the mountains of the Western Cape contribute a great deal of water to mountain runoff through cloud droplet capture as well as through low intensity rainfall. Moist surface winds coupled with high altitude lower pressure systems are responsible for more significant rainfall events in the province, colloquially known as "black south-easters" which have even been known to produce flooding.

The Western Cape has experienced droughts in the past and will continue to do so going into the future as natural climate variability continues. There are currently no long term changes in rainfall identifiable in historical weather records. This does not mean that changes are not occurring, it just means that currently there is insufficient evidence to suggest that any changes identified are not just an artefact of natural cycles (10-30 year cycles) rather than long term steady change. Some small changes in the number of rainy days per year have been detected, with decreases in the number of rainy days in some areas. Both daytime maximum and night time minimum temperatures have been increasing steadily over the past 50 years.

Narrative 1: A drier hotter, windier future

In this narrative the climate of the Western Cape will continue to be characterised by cycles of drier years and wetter years for the next 20 to 30 years. At the same time average temperatures rise at around 0.5 °C /decade so the average temperatures will reach 1.5 °C higher than recent historical averages somewhere between 2040 and 2060. The impact of these higher temperatures will increase the frequency and length of hot spells in summer, as well as decrease the frequency and duration of cold spells in winter. The increasing effect of the sub-tropical high pressure systems combined with more intense inland heating will result in stronger summer south-easterly winds. Higher wind speeds combined with higher temperatures will strongly influence evaporation and evapotranspiration either resulting in drier soils and crops or increasing demand for irrigation, particularly of summer crops. Higher evaporation from dams, combined with competing demands from agriculture and rapidly growing urban populations will place significant strain urban water supply systems.

Moving towards the middle of the 21st century natural cycles of rainfall begin to shift towards more frequent dry years and consecutive dry years (such as the 2014-2015 years). Temperatures will continue to rise along with summer wind speeds which enhance evaporation, so reduced rainfall will only exacerbate the challenge of increased evaporation from agricultural land, natural ecosystems, and water storage dams. Competition for water between agriculture, industry and urban water supply could become critical with water cuts becoming the only viable solution during extreme dry years.

With average temperatures now reaching 2 °C higher than the recent past agricultural activities will become unviable, including some fruit farming which requires low temperatures to develop and possibly certain livestock that are unable to cope with sustained higher temperatures. Added to these summer stresses, winter storm intensity begins to increase resulting in more frequent heavy rainfall events in winter which produce flooding and related damage.

Narrative 2: A warmer wetter future

In this narrative the climate of the Western Cape will continue to be characterised by cycles of drier years and wetter years for the next 20 to 30 years. At the same time average temperatures rise at around 0.5 °C /decade so the average temperatures will reach 1.5 °C higher than recent historical averages somewhere between 2040 and 2060. The impact of these higher temperatures will increase the frequency and length of hot spells in summer, as well as decreased frequency and duration of cold spells in winter. The increasing effect of the sub-tropical high pressure systems combined with more intense inland heating will result in stronger summer south-easterl winds. Higher wind speeds combined with higher temperatures will strongly influence evaporation and evapotranspiration either resulting in dry soils and crops or increasing demand for irrigation, particularly of summer crops. Higher evaporation from dams, combined with competing demands from agriculture and rapidly growing urban populations will place significant strain urban water supply systems.

Moving towards the middle of the 21st century natural cycles of rainfall will continue, but changes in average rainfall begin to emerge. Rainfall in the mountains increases as a result of more moist and energetic winter storms, as well as increased moist warm southerly flow off the ocean in the summer months. While coastal and inland plains do not experience these changes directly, they have important impacts on water supply and irrigation as river flows increase and runoff into dams increase.

However, increased rainfall is offset by increased evaporation due to higher temperatures (reaching 2 °C higher than current) and stronger winds. This results in increasing demand for irrigation and higher losses from dams. Higher urban populations also place ever increasing demands on water supply systems. Therefore, while the relatively small increases in rainfall may partly delay the need for adaptation measures, adaption to reduce water demands is still required. Higher temperatures will still result in some agricultural activities being unviable, regardless of changes in rainfall. Inland plains do not receive increased rainfall, and so follow very similar story lines to the dry narrative above.

3.3.6.3 Eastern Cape

The Eastern Cape, like the Western Cape, is characterized by a very diverse climate due to the proximity to the ocean and extensive mountain ranges and altitude variations. Minimum temperatures in Barkley East (1800 m) hover around 0 °C during the winter months, with snow not an unusual occurrence. Port St Johns on the other hand experienced average winter temperatures more than 10 °C warmer. The significant east-west mountain ranges produce stark rainfall climate gradients. Willowmore receives around 240 mm/year with mostly summer rainfall, whereas Tsitsikamma, a mere 120 km south, receives around 720 mm/year of all year around rainfall.

Rainfall is produced by a combination of three processes. The influence of cold fronts sweeping over the south of the country produces rainfall through the winter months along the coast and in the coastal mountains. Further inland (north) the influence of these cold fronts diminishes and summer rainfall dynamics (surface heating and convective/thunderstorms) dominate. During summer, onshore flow of relatively moist air forced to rise by coastal mountains produces substantial summer rainfall.

Historical rainfall trends over the last 50 years are very unclear, with little significant changes detectable except for a possible increase in wet days in summer in the western side of the province and the opposite signal in the north east. Temperature trends exhibit consistent warming of daytime maximums, and some less consistent increases in night time minimum temperatures.

Narrative 1: A warmer future

In this narrative for the Eastern Cape, the province continues to experience cycles of dry years and wet years. Temperatures rise consistently by 1.5 °C higher than recent averages between 2040 and 2060. The impact of these warming temperatures will be increased frequency and length of hot spells in summer, as well as decreased frequency and duration of cold spells in winter. Higher temperatures will strongly influence evaporation and evapotranspiration, either resulting in drier soils and crops or increasing demand for irrigation, particularly of summer crops. Higher evaporation from dams, combined with competing demands from agriculture and rapidly growing urban populations will place significant strain on urban water supply systems.

Warming results in a stronger heat low pressure in the interior of the country, which influences the northern part of the province and results in more intense rainfall events, even if long term annual rainfall totals are largely stable. These intense events have great impact on infrastructure such as roads and storm water systems. Increased ocean temperatures in the warm Agulhas current produce intense local convective storm systems, resulting in heavy rain and flooding along the coast and coastal mountains. Associated storm surge superimposed on rising sea-levels begins to impact coastal infrastructure, much of which is associated with tourism.

Narrative 2: A warmer drier future

In this narrative for the Eastern Cape, the province continues to experience cycles of dry years and wet years. Temperature increases over the period 2040-2060 frequently exceed 1.5 °C compared to present-day climate. The impact of these temperature increases will be increased frequency and length of hot spells in summer, as well as decreased frequency and duration of cold spells in winter. However, the frequency of dry years begins to increase, and multi-year droughts become more common. Higher temperatures, combined with low rainfall in dry years, strongly influence evaporation and evapotranspiration either resulting in drier soils and crops or increasing demand for irrigation, particularly of summer crops. Higher evaporation from dams, combined with low rainfall in dry years, and competing demands from agriculture and rapidly growing urban populations will place significant strain on urban water supply systems.

Warming results in a stronger heat low pressure in the interior of the country, which influences the northern part of the province and results in more intense rainfall events, even if long term annual rainfall totals are slowly declining.

These intense events have great impact on infrastructure such as roads and storm water systems. Increased ocean temperatures in the warm Agulhas current produce intense local convective storm systems, resulting in heavy rain and flooding along the coast and coastal mountains. Associated storm surge superimposed on rising sea-levels begins to impact coastal infrastructure, much of which is associated with tourism.

3.3.6.4 KwaZulu-Natal

KwaZulu-Natal is the wettest province in South Africa, with high rainfall totals occurring along both the eastern escarpment and over the coastal areas. It is a summer rainfall region that experiences hot and humid summers and mild winters.

Narrative 1: A hot and dry future

KwaZulu-Natal may plausibly experience a climate future that is significantly hotter and drier compared to the present-day climate. Under low mitigation, temperature increases as large as 3 °C may occur by 2040-2060, with associated drastic decreases in rainfall. Such a climate regime will also be associated with an increase in the frequency of occurrence of heat-wave days and high fire-danger days and more El Niño induced drought events. Key impacts under such a scenario include significantly reduced yield from both the forestry and sugar cane industries. Human health may be increasingly affected by oppressive temperatures.

Narrative 2: A hot future with increased rainfall

The main alternative future for KwaZulu-Natal is similar to narrative 1, but with the difference that rainfall over the province increases substantially, including an increase in intense thunderstorms and damaging flood events. Under such a future there are more options for the sugarcane and forestry sectors, but with frequent damage to infrastructure such as roads and bridges. In the increasingly hot and humid climate, pests and diseases affecting crops, the forestry sector and also human and animal health may become increasingly abundant.

3.3.6.5 Mpumalanga

Mpumalanga's Lowveld region experiences a sub-tropical climate, with high rainfall totals towards the escarpment in the west and with a drier climate to the east. The Mpumalanga Highveld experiences cold winters with frost events, with summers being warm and with rainfall occurring mostly in the form of thunderstorms.

Narrative 1: A hot and dry future

Mpumalanga may plausibly experience a climate future that is significantly hotter and drier compared to the present-day climate. Under low mitigation, temperature increases as large as 3 °C may occur by 2040-2060, with associated drastic decreases in rainfall. Such a climate regime will also be associated with an increase in the frequency of occurrence of heat-wave days and high fire-danger days. Such a change towards a generally warmer and drier climate would pose significant threats to the forestry sector, due to the likelihood for more frequent forest fires occurring during more frequent periods of drought.

Narrative 2: A warmer future with increased rainfall

The main alternative narrative for Mpumalanga still implies significant increases in temperature, consistent with narrative 1. The main difference in this scenario is that rainfall totals increase under climate change, rather than to increase. Such an increase may imply the more frequent occurrence of land-falling tropical lows over the Lowveld regions, with potentially significant impacts on tourism and infra-structure in areas such as Kruger Park a town in the Lowveld region. Under such a scenario drought will not be such a major problem for the forestry sector as under narrative 1, but the increased occurrence of pests and pathogens affecting forestry and agriculture may well pose an alternative set of challenges.

3.3.6.6 Limpopo

Limpopo is a summer rainfall region that generally experiences hot summers and cooler winters. Rainfall varies greatly across the province, with large parts of the Limpopo basin being semi-arid, and with high rainfall and rainforests along the eastern escarpment of the province. The province sporadically suffer from devastating flood events, when tropical lows or cyclones from the Indian Ocean make landfall over neighbouring Mozambique, or even over Limpopo itself.

Narrative 1: A hot and dry future

Limpopo is plausible, even likely, to experience a climate future that is significantly hotter and drier compared to the present-day climate. Under low mitigation, temperature increases as large as 7 °C may occur by the end of the century, with increases of about 4 °C plausible by the period 2040-2060. Such a climate regime will also be associated with an increase in the frequency of occurrence of heat-wave days and high fire-danger days. It is likely that the province may become drier under climate change, with more frequent El Niño induced drought events. Under such a scenario, dryland agriculture and livestock production in Limpopo will become increasingly less viable.

Narrative 2: A warmer future with more flood events

The main alternative future for Limpopo is a future that is in fact projected by a minority of climate models, namely a future where the province becomes wetter, at least in the Limpopo basin and along the escarpment, due to a greater frequency of more intense tropical lows and cyclones making landfall. Under such a scenario, the province will still need to deal with the negative impacts of increasing temperatures as described in narrative 1. Instead of drought, however, sporadic and devastating flood events will be a key impact to deal with.

3.3.6.7 Gauteng

The Gauteng Province is the economic heartland of South Africa. The province falls in the summer rainfall region, and receives the bulk of its rainfall in the form of thunderstorms. Annual rainfall totals reach 700 mm over much of the province. Winters over Gauteng are dry and associated with clear skies, cold nights that occur in association with the formation of strong inversion layers and polluted mornings. It is critical realise that Gauteng's water security does not only depend on local rainfall and streamflow and dams located within the province, but that about 40% of Gauteng's rainfall is provided by the mega-dream region of south-eastern South Africa.

Narrative 1: a warmer future with reduced water security

Under low mitigation Gauteng may plausibly experience temperature increases of 3-4 °C in the during the period 2040-2060, with associated drastic increases in the annual number of very hot days, heat-wave days and high fire danger days, but with decreases in the number of cold nights and days with frost. These changes in temperature, irrespective of rainfall changes, may be expected to impact drastically on the province. A key impact may be that of oppressive temperatures on human health and mortality, especially where people live in informal settlements with no access to air conditioning and without easy access to water. Under such conditions, the elderly is most vulnerable. Factories and households in Gauteng will experience an increasing need for air conditioning towards achieving human comfort, implying an increased energy demand. The local production of maize and livestock within the province will be negatively affected by rising temperatures, but the production of tomatoes will become viable in winter as the number of frost days decrease to insignificant values. In winter, strengthening inversion layers will lead to further deterioration in air quality. The drastic increases in temperature may occur in association with the more frequent occurrence of drought over southern Africa, including drought in the mega-dam region. This will significantly impact on Gauteng water security and may strongly constrain the province's future economic growth. Locally, increases intense thunderstorms bringing hail, damaging winds and flash floods are plausible.

Narrative 2: A warmer future but water secure future

An alternative narrative for Gauteng follows the same outcomes in terms of temperature than for narrative 1, but with the important exception that water yield in the mega-dam region of South Africa is not compromised by climate change. In fact, the opposite may occur, namely that more frequent and intense thunderstorms over the eastern escarpment region lead to enhanced streamflow. Under such a scenario Gauteng will still need to deal with significant problems caused by rising temperatures and local increases in extreme rainfall events, but with a relatively secure water supply.

3.3.6.8 Free State

The Free State spans the centre of the country, and climate ranges from the relatively dry, hot and arid west (Bloemhof receives around 450 mm/year) and south through to higher altitude cooler wetter climate in the north and east (Royal National Park receives 1200 mm/year). It is entirely a summer rainfall region, with rainfall resulting from either local small scale convective events or larger organised convection. Rainfall in the province is partly linked to ENSO, though it is not uncommon for El-Niño years to be associated with normal or even above normal rainfall. The province is the 'bread basket' of the country with extensive maize, wheat, and other crop production. This is a result of generally good soils and moderate climate, with sufficient rainfall to allow rain-fed agriculture.

Historical rainfall trends are complex with no clear picture emerging. Some locations in the central areas seem to show decreased mid and late summer rainfall, while others in the west show slight increases. However patterns are very mixed, with most stations showing no significant changes. Temperatures have largely been increasing, particularly in winter.

Narrative 1: A warmer drier future

In this narrative for the Free State the province continues to experience cycles of wetter and drier years, with drier years tending to be warmer than wetter years. However, increasing temperatures reach 2 °C higher than current temperatures by between 2040 and 2060, resulting in increased frequency and duration of hot spells in summer with potential impacts on key crop development stages. Most rapid warming is experienced in the months before the summer rainfall begins.

Increased and more intense sub-tropical highs produce enhanced subsidence over the province, suppressing moisture transport into the region and convective activity. The result is reduced frequency and magnitude of rainfall events, and generally reduced annual rainfall totals. However convective events, when they occur, are more intense resulting in localised flooding and related damage.

Increasing temperatures increases evaporation, resulting in drier soils and greater loss from dams, particularly shallow farm dams. Combined with generally reduced rainfall, this means that even in relatively normal rainfall years crops experience greater water deficit and water supply for irrigation, human consumption, and livestock is placed under strain. Higher temperatures begin to impact some livestock as well. Dry years, combined with 2 °C higher temperatures produce higher impacts in the province than the 2015/2016 drought.

Narrative 2: A warmer wetter future

In this narrative for the Free State the province continues to experience cycles of wetter and drier years, with drier years tending to be warmer than wetter years. However, increasing temperatures reach 2 °C higher than current temperatures between 2046 and 2065, resulting in increased frequency and duration of hot spells in summer with potential impacts on key crop development stages. Most rapid warming is experienced in the months before the summer rainfall begins.

An intensified heat low, resulting in enhanced moisture transport into the east of the province, results in marginally increased annual rainfall totals in the east. These changes are however very limited towards the west, where increased subsidence suppresses convection and rainfall remains similar to the present-day day. Convective rainfall events, when they do occur are more intense, resulting in localised flooding and related damage.

Increasing temperatures increase evaporation, resulting in drier soils and increased loss from dams, particularly shallow farm dams. In wetter years the increased rainfall offsets the evaporative losses to some degree depending on the area. But even in relatively normal rainfall years crops experience greater water deficit and water supply for irrigation, human consumption, and livestock is placed under strain. Higher temperatures begin to impact some livestock as well. Dry years, though less frequent than currently experienced, combined with 2 °C higher temperatures produce greater impacts in agriculture and human settlements in the province than the 2015/2016 drought.

3.3.6.9 North West

North West is a summer rainfall region that receives almost all of its rainfall during the summer half-year period of October to March. The western half of the North West Province is a semi-arid region that receives less than 500 mm of rainfall annually, with rainfall totals only being slightly higher in the eastern parts of the province. The province is highly vulnerable to El Niño induced drought events, of which the devastating 2015/16 drought is a recent example.

Narrative 1: A hot and dry future

North West may plausibly (under low mitigation) experience a climate future that is significantly hotter and drier compared to the present-day climate. Under low mitigation, temperature increases as large as 6 °C may occur in the far-future, with associated drastic decreases in rainfall. Such a climate regime will also be associated with an increase in the frequency of occurrence of heat-wave days and high fire-danger days. Under this narrative, which represents a likely climate future for the province, climate change impacts will be devastating for both the livestock and dryland agriculture in the far-future under low mitigation.

Narrative 2: A warmer future with more frequent wet-spells

Under high mitigation, temperature increases may still be as high as 4 °C in the second half of the 21st century, but with the more frequent formation of tropical-temperate troughs and associated occurrence of wet spells. Both the livestock and dryland agriculture sectors will experience largely negative impacts under this narrative, mainly through the impact of oppressive temperatures.

3.3.7 Conclusion

Significant progress has been made in South Africa since the SNC, in terms of the local generation of detailed regional climate futures for the country. Extensive ensembles of projected climate change futures have been available for the TNC, derived using both statistical and dynamical downscaling techniques. These projections make feasible the identification of plausible climate futures for each of the South African provinces, and in some cases, the identification of actionable messages for adaptation. A key feature of the projected climate change futures of South Africa is that temperatures are to increase drastically under low mitigation. For the far-future period of 2080-2099, temperature increases of more than 4 °C are likely over the whole of South Africa, with increases of more than 6 °C plausible over large parts of the western, central and northern interior regions of the country. Such increases will also be associated with drastic increases in the number of heat-wave days and very hot days, with potentially devastating impacts on agriculture, water security, biodiversity and human health. The model projections are indicative that a modest-high mitigation pathway can still significantly decrease this amplitude of warming – most projections suggest that under RCP4.5, for example, temperature increases over the interior can be constrained to 2.5 to 4 °C. Nevertheless, it should be realised that South Africa is plausibly committed to relatively large increases in near-surface temperatures, even under modest-high mitigation futures.

Under low mitigation, it is also likely that the larger South African region will experience generally drier conditions. This pattern is projected robustly by GCMs and their statistical and dynamic downscalings, and is of great significance: South Africa exhibits even under present-day climate a generally dry and warm climate – should this low mitigation future of significantly hotter and drier conditions materialise, it will greatly limit the available opportunities for adaptation. It may be noted that under low mitigation, a minority of downscalings are indicative of rainfall increases over the central interior of South Africa, and/or over the southern interior regions and the Cape south coast. Moreover, extreme convective rainfall events are projected to plausibly increase over the interior regions under low mitigation, even in the presence of a generally drier climate. Under modest-high mitigation, the projections are indicative of potentially very different rainfall futures for South Africa. Even under RCP4.5, a modest-high mitigation pathway, the projected pattern of drying is significantly weaker. In fact, a fairly large number of projections are indicative of generally wetter conditions over the central and eastern interior regions, whilst the remaining projections remain indicative of generally drier conditions. This, in combination with the significantly reduced warming that is projected for southern Africa under high mitigation, emphasizes how important it is for South Africa to strive for a (global) high mitigation pathway.

3.4 Socio-economic Scenarios for Climate Vulnerability Assessment for South Africa

3.4.1 Rationale

The Intergovernmental Panel on Climate Change (IPCC) assessment of climate change indicated that without further mitigation action, average global temperatures could be as high as 4.8°C above pre-industrial levels by 2100 (IPCC Fifth Assessment Report). At a global level, warming of this magnitude will bring unprecedented climate variability and extremes, which would permanently alter both marine and terrestrial ecosystems and cause sea levels to rise. For Africa, global warming could translate into an increase in temperature by as much as 6°C in some areas, with **sub-Saharan Africa a region identified as being most vulnerable to drought and climate change-induced impacts** (IPCC, 2014). Climate change will also likely increase the frequency and magnitude of many extreme weather events. The impacts of such a climate will include increased natural disasters that will cause damage to infrastructure and have diverse **socio-economic impacts, with significant effects on agriculture and rural livelihoods** (World Bank, 2013).

The United Nations Framework Convention on Climate Change (UNFCCC, 1992), ratified by South African Government in August 1997, makes commitments to achieve stabilisation of the concentrations of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The most important provision by far is embedded in Article 2 which reads, *"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."* While the first part of the Convention's objective addresses predominantly mitigation, the second part explicitly addresses adaptation, thereby highlighting the need to ensure that food production and sustainable development are not threatened. It can be argued that adaptation imperatives are the primary objective of the agreement, as the poorly defined concept of 'dangerous anthropogenic interference' can only be understood in the context of its potential negative impact upon people and ecosystems. In addition, mitigation action could limit the costs of adaptation significantly; since without swift and concerted mitigation action, adaptation requirements and costs will grow and the adaptation gap will continue to widen. This aspect is highlighted by Article 4.1 of the UNFCCC: *"All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall: (f) Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change"*. However, while there are some provisions to address adaptation in the UNFCCC, their implementation in the first 20 years has been patchy, opportunistic and philanthropic in nature, rather than being **guided by the differentiated responsibilities and delivered as the obligations of the signatories.**

Many developing countries are heavily-reliant on natural resources, which are highly vulnerable to climate change. **Africa's low adaptive capacity to climate**

change is due to developmental challenges including: endemic poverty; complex governmental and institutional aspects; limited access to capital, markets, poor infrastructure and technology; complex disasters and conflicts and degradation of the ecosystem (Boko, *et al.* 2007). Therefore, Africa potentially faces **mutually reinforcing challenges to respond to climate change amidst a poor ability to do so.** The requirement to respond to climate change may seem like an unfair burden for developing countries in Africa that are responsible for a few percent (3.3 % in 2011) of the global carbon dioxide emissions. Furthermore, there is an increased poverty burden since developing countries are heavily reliant on natural resources and agriculture and hence highly vulnerable to climate change. In addition, there are **concerns that climate change mitigation could threaten the ability of African countries to follow the standard industrialisation pathway to high income status and stunt economic growth.** Implementing policies and plans to address the impacts of climate change also has an opportunity cost; by diverting resources away from other pursuits like poverty eradication and sustainable development. In pursuing material parity in climate change adaptation and achieving agreed multilateral processes for adaptation planning and action; the African Group has made a proposal for a Global Goal for Adaptation (GGA) in the Paris Agreement that reflects the linkages between mitigation effort, temperature increase, adaptation needs and differentiated responsibility or "fair share".

Therefore, the response of the earth system will depend on prevailing atmospheric conditions, as well as the success of **mitigation and adaptation** measures currently being tailored to anticipate and respond to climate change impacts. Mitigation and adaptation measures are influenced by a country's development pathway and take into consideration changes in population, consumption, governance and policy, economic development, as well as technology and innovation. Climate change has the potential to alter socio-economic development and prevent the country from achieving its development goals. While considerable efforts should be made to mitigate climate change and avoid impacts, it is recognised that **not all climate change risks can be mitigated and some climate change is inevitable.** Therefore, there is a need to **both mitigate and adapt to climate change, with the aim of minimising the climate change risks through improving climate change resilience.** Central to achieving this is an improved understanding of complex socio-ecological systems, and the **inter-connectedness between the climate change biophysical impacts and climate governance.** This section of Chapter 3 aims to provide a framework that incorporates socio-economic modelling scenarios into South Africa's climate change adaptation planning and response.

3.4.2 Climate risk and adaptation in South Africa

In South Africa climate risk is influenced by socio-economic factors such as governance, poverty and unemployment, and service delivery. Climate change will likely increase inequalities and poverty, since those that rely on the natural resource base for their livelihoods are more at risk. The National Climate Change Response Policy identified the need for developing national and sub-national adaptation scenarios for South Africa - under plausible future climate conditions and development pathways. This is being carried out through the Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) that aims to inform future planning and development decisions for a climate resilient society. The first phase of the Long Term Adaptation Scenarios (LTAS) established a collective understanding on South Africa's climate change trends and projections. It summarised key climate change impacts and identified potential response options for primary sectors; namely: water, agriculture and forestry, human health, marine fisheries, and biodiversity. Some of the key findings include:

(i) Agriculture and forestry. The effect of climate change on biophysical factors (i.e. temperature and rainfall) and the significant impacts on agricultural production have been well described. There are downstream economic impacts to value-adding of the agro-processing and socio-economic factors that affect policy and practice in agriculture and are less well understood. In addition, there is little information on the climate risks to small-scale and subsistence farmers that intimately depend on natural resources for their livelihoods.

(ii) Human health. There are recognised impacts to human-heath from climate change; including heat stress, increased vector-borne diseases, food insecurity, hunger and malnutrition. However, the combined effects of biophysical and socio-economic drivers of human health and disease and the required ability to manage and respond to these challenges are uncertain.

(iii) Marine and fisheries. The climate change risks to marine and fishery resources include rises in temperature, rainfall, and sea level, coastal storms and the acidification of estuaries. This may diminish fish stocks, alter markets, and influence tourism in the marine environment.

(iv) Biodiversity. Climate change will have numerous impacts on South African biodiversity and ecosystem services, and therefore requires a clear adaptation response (National Biodiversity Framework, the National Protected Area Expansion Strategy and the Climate Change Adaptation Plans for South African Biomes). Loss of Biodiversity and ecosystem services will impact all sectors, particularly those that rely on natural resources, such as agriculture, tourism and subsistence livelihoods. Ecosystem-based Adaptation and the use of biodiversity off-sets is a recommended response, and can be implemented using guidelines as outlined by the Strategic Framework and Overarching Implementation Plan for EbA. Although research has started to address the impacts of climate change on the extent, integrity and functioning South Africa's biomes, it is still unclear how diminishing biodiversity and ecosystem services influence socio-economic outcomes in terms of livelihoods and economic activity (i.e. medicinal plants, pollination and recreation).

(v) Water. The biophysical vulnerability assessment of the water sector has been assessed at catchment level, and adaptation options proposed to address growing water scarcity. However, there is a need to further understand the link between climate change, future population growth, and water supply and demand. In particular, there needs to be a better understanding of the influence of socio-economic factors on the water-supply and demand; such as migration, economic growth and energy demand, as well as the development of more integrated water-resource management.

In general, LTAS identifies the bio-physical vulnerability of the sectors, but does not to quantify the number of people affected in terms of population at risk. In addition, the role of the economic growth and governance in the ability to adapt appropriately to climate change is poorly defined and the key role players required for implementation of climate change adaptation at the local scale not identified. Therefore, an improved understanding between the country's development aspirations (as articulated in South Africa's National Development Plan) and climate change adaptation needs to be understood.

Understanding climate risks and identifying key areas of concern is critical for developing appropriate adaptation policies and scenarios. The possibility of increased disaster risk is considered to be one of the most concerning and potentially costly impacts of future climate change in South Africa and globally. Disaster risk is defined as the likelihood, over a specified time period, of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions; leading to widespread adverse human, material, economic, or environmental effects that require immediate responses to satisfy critical human needs and may require external support for recovery. This implies that understanding such risks would be a function of the following:

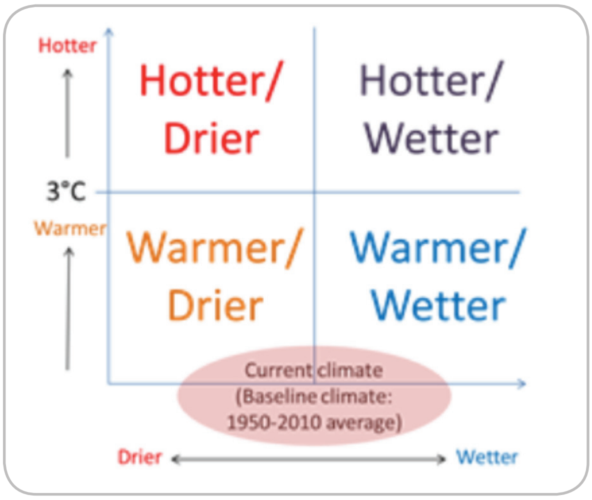


Figure 3.11: LTAS phase I plausible climate futures

Climate risk = frequency (probability per climate event)
X exposure (assets at risk of potential loss)
X severity (consequence/impact of the climate event)

Where:

Frequency: Probability of disruptive climate events due to higher temperature, rising sea-levels, changing precipitation, greater and intense storms, etc.

Exposure: A function of population growth and development.

Severity: A function of the consequence or impact of the scale of the asset loss due to the climate risk.

Our understanding of the futures climate risks, in terms of frequency (probability per climate event), is still at an early stage of development. The work to date, as illustrated by the first phase of the Long-Term Adaptation Scenarios, defines four possible climate futures for the country:

1. Warmer (<2 °C above 1961-2000) and wetter with greater frequency of extreme rainfall events;

2. Warmer (<2 °C above 1961- 2000) and drier, with an increase in the frequency of drought events and somewhat greater frequency of extreme rainfall events.

3. Hotter (> 2°C above 1961-2000) and wetter with substantially greater frequency of extreme rainfall events.

4. Hotter (> 2°C above 1961-2000) and drier, with a substantial increase in the frequency of drought events and greater frequency of extreme rainfall events (Figure 3.11).

These four scenarios were used to define some of the physical risks and impacts of climate change in South Africa for the water, agriculture and forestry, human health, marine fisheries and biodiversity sectors. This was very much an impact-based approach, but the results from the Long-Term Adaptation Scenarios Flagship Research Programme phase two project (LTAS) II) incorporated vulnerability assessments to help understand the capacity to manage climate risk and highlighted the need to understand the physical, social and ecological aspects of climate change. As vulnerability is a function of the impact of a risk on a system modified by the systems response to the risk, climate risk is a function of exposure, vulnerability and adaptive capacity. i.e.:

Climate risk = vulnerability X exposure (assets at risk of potential loss) **X severity** (consequence/impact of the climate event)/ **adaptive capacity**

Where:

Exposure: the contact between the climate agent in question and the target (i.e. individual/community/ population) in which it will impact.

Vulnerability: the characteristics of the population and the extent to which social and biophysical elements are sensitive to changes in weather and climate.

Adaptive capacity: refers to those social and ecological elements that enable the system to respond to the risk.

Severity: A function of the consequence or impact of the scale of the asset loss due to the climate risk.

With the understanding of addressing climate risk through **exposure, sensitivity and adaptive capacity** there is a need to take into account the aspirations and objectives of South Africa's National Development Plan and align them with the climate change futures scenarios. Aside from the LTASII, there are few studies assessing climate risks, and how this will influence the social and economic wellbeing and growth of the country. There are virtually no studies on how changes in the structure and growth of the economy, and local and global governance can affect the capacity and ability to respond effectively to climate change. There has been a limited assessment of the costs of climate change impacts, as well as cost of climate change response - both for mitigation and adaptation. The Climate Change Response Policy (DEA, 2011a) confirms the need for additional research to understand and quantify the socio-economic risks resulting from a range of climate futures that should inform planning and practice. Therefore, there is a clear need to identify and cost-adaptation measures as this uncertainty has constrained implementation of climate change adaptation measures (Ziervogel *et al.*, 2014).

3.4.3 Socio-economic modelling

The NDP outlines South Africa's socio-economic aspirations whereby all South Africans have a decent standard of living through the elimination of poverty and inequality by 2030 (NPC, 2012). Climate change has the potential to exacerbate poverty and inequality while also undermining social justice and cohesion (DEA, 2014a). In order for South Africa to progress to the level of development that is envisioned in the NDP, there is a need to transform the country's economy while building the capability of individuals and communities to respond to climate change by providing basic services for a decent life for all. Socio-economic and anthropogenic factors including that of population-growth demographics, decisions on electricity, technology innovation and good governance are some of the drivers that influence the projected changes in greenhouse gas emissions and consequent climate change impacts. Our current understanding of these factors and the trends are summarised below:

(i) Demographics. Fertility, mortality and migration are the key factors shaping the country's population trends. The general trend is that of an increasing population in the country by 2030-35 with economic growth, human migration, fertility and health services (HIV/AIDS prevention and treatment) being the driving factors (ISS, 2013; NPC, 2012). South Africa is also expected to have an evolving double disease burden in the ongoing transition from communicable to non-communicable diseases. This will be due to diseases extending their natural range, the emergence of new patterns as a result of climate change and extreme weather events; as well as an increase in deaths from non-communicable diseases - such as cardiovascular diseases, cancer, violence and injuries (ISS, 2013). At the provincial level, current scenarios indicate that by 2050 there will be a general increase in population in all provinces based on migration trends and using the residual analysis technique (ISS, 2013; NPC, 2012). Gauteng and the Western Cape are projected to have the highest increase in population by 2050, while there is relatively less increase expected in provinces such as the Eastern Cape, Free State, Mpumalanga, North West and Northern Cape.

(ii) Economic growth is one of the main drivers in combating unemployment and poverty in South Africa. The NDP has set targets in which the unemployment rate declines from 24.9% in 2012 to 6% by 2030, while the Gross Domestic Product (GDP) increases by an average rate of 5.4% per annum. The GDP growth rate in 2015 was 1.3%, mainly due to the slowdown in the mining and agricultural sectors. This rate is significantly lower than the average growth rate envisaged in the NDP. Other scenarios defined by organisations such as the Institute for Security Studies are premised on growth rates that are significantly lower than that envisioned in the NDP. These scenarios show a concerning trend of slow growth and underline the urgent need to stimulate economic activity and develop a more inclusive economy by addressing inequality, poverty and unemployment. Various other factors can affecting the country's economy; including shifts in global economic and political power; power shortages, water shortages,[5] degree of investment in economic infrastructure, corruption, social cohesion and equity (The Presidency, 2008; Cilliers, 2015).

(iii) Natural resource use. The use of natural resources will depend on the chosen development trajectory and resource intensity of the South Africa economy. South Africa is regarded as a water-scarce country; however, projections suggest a continued increase in water demand. A continued increase in water demand coupled with projections for a drier and hotter future – with less precipitation in some areas – is a serious concern for the country's future water security and immediate efforts should be put in place to adapt accordingly. South Africa produces two-thirds of Africa's electricity and 90% of this is generated in coal-fired power stations (DoE, 2016). Current scenarios which use data from the BP statistical review of world energy (2013) indicate a steady increase in energy demand in South Africa until 2030 (ISS, 2016). While there is an increase in the adoption of renewable energy, the continued reliance on coal and a large increase in nuclear power to add to the future baseload power - 65% coal, 20% nuclear and 15% renewables by 2030 (Integrated Resource Plan (IPR2), will allow South Africa to make significant progress in

5. See S Hedden, Parched prospects II: A revised long-term water supply and demand forecast for South Africa, African Futures Paper no 16, Institute fore Security Studies, Pretoria, 22 March 2016, available at https://www.issafrica.org/publications/papers/parched-prospects-ii-a-revised-long-term-water-supply-and-demand-forecast-for-south-africa meeting its COP 21 commitments, but will require a significant capital investment. Natural resource shortages, particularly water, can have implications for the economy and society with impacts on the cost of food production and mobility of goods and people.

(iv) Climate governance. In 1960 annual carbon emissions in South Africa were 26.7 Megatonnes and by 2010 this had increased to 125 Megatonnes. The country's carbon emissions from fossil fuels (especially coal) are likely to continue increasing until 2030 ('peak, plateau, decline' or PPD trajectory that South Africa committed to UNFCCC in 2009, COP15) and these are defined in intended nationally-determined contribution (INDC). The INDC projects indicate that between 2025 and 2030, emissions will be in a range between 398 to 614 Megatonnes carbon dioxide-equivalent. South Africa's greenhouse gas emissions are expected to peak then plateau for approximately a decade to 2035 and decline in absolute terms thereafter. This will require effective implementation of the full suite of policies and plans available at local, provincial and national levels to achieve this desired peak, plateau and decline trajectory.

(v) Cultural and social cohesion. Social cohesion goes across class, gender, race and ethnic divisions and is dependent upon the value systems within society. Social cohesion can be strengthened through education, religion, community and providing platforms for sharing the nation's arts and cultural productions and providing a unified action to respond to climate change (The Presidency, 2008).

(vi) A key factor that can help to address poverty, inequality and unemployment in South Africa is **improved governance,** the combating of corruption and the establishment of a capable, developmental state able to play a socially transformative role.

Generating socio-economic scenarios[6] that take all of these considerations into account is challenging, due to the complexity of the associated systems and the need to structure interactions in their appropriate interdependent relationships. Since the future remains essentially unknown, the use of scenarios can give representations of possible futures that are useful to frame and inform policy choices. These efforts typically include a qualitative (or narrative) element associated with quantitative indicators. The UNDP Adaptation Policy Framework identified demographics, economic growth, natural resource-use, governance, policy and cultural cohesion to be the key drivers of socio-economic change (Malone and La Rovere, 2005). Globally, the majority of associated work has focussed on the demographic and economic considerations with little or no work on the policy and cultural indicators due to data availability. Recent research on modelling socio-economic futures and development scenarios for South Africa has been carried out by the National Planning Commission and the Presidency's Policy Co-ordination and Advisory Services, as well as organisations such as the Institute for Security Studies (in partnership with the Frederick S. Pardee Center for International Futures) and global development organisations such as UNDP, World Bank and World Watch Institute. It is noteworthy that no socio-economic models for South Africa have yet incorporated the climate change futures to provide an

6. Scenarios describe a comprehensive description of the future of human-climate system using qualitative and quantitative information.

integrated assessment of climate change. This is needed so that climate change impacts can be explored in the overall context of **South Africa's capability to mitigate and adapt, and its shared responsibility in global climate governance.**

3.4.4 Framework for integrating socio-economic futures into climate adaptation planning

The IPCC has developed a set of Representative Concentration Pathways (RCPs) that explore alternative futures with different levels of global greenhouse gases. Table 3.3 summarizes key elements of the four RCP's. Climate modelling teams now utilise the RCPs as input into the model ensemble projections for future climate change.

Table 3.3: Representative Concentration pathways in the year 2100 (Source: O'Neill, 2011)

	Radiative forcing	CO_2 equivalent concentration	Rate of change in radiative forcing
RCP 8.5	8.5 W/m^2	1350 ppm	Rising
RCP 6.0	6.0 W/m^2	850 ppm	Stabilizing
RCP 4.5	4.5 W/m^2	650 ppm	Stabilizing
RCP 2.6	2.6 W/m^2	450 ppm	Declining

The development of socio-economic scenarios that are consistent with the RCP pathways has also been done at a coarse international level through integrated assessment modelling, and there have been some analyses of impacts, adaptation and vulnerability based on existing emission scenarios (Nakicenovic *et al.,* 2013). The development of the four new paths of radiative forcing (RCPs), the future social conditions, the climate change simulations (aligned to the RCPs) should be integrated to explore the alternative mixes of climate change mitigation, adaptation and impacts (O'Neill and Schweizer 2011), as depicted in Figure 3.12.

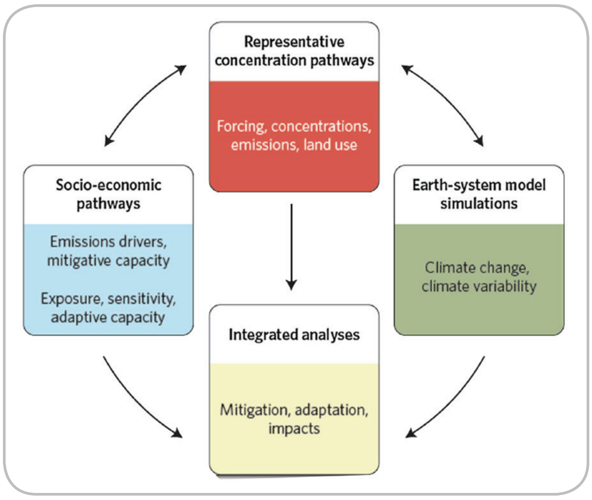


Figure 3.12: The parallel process conceptual diagram for the development of new, integrated scenarios of climate change (Source: Moss et al., 2010)

The integration of socio-economic and climate scenarios are essential to investigate the degree to which adaptation and mitigation could reduce the projected impacts of climate change, as well as to estimate the cost of action versus the cost of no action. The scenarios can then also be used to inform boundary conditions for mitigation, to assess the cost-effectiveness of local mitigation measures which can include land-use planning at the local level and changes in regional energy systems (IPCC, 2010).

The developed scenarios should provide both qualitative and quantitative descriptions of possible socio-economic and ecological futures that influence mitigation and adaptation, with the aim of improving decision-making and informing climate governance. The integrated scenarios would then bridge the gap between different disciplines regarding the level of climate change and its impacts on human development trends in relation to drivers of climate change, mitigation of greenhouse gas emissions and the capacity to adapt to climate change. The Shared Socio-economic Reference Pathways (SSPs) serve as defined scenarios to complement the RCPs (IPCC, 2010) and consist of balancing the socio-economic challenges of mitigation and adaptation – see Figure 3.13 and Table 3.4. It is noteworthy that a globalised, highly-developed and eco-friendly world, with regional sustainable development would offer low mitigation and low adaptation challenges, but would require good governance, rapid technological development and dissemination and low population growth (SSP1 scenarios). The extreme alternative to this scenario would be the failure of efforts at both adaptation and mitigation characterised by a high population and poorly-established institutions and governance (SSP3 scenarios). In instances where mitigation and adaptation is not combined, shifts towards SSP4 and SSP5 may be experienced, with either high adaptation or mitigation challenges dominating these scenarios (Van Vuuren *et al.*, 2013).

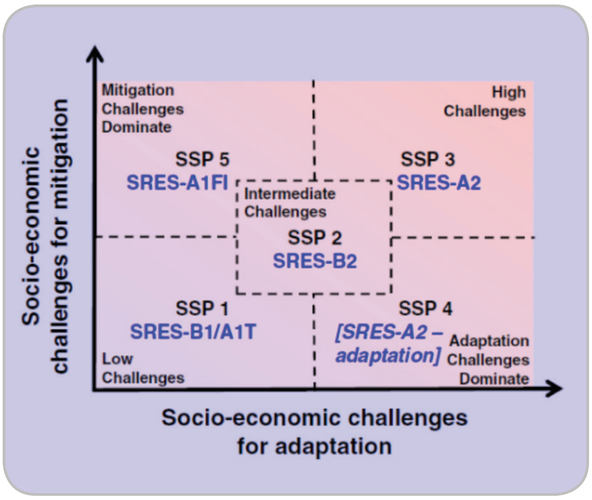


Figure 3.13: A suggested mapping of the Shared Socio-economic Reference Pathways (SSPs) in terms of mitigation-adaptation (based on O'Neill et al. 2013)

Table 3.4: Assumptions of scenarios of mitigation and adaptation (Van Vuuren et al., 2013)

Archetype	**Global Sustainable development**	**Business as usual**	**Regional competition**	**Economic optimism**	**Reformed markets**	**Regional sustainability**
SSP mapping	**SSP1**	**SSP2**	**SSP3/SSP4**	**SSP5**		
Economic development	Ranging from slow to rapid	Medium	Slow	Very rapid	Rapid	Medium
Population growth	Low	Medium	High	Low	Low	Medium
Technology development	Ranging from medium to rapid	Medium	Slow	Rapid	Rapid	Ranging from slow to rapid
Main objectives	Global Sustainability	Not defined	Security	Economic growth	Various goals	Local sustainability
Environmental projection	Proactive	Both reactive and proactive	Reactive	Reactive	Both reactive and proactive	Proactive
Trade	Globalisation	Weak globalisation	Trade barriers	Globalisation	Globalisation	Trade barriers
Policies and institutions	Strong global governance	Mixed	Strong national governments	Policies create open markets	Policies target market failures	Local actors
Vulnerability to climate change	Low	Medium	Mixed - varies regionally	Medium-high	Low	Low
Other mappings:						
SRES	**B1 (AIT)**	**B2(*)**	**A2**	**A1F1**		**B2(*)**
GEO3/GEO4	Sustainability First		Security First	Markets First	Policy First	
Global Scenario Group	New Sustainability Paradigm		Barbarisation	Conventional World	Policy Reform	Eco-communalism
Millennium Assessment	Technogarden		Order from Strength		Global Orchestration	Adapting Mosaic

* *The B2 storyline emphasized a focus on environmental and social issues from a regional perspective; in the quantitative elaboration, however, the choice was made to use medium projections for all relevant variables. Therefore, the B2 scenario is listed here in two columns.*

Note: This table summarises key assumptions in very general terms. Where differences within a set of scenario families exist, broad ranges are indicated. For references to scenario exercises, see text

The modelling of coupled socio-economic and climate change futures will therefore need to explore a range of scenarios that use the RCP and SSP as reference. The **modelling of climate change adaptation will depend on the prevailing mitigation** as well as the social and ecological vulnerability at a particular locality or region. A proposed framework to guide the modelling of adaptation to climate change should include socio-economic scenarios that integrate with climate change projections and reference mitigation commitments while also ensuring that they are:

- Relevant and appropriate for use at various levels by both the public and private sector in decision-making and in assessing the vulnerability to climate change;
- Reliable, and based on logical assumptions which do not over-estimate climate risks and is robust in terms of climate change impacts and risks, with clear boundaries of risk assessments;
- Based on established methodologies with transparency, open access of data, modelling and assumptions that can provide contextual guidance for interpretation
- Dynamic in order to account for internal feedback effects and enabling the forecasting over various periods of time (short-, medium- and long-term).

The premise of a socio-economic modelling framework is therefore a **dynamic coupled socio-ecological system** (Figure 3.14). Human systems can be conceived as classes of agents and larger structures within which those agents interact. The structures normally account for a variety of stocks (people, capital, natural resources, knowledge, culture, etc.) and the flows that change those stocks over time. Agents act on many of the flows, some of which are especially important in changing stock levels like births, economic production, or technological innovation. Over time, agents and the larger structures evolve in processes of mutual influence and determination. The costs of adaptation will need to be based on markets that have key stocks in the form of capital, labour pools and accumulated technological capability. In addition, non-market-based financial transfers among such agents with exchanges in a market system will need to be accounted for using social accounting matrices (SAM); and this is particularly relevant for South Africa with an informal second economy. Furthermore, governments interact with each other in larger inter-state systems that frame the pursuit of security and cooperative interaction like climate change agreements. Similarly, the human actor classes interact with each other and the broader environment and in doing so influence the prevailing practice, technological innovation and climate governance. These power relationships will need to be represented and accounted for in the action-reaction dynamics of the modelling. Understanding the stocks and flows in the model is vital to gain an insight into the system's behaviours. Stocks are variables with levels that accumulate or decay over time. For example, the number of people living in a given country is a stock of population. Flows are time-specific values that either add to or take away from stocks, such as the number of births added to a population in a given year. Depending on the rates of births and deaths, population levels will grow, shrink, or equilibrate at a stable level.

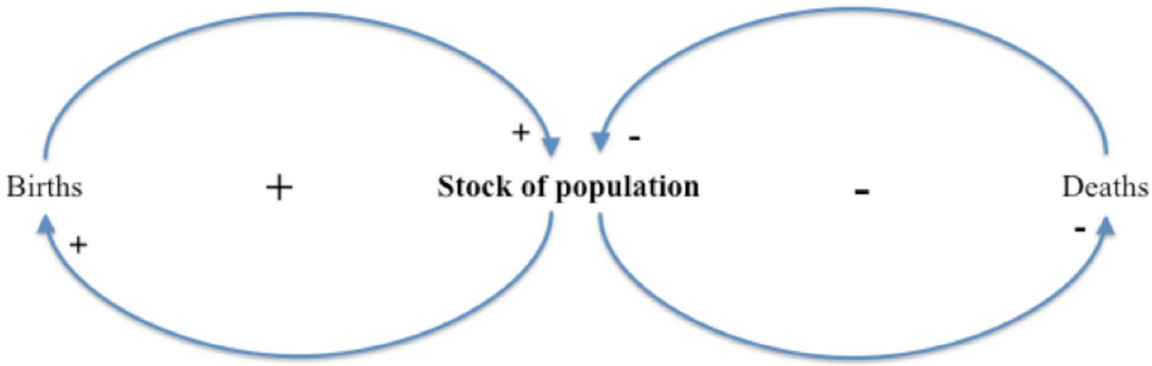


Figure 3.14: A causal-loop diagram to represent the stock of population that depends on the birth and death rate amongst other factors

There is, however, much that is missing from the above diagram, and a more nearly-complete understanding of population growth would require an analysis of the deeper drivers of each proximate driver of population, such as the effect that education has on the number of children families have.

A fully integrated modelling approach with socio-economic and climate change futures would include various stocks and flows within the following categories:

- Environmental Sustainability: Atmospheric carbon dioxide levels, world forest area, and fossil fuel usage
- Social/Political Change: Life expectancy, literacy rates, level of democracy, the status of women, shifts in values
- Demographic Futures: Population levels and growth, fertility, mortality, migration rates
- Food and Agriculture: Land use and production levels, calorie availability, and malnutrition rates
- Energy: Resource and production levels, demand patterns, the share of energy coming from renewables
- Economics: production by sector, consumption, trade patterns and structural change
- Global System: Country and regional power levels

It is proposed that the socio-economic modelling framework for climate change adaptation consists of modules that are inter-connected and can be accessed through a single graphical user-interface, similar to that of the International Futures forecasting system (www.pardee.du.edu); described in Figure 3.15. This is an example of the components (or modules) that could be utilised for socio-economic futures modelling, together with some of the key characteristics that guide each system.

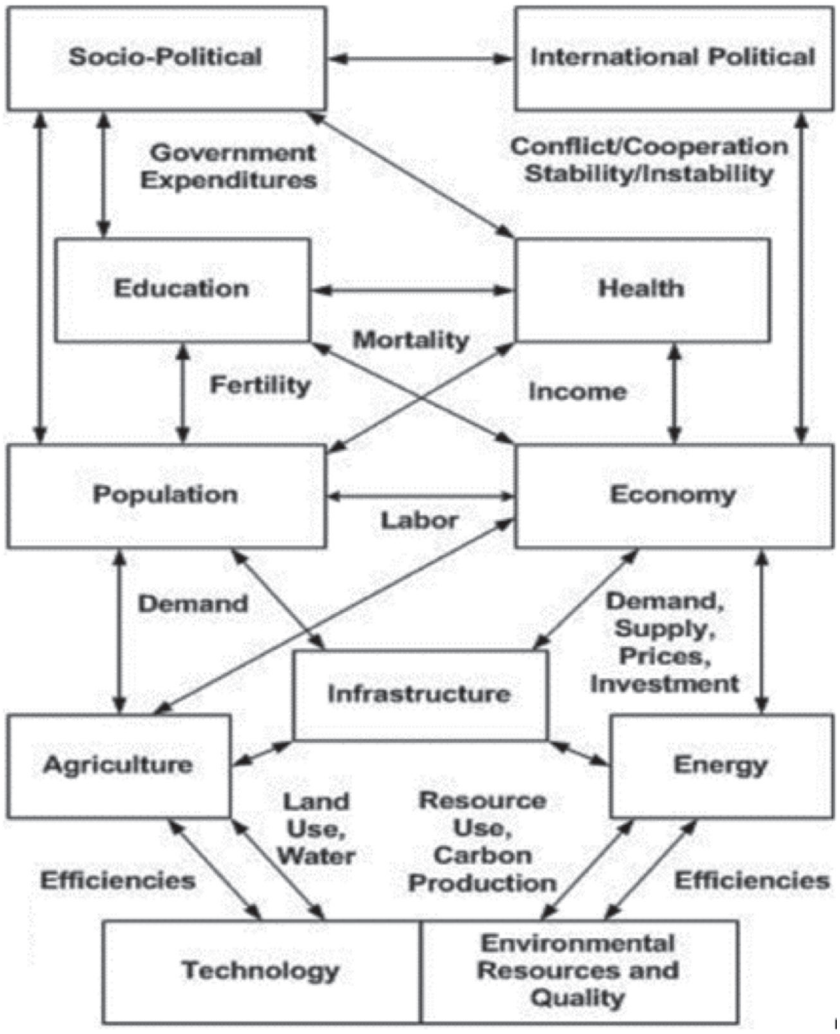


Figure 3.15: Proposed modules of the socio-economic adaptation modelling framework (from IFS)

The population module:

- represents 22 age-sex cohorts to age 100+ in a standard cohort-component structure (but computationally spreads the 5-year cohorts initially to 1-year cohorts and calculates change in 1-year time steps)
- calculates change in cohort-specific fertility of households, in response to income, income distribution, infant mortality (from the health model), education levels, and contraception use
- uses mortality calculations from the health model
- separately represents the evolution of HIV infection rates and deaths from AIDS
- computes average life expectancy at birth, literacy rate, and overall measures of human development (HDI)
- represents migration, which ties to flows of remittances.

The economic module:

- represents the economy in six sectors: agriculture, materials, energy, industry, services, and information/communications technology (ICT)
- computes and uses input-output matrices that change dynamically with development level
- is an equilibrium-seeking model that does not assume exact equilibrium will exist in any given year; rather it uses inventories as buffer stocks and to provide price signals so that the model chases equilibrium over time
- contains a Cobb-Douglas production function that (following insights of Solow and Romer) endogenously represents contributions to growth in multifactor productivity from human capital (education and health), social capital and governance, physical and natural capital (infrastructure and energy prices), knowledge development and diffusion (research and development [R&D] and economic integration with the outside world)
- uses a Linear Expenditure System to represent changing consumption patterns
- utilizes a "pooled" rather than bilateral trade approach for international trade, aid and foreign direct investment
- has been imbedded in a social accounting matrix (SAM) that ties economic production and consumption to representation of intra-actor financial flows.

The agricultural module:

- represents production, consumption and trade of crops and meat; it also captures ocean fish catch and aquaculture, but in less detail
- maintains land use in crop, grazing, forest, urban, and "other" categories
- represents demand for food, for livestock feed, and for industrial use of agricultural products
- is a partial equilibrium model in which food stocks buffer imbalances between production and consumption and determine price changes
- overrides the agricultural sector in the economic module unless the user chooses otherwise.

The energy module:

- portrays production of six energy types: oil, gas, coal, nuclear, hydroelectric, and other renewable energy forms
- represents consumption and trade of energy in the aggregate
- represents known reserves and ultimate resources of fossil fuels
- portrays changing capital costs of each energy type with technological change as well as with draw-downs of resources

- is a partial equilibrium model in which energy stocks buffer imbalances between production and consumption and determine price changes
- overrides the energy sector in the economic module unless the user chooses otherwise.

The infrastructure module:

- forecasts physical extent of, and citizen access to road transportation, water and sanitation, electricity, and information and communications technology
- calculates the public and private financial costs of infrastructure construction and maintenance

The environmental module:

- tracks annual carbon dioxide emissions from fossil fuel use
- represents carbon sinks in oceans and forest land and models build-up of carbon dioxide in the atmosphere
- calculates global warming and links it to country-level changes in temperature and precipitation over time which, with the addition of carbon fertilisation, impact agricultural yields
- represents indoor solid fuel use and its contribution to health-related variables
- forecasts outdoor urban air pollution and links with respiratory disease
- models fresh water usage as a percentage of total water availability

The education module:

- forecasts rates of intake and completion across formal education levels—primary, lower secondary, upper secondary and tertiary—for both sexes
- forecasts average years of education for the population as a whole
- captures educational attainment by age-sex cohort

The health module:

- accounts for major causes of disability and death across major World Health Organization categories
- measures the impact of health outcomes on the economy, through human capital's contribution to multifactor productivity

The socio-political module:

- represents government finance, social conditions, and attitudes of individuals, and qualitative and quantitative indicators of governance

The international political module:

- traces changes in power balances across states and regions
- allows exploration of changes in the level of interstate threat, both as an index and probabilistic measure

The technology module:

- is distributed throughout the overall model
- allows changes in assumptions about rates of technological advance in agriculture, energy, and the broader economy
- is tied to the governmental spending model with respect to research and development (R&D) spending

The relationships between variables of the system are described mathematically, based on historical data and trends. A dynamic Computable General Equilibrium (CGE) modelling approach allows scenario analysis with the alteration of parameters (often including multipliers) that drive different variables within the model and the incorporation of stochastic elements can be used to assess impacts from extreme weather events on the economy (dynamic stochastic general equilibrium model). Through the identification and validation variables (stocks and flows) and their quantification, a system modelling approach can describe the forward and backward linkages, inter-connectedness between different elements, and the feedbacks that determine the overall system behaviour. This provides users of the model with the ability to change parameters and the initial conditions of the model in order to explore a range of uncertainty or to consider policy leverage. In addition, a scenario tree allows for a number of different interventions and allows users to frame uncertainty surrounding: initial conditions (How much oil is really out there?); technology growth rates (What happens if longevity increases?), agent behaviour (What happens if people save more and consume less?) and relationships between parameters (What happens if assumptions about elasticity of energy demand to its price are too low?).

3.4.5 Understanding climate impacts and costs

The LTAS report on economics of climate change adaptation (Report 6) illustrates the potential macro-economic impacts of future climate change on the South African economy with a dynamic computable general equilibrium (CGE) model to simulate the economy-wide impacts for the period 2010-2050. Three biophysical infrastructures critical for the country's economy are modelled water supply and water use (including urban, industrial and agriculture); (ii) roads; and (iii) coastal infrastructure. The scenarios indicate that at national level the economic impacts of climate change are minimal; however at sub-national level there is a higher variability with the most vulnerable communities likely to be the most severely impacted. At national level the impacts of climate change on the economy are minimal given the projected average annual economic growth rates, especially in the period before 2035 but the impacts may be more pronounced with time. Economic impacts are likely to be most significant at a sub-national level and for specific sectors affecting productivity such as agriculture and its agro-processing. This could enhance inequality and unemployment especially for regions that are dependent on agriculture which can result in increased rural-urban migration. Poverty and inequality in agriculture will affect mostly the unskilled workers who will not easily be absorbed into other economic sectors. Several areas of future research were identified to improve understanding on the impacts of climate change; such as estimating the anticipated impacts of extreme weather events and the associated adaptation costs for specific infrastructure (dams and bridges on other critical infrastructure such as energy, health and telecommunications), the human migrations and distributional shifts in wealth that will accompany climate change impacts, as well as new opportunities; such as possible areas that could provide hydroelectricity under the wetter climate change future scenarios in South Africa.

An integrated approach to modelling climate change impacts and socio-economic futures will enable estimates of the costs of various actions or responses. The climate governance costs will need to be framed by the degree of mitigation compared to adaptation, of the appropriate scale (global, regional, national, and sub-national scales) and the degree of vulnerability. For example, in South Africa, coastal communities may face considerable risk of flooding and extreme weather events due climate change and will need considerable investments to enable them to adapt. At the same time, climate change and extreme heat and drought in the interior of the country could result in a decline in agricultural output and food shortages that would require different policy interventions. Understanding the economics of these adaptation options will require a spatial and temporal assessment of climate change and extreme weather events in South Africa, together with a spatial map of the socio-economic status and climate change vulnerability at appropriate scale. Based on a risk assessment of the climate change impacts to the profitability of various sectors of the economy, the socio-economic modelling will be able to assess the potential sectoral gains/losses arising from climate variability and climate change. This can be expressed as the gross value add (GVA) per sector (i.e. water, agriculture and forestry, human health, marine fisheries and biodiversity sectors defined by the LTAS) and the loss in GVA from climate change impacts assessed on the same basis as the costs required to adapt to climate change. When incorporated into the national system of accounts, the GVA loss from climate change can effectively inform government spending and climate change governance.

3.5 Development of a Risk Assessment Methodology and Vulnerability Indices

3.5.1 Introduction

Vulnerability is defined in IPCC AR5 as the "propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (Field *et al.* 2014).

The concept of vulnerability has become increasingly important in the climate change research community, with extensive developments taking place in the vulnerability assessment field over the last few decades. While generally applied as a prerequisite for the construction of adaptation strategies and policies, there is, as of yet, limited evidence linking vulnerability assessment practice to decisions that have reduced vulnerability (Preston *et al.* 2011). The complexity of vulnerability further implies that a multitude of methodologies for assessing vulnerability have emerged, with a lack of consensus around the most appropriate framework and 'best' methodologies for assessments. A number of challenges exist in relation to the development of any one vulnerability assessment methodology, and the development of a one-size-fits-all solution is neither feasible nor defensible as vulnerability is geographically and socially differentiated.

Challenges associated with the development of a vulnerability assessment methodology

General challenges:

Systems under assessment are highly complex and dynamic. In many cases the interactions between biophysical and socio-economic dimensions are poorly understood and as such vulnerability assessments often do not include both biophysical and socio-economic determinants of vulnerability (Preston, 2012).

Vulnerability assessments frequently do not go beyond an academic exercise and this has ethical issues when engaging stakeholders and communities in vulnerability assessments. There is generally a paucity of reliable, readily-available, and representative data for desired indicators of vulnerability. Any measure of vulnerability needs to capture the influence of processes operating on all relevant scales.

Climate-specific challenges:

Any measures or indicators of vulnerability need to be capable of identifying both the current state and any future trend. There is a degree of uncertainty in scenarios of future states in climate as well as social and economic futures.

This section of Chapter 3 intends to strengthen future vulnerability assessment work in South Africa. It does so by presenting major theoretical and conceptual framings and common approaches, and, building on South African expert insights and recommendations, provides practical translations of these framings and best-practice guidelines for how to approach vulnerability assessments. It also provides a number of South African case study examples, and outlines vulnerability assessment tools that are available in South Africa.

3.5.2 Framing of vulnerability by IPCC and common approaches

The vulnerability framing presented by the IPCC has shifted somewhat from that of the 3rd and 4th assessment reports, where vulnerability was seen as a function of exposure, sensitivity and adaptive capacity. In the more recent IPCC reports, the SREX (2012) and the 5th assessment report (2014), vulnerability is seen as a multidimensional concept where risk is determined by the interaction of climate change with related hazards, exposure and evolving vulnerability, which encompasses elements of sensitivity and adaptive capacity.

Vulnerability frameworks tend to be conceptually broad, and offer limited guidance on how they should be operationalised. Many vulnerability frameworks recognise vulnerability as a product of multiple stressors, and thus analyse multiple stressors. Conceptualising exactly how different stressors interact and how they are perceived to interact in the future is however challenging. What is more, vulnerability is not readily measurable and observable, and there is great difficulty in defining criteria for quantifying vulnerability. Still, a number of measures of vulnerability have been developed and applied, all of which have their strengths and limitations. Elements of the different approaches and methods are often used in combination.

Indicator-based methodologies produce measurable outputs across various spatial scales, and are generally popular with decision-makers. However, the output is limited by the subjective nature of selecting indicators, and by the difficulty in testing and validating the metrics used. Model and GIS-based methodologies tend to incorporate biophysical and socio-economic modelling, and display vulnerability spatially through mapping. Research has however found that these maps can make stakeholders feel over-confident, creating the impression that there is sufficient information when the method might actually fail to encapsulate a number of factors, such as spatial and temporal drivers of structural inequalities. Participatory approaches tend to apply location-specific methods and tools, and are generally bottom-up processes that recognise multiple stressors beyond those of climate. While participatory processes have the potential to build understanding and drive change from 'within,' the perception and understanding shared by participants should ideally be complemented with supporting socio-economic and biophysical data.

3.5.3 Moving towards improved understanding of vulnerability in South Africa

Outlining strengths and weaknesses of past VAs helps build understanding of the role of vulnerability assessments in facilitating climate adaptation, and the challenges and opportunities thereof (after Preston 2012:49):

Strengths:

- Vulnerability assessments provide platforms upon which researchers and stakeholders can learn collectively
- Frequent recognition of the role of biophysical and socio-economic determinants of vulnerability
- Strong emphasis on assessment at the local scale
- Assessment is flexible, with methods tailored to particular contexts and applications
- Assessments are undertaken by teams of experts conveying credibility to assessment methods and outputs

Weaknesses

- Lack of consistent methodology and comparability
- Frequent lack of clarity regarding what is vulnerability and to what
- Limited consideration of multi-scale determinants of vulnerability and their teleconnections
- Inconsistent use of scenarios to represent future biophysical and socio-economic states
- Limited consideration of adaptation/mitigation options to reduce vulnerability

In South Africa, there is a constantly growing body of sectoral knowledge on climate change vulnerability. The country saw a great expansion of information from the SNC (2011) to the much more detailed and in-depth LTAS reports (2013/2014). The collation and comparison of such information is however challenged by the necessary lack of consistency in terms of the definitions and approaches to vulnerability. It is thus difficult to get an overall picture of the nature and magnitude of vulnerability in South Africa, and there seems to be a gap in terms of bringing together all the vulnerabilities and impacts identified in different sectors and identifying overlaps, linkages or potential cascading effects.

3.5.4 Best practice guidelines and practical tools

A set of best practice guidelines should be considered when undertaking VAs. It is best practice when:

- The VA **design is guided by the context** in which it will be used. Because there are a variety of possible VA outputs depending on the method applied, an initial consideration of how the information will be used is essential for the design of the process.
- The VA takes the entire coupled system into account, **considering climatic, biophysical, and social, economic and political components.**
- The design of the VA **process recognises that vulnerability is not static through time**, and, depending on how long it will be used for, might need to allow for new information to be incorporated over time.
- The VA is based on **the latest science and conceptual framing,** and clearly defines the concepts as they are applied in the assessment. Thus, for example applying the latest IPCC report projections (AR5) rather than those coming out of the previous IPCC report (AR4), and specifying clearly how adaptive capacity, exposure and sensitivity are defined, what aspects of each conceptual element are considered and why. Showing a clear linkage to the aim/purpose of the VA.
- The **realities of what the science can and cannot provide** is accounted for. For example, messages about future change must be framed around the extent to which they are scientifically defensible (i.e. temperature increase of between 1.5 to 2˚C versus wheat production in X area will decline).
- The VA **incorporates a variety of methods,** combining qualitative/quantitative, bottom-up/top-down, and thus balancing participatory input and objectivity. This might imply feeding impact modelling outputs (i.e. crop or hydrological modelling) or Stats SA data into a participatory process. Or it could mean complementing spatial indicator mapping that identifies vulnerable areas with a participatory process that further unpacks the understanding of the areas identified as vulnerable.
- Only **scale-appropriate data** is included in the VA. There is a large range of data sources, and the data applied in the VA needs to be considered carefully in relation to the scale at which the assessment is conducted. For example, a map of South Africa based on Global Climate Model output is not likely to be an appropriate stand-alone resource for a VA at a local municipality scale. However, when utilising higher resolution data, the uncertainties introduced during the downscaling process should be considered in its application. Better understanding of the scale at which data can be applied defensibly may require consultation with whoever produced the data.
- The VA **incorporates stakeholder participation.** While some level of understanding of a system's vulnerability can be developed through external exploration, there are intricacies inherent in the system, be it a small village or a provincial government, which are best known by the individuals that are operating within the system. The way in which stakeholders engage will depend on the method and context in which the VA will be used. For example, it might entail including stakeholders in the process of identifying and weighting vulnerability indicators, and/or working with stakeholders to identify elements of exposure, sensitivity and adaptive capacity.
- The VA process **contributes to developing the capacity of relevant stakeholders.** Participation in the VA process in itself builds an improved understanding of the system at hand, in the context of a changing climate. This implies that the VA process itself can be considered to be as important as the output of the assessment.

- A VA that is **conducted as a step towards developing climate change adaptation strategies and actions incorporates the stakeholders** that are responsible for developing and implementing the actions in the process. This is to ensure the feasibility of the adaptation actions developed, and to ensure that those responsible for implementation understand why the actions have been developed.
- The limitations of the VA method applied are acknowledged and transparent.

A number of national tools that can assist government and practitioners in evaluating the impacts, vulnerability and adaptation to climate change already exist. These include: the Let's Respond Toolkit, designed to help local governments in South Africa to integrate climate change considerations into the Integrated Development Plans (IDP) process; the South African Risk and Vulnerability Atlas (SARVA), aimed at providing up-to-date information that can support decision-making through identification of risk and vulnerability; and the Climate Change Response Plan Toolkit, which includes a step-by-step guide for conducting vulnerability assessments through a combined indicator and participatory process approach.

3.6 Vulnerability and Adaptation Assessments of Key Socio-economic Sectors

Building upon the work conducted in the Long Term Adaptation Scenarios (LTAS) Research programme (DEA 2013), this section reviews and prioritise the most significant climate change risks and vulnerabilities for the following sectors; Agriculture and Forestry, Water Resources, Forestry, Terrestrial Ecosystems, Coastal Zone, Health, Urban and Rural Settlements, and Disaster Risk Management. Key messages for each sector are presented below and summarised in Table 3.10

Section 3.5 of this chapter was used as a guide to assess each of the sectors. A five-step process was followed (See Appendix B3) in each sector assessment in order to characterise the three core components of vulnerability: exposure, sensitivity and adaptive capacity.

While the assessment was conducted using a sectoral approach, the methodology attempted to also identify cross-sectoral issues that can be incorporated into an integrated overview. The review and prioritisation of the most significant sectoral climate change risks and vulnerabilities (both biophysical and social) was complemented through a literature review, including grey literature, of vulnerability work that has taken place in South Africa since the 2nd National Communication (SNC) to UNFCCC (DEA 2011). A review of the barriers to adaptation, the available information and data gaps, as well as the adaptation priorities are presented for each sector. Furthermore, as it is acknowledged that climate change may also present specific opportunities to some sectors, assessment of these was included in the sector reviews described below.

The assessments are focussed on the national scale and, where possible, provincial-level details are presented in order to demonstrate the spatial distributions of vulner-

ability across South Africa. Each assessment is based on the climate change projections and associated provincial narratives provided in Section 3.3.6 of this chapter.

3.6.1 Agriculture and Forestry

3.6.1.1 Introduction

The South African agricultural sector is highly diverse in terms of its activities and socio-economic context. The agriculture sector employs approximately 860,000 people and is critical in terms of national food security as well as supporting thousands of urban and rural households in terms of subsistence agriculture and small-scale production. Agricultural production in South Africa ranges from the intensive production of horticultural crops, to large-scale production of cereals, oil seeds, sugarcane, and tropical, subtropical and temperate fruit crops. Livestock production and its associated products constitute anywhere from 40% (Western Cape) to over 70% (i.e. Gauteng) of the provincial agricultural economy (Stats SA, 2007). Only 14% of the country, however, is currently considered potentially arable, with only one-fifth of this land having high agricultural potential.

Climate limitations are important in determining potential agricultural activities and suitability across the country. However, irrigation and conservation-tillage practices can overcome rainfall constraints, both in the high-value commercial agricultural sector and for smallholder farmers. Irrigation for agricultural production is estimated to consume in excess of 60% of South Africa's surface water resources, as well as a significant fraction of extracted groundwater. This makes the sector the primary water user in South Africa, and therefore a key focus area for developing adaptation responses that involve water and consider food security and other socioeconomic implications. The agriculture and forestry sector is also critical in terms of climate change mitigation, particularly in terms of the potential impacts on national carbon sinks and carbon sequestration including both forests and land use impacts.

3.6.1.2 Risks and Vulnerabilities

The agricultural sector is considered to be one of the most critical economic sectors in terms of potential impacts of climate change in South Africa. Agriculture is impacted directly by changes in precipitation, temperature and evaporation and through secondary impacts, including disaster risk and health issues. The most significant climate change risks and vulnerabilities are summarised below:

- Increasing temperatures and more variable precipitation across the country are likely to have significant impacts on a wide variety of crops and forestry products;
- Irrigation demands are projected to increase due to increased temperatures;
- Spatial shifts in the optimum growing regions for field crops and forestry;
- Yields of rain-fed crops such as maize, wheat and sorghum are negatively impacted;
- Increased temperatures will have serious implications for farm labour (see Health sector review for more details on heat stress);
- Increased temperatures will negatively impact on livestock production, particularly in the Northern Cape;
- Increasing risk of floods and other extreme events impacting on crops, as well as potential impacts on related infrastructure and distribution networks;
- Increasing demands from other sectors, particularly cities, will increase competition for scarce resources such as water and productive land;
- Climate change effects on plant and animal diseases and insect distribution could adversely affect crop yields and livestock production;

South Africa's vulnerability to drought : 2015-2016 agricultural drought

South Africa experienced a strong *El Niño* which resulted in the worst nationwide drought since the 1930's (SAWS, 2016). An agricultural drought is a period of time (either months or years) when the moisture supply of a region falls to a level where crop and range production is severely impacted (Quiring & Papakryiakou, 2003). The agricultural sectors that have been most severely affected are maize, wheat and sugarcane along with beef and sheep production. The majority of maize (83%), wheat (53%) and sugarcane (73%) are produced under dryland conditions making them especially vulnerable to periods of drought (Agri-SA, 2016). The following provinces have subsequently been declared drought disaster areas:

- Free State;
- KwaZulu-Natal;
- Limpopo;
- Mpumalanga;
- Northern Cape;
- North West;
- Western Cape (with areas of the Eastern Cape also affected).

3.6.1.3 Adaptation

Climate change problems are super-imposed upon the many other challenges and stressors that the South African agriculture sector already faces such as environmental degradation, disease outbreaks, and higher input costs. To a certain extent, farming communities already adapt and cope with a variable climate (DEA, 2013). Managing an uncertain future climate thus involves understanding vulnerability and reducing the associated risks (Andersson *et al.*, 2009).

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

3.6.2 Coastal Zone

3.6.2.1 Introduction

Numerous long-term changes in physical forcing have been observed at a global, synoptic (basin), regional and local scales as a result of climate and other anthropogenic-induced changes. Impacts of these on biological processes that support fish and fisheries production in both marine and freshwater ecosystems in coastal zones have been noted and may be used as proxies for further estimating global climate change impacts. Some of these physical factors include atmospheric circulation, intensity and variability patterns, ocean stratification, currents and mixing, as well as hydrological cycles and seasonal patterns. Important consequences of climate change of importance to coastal environments and fisheries in South Africa are:

i. Modification of terrestrial climatic and hydrologic processes;

ii. Change in coastal and oceanic circulation processes;

iii. Ocean acidification;

iv. Increased sea surface temperature (SST);

v. Sea level rise (SLR);

vi. Increase in sea storminess; and

vii. Changing wind systems

3.6.2.2 Risks and vulnerabilities

- The primary hazards to (physical) South African (SA) coastal infrastructure related to the sea are direct wave impacts, coastal flooding and inundation, and erosion and under-scouring (Theron et al., 2010). Rises in sea level, combined with rises in SST, and an increase in storms and extreme events such as cyclones in the tropical Indian Ocean, have the potential to inundate harbours, marine aquaculture farms and fish-processing plants close to the shoreline.
- The problem with Sea Level Rise (SLR) is not just the vertical rise but also its interaction with changing storm intensities and wind fields which produces sea conditions that will progressively overwhelm existing infrastructure. Higher sea levels will lead to smaller storm events being able to overtop existing storm-protection measures.
- Considering only topography, the lower-lying cities, such as Saldanha and Cape Town are thus more under threat by SLR than elevated cities such as East London and Durban.
- A recent study of changes in sea-surface temperatures between 1950 and 1999, identified an area of ocean to the south and east of South Africa as having experienced warming that puts them within the top 10% of such areas globally.
- Given the anticipated increasing upwelling conditions in the future, surface waters around South Africa is expected to experience more frequent occurrence of low-pH waters.
- All coastal fisheries are susceptible to increased sea storminess; small-scale artisanal ones even more so. A general increase in wind strength, and in the frequency and strength of storms and extreme weather events will make it more dangerous and difficult to catch fish, and will also reduce the number of days on which the boats are able to go to sea.

3.6.2.3 Adaptation

Considering the South African marine fishing industry (including large-scale industrial, small-boat commercial, small-scale, recreational and marine aquaculture sectors), the large-scale industrial and recreational fishers are seen as the most adaptable and the small-scale fishers the least adaptable. Possible adaptation measures for linefish include targeting other species, improving catching efficiency, putting catches to better use, moving to larger vessels and introducing specific management measures to alleviate fishing pressure on species most threatened by climate change. The measures suggested for the small pelagic fishery include better use of present resources, developing fisheries for alternative pelagic species and mesopelagic fish, moving to alternative catching methods and larger vessels, and allowing for increased variability in abundance and availability in management strategies. The adaptation measures suggested for the marine aquaculture sector are somewhat longer-term, as the threats facing this sector do not appear to require such urgent action. They range from protecting existing farms from increased storm activity and rising sea-level to controlling the in-farm environment more effectively and switching to, or developing more climate-resilient farmed species (Table 3.5). Better and longer-range prediction of Harmful Algal Blooms (HABs) and other harmful events and trends such as ocean acidification are also proposed as adaptation measures.

Table 3.5: The impact of rising sea levels on coastal areas and societal adaptive measures. The measures are classified as: [P] - Protective, [A] - Adaptive, and [R] - Retreat measures. (Adapted from Bollmann, 2010)

Effects of sea-level rise on natural coastal systems		Possible protective/adaptive measures	Relative costs
1. Flooding of low-lying areas and resultant damage	a) Storm tides b) Backwater in estuaries	1. Adapted lands development planning [A/R] 2. Dyke relocation [A/R] 3. Foreshore reclamation [P/A] 4. Beach nourishment, sediment protection [P]	1. Low to medium (ongoing) 2. Very high (once - off) 3. High (recurrent) 4. Medium/low (ongoing)
2. Loss of or changes to coastal wetlands		1. Construction of groynes, bank protection, sea walls [P] 2. Beach nourishment, dune protection [P] 3. Underwater reefs, breakwaters [P] 4. Development - free zones [R]	1. Medium to high (construction) 2. Medium/low (ongoing) 3. Medium to high (construction) 4. Low to high (once - off)
2. Direct and indirect morphological changes, particularly erosion of beaches and bluffs		1. Construction of groynes, bank protection, sea walls [P] 2. Beach nourishment, dune protection [P] 3. Underwater reefs, breakwaters [P] 4. Development - free zones [R]	1. Medium to high (construction) 2. Medium/low (ongoing) 3. Medium to high (construction) 4. Low to high (once - off)
3. Intrusion of saltwater	a) into surface water b) into ground water	1. Dams and tide gates to prevent influx of saltwater [P] 2. Adapted / reduced withdrawal of water [A/R] 3. Pumping in of freshwater [P] 4. Adapted withdrawal of water [A/R]	1. High (construction, maintenance) 2. Low (ongoing) 3. Medium (recurrent) 4. Low (permanent)
4. Higher (ground)water levels and limited soil drainage	1. Soil/land drainage improvement [P] 2. Construction of pumping stations [P] 3. Altered land use [A] 4. Designation of flood areas/ high risk areas [A/R]		1. High (ongoing) 2. Very high (construction, maintenance) 3. Low (permanent) 4. Very low (recurrent)

3.6.3 Estuarine Environments

3.6.3.1 Introduction

Southern African estuaries are highly variable in size, shape, degree of marine/riverine influence and catchment characteristics (Reddering 1988). The estuaries of the region also represent highly variable habitats in which conditions such as mouth state, water depth, salinity, temperature, turbidity and dissolved oxygen concentrations can fluctuate rapidly, both temporally and spatially (Day 1981). South African estuaries' role as fish and prawn nursery grounds and important feeding areas for migrant birds is of particular importance as they contain much of the only sheltered habitat along the southern Africa coastline, due to its highly exposed linear nature (Beckley 1984).

Estuary response to climate change processes will vary according to estuarine type. For example, large and small estuaries respond differently to flow reduction, with large estuaries (associated with high tidal flows) being less sensitive in comparison with small systems, which are highly dependent on river inflow to maintain their natural mouth state regime. The interaction between climate change stressors, estuarine process and features and biotic response are therefore complex with multiple interactions which can both amplify and moderate responses.

3.6.3.2 Risks and Vulnerabilities

Analysis shows that KZN and West Coast estuaries will be the most influenced by climate change from a structural and functional perspective. This is contrary to the current monitoring programmes which are focussing on biotic responses in the biogeographic transition zones (e.g. Transkei and western Southern Cape).

In summary, the impacts of climate change on estuaries include: 1) Changes in precipitation and associated runoff with the following consequences for estuaries: a) Modifications in the extent of saline water intrusion; b) Shifts in the frequency and duration of estuary mouth closure; c) Decrease or increase in nutrients fluxes; d) Changes in the magnitude and frequency of floods and related sediment deposition/erosion cycles); and, e) Changes in the dilution and or flushing of pollutants; 2) Rising temperatures from both the land and sea impacting on estuarine processes and biotic distribution; 3) Sea level rise and related impact on salinity and mouth state; 4) Changes in ocean circulation patterns; and 5) Increase in frequency and intensity of coastal storms also impacting on salinity and mouth state.

In the case of KwaZulu-Natal the major driver of change is increased runoff into the numerous small, perched temporarily open/closed estuaries, which will result in more open mouth conditions, a decrease in retention time and a related decrease in primary productivity and nursery function. This is best illustrated by the fact that estuary volume of these small perched systems shrinks by 50 - 90% when open to the sea. In contrast, West Coast estuaries will be negatively impacted as a result of reduction in runoff, related decrease in nutrient supply and an increase in sea level rise. This in turn will increase salinity penetration in permanently open estuaries and increase mouth closure in temporarily open ones. Similar to KwaZulu-Natal, West Coast estuaries will experience a decline in primary production and loss of nursery function.

Although Wild Coast, Eastern and Southern Cape estuaries will show some shifts in mouth states, nutrient supply, salinity distribution and ultimately production (e.g. fisheries), the most obvious impacts of climate change along these coastal regions will be the change in temperature (nearshore and land), associated species range expansions or contractions and changes in community structure. The bimodal rainfall zone of the Southern Cape is projected to show an increase in the frequency and magnitude of large floods as well as the duration and intensity of droughts. This region is characterised by medium to small catchments wherein bimodal rainfall ameliorates flow variability and confers a degree of stability on estuarine habitats. An increase in the magnitude of floods can cause deeper scouring of mouth regions, thereby increasing tidal amplitude and exposure of subtidal habitats and communities.

The effect of sea level rise, and related increase in tidal prisms, will be less apparent along the KwaZulu-Natal coastline, where with the exception of estuarine lakes and bays, the majority of estuaries are perched, whilst it will be more apparent along the southern and Western Cape coast with their more extended coastal floodplains.

The far-future scenarios under both the high and low mitigations pathways, holds severe consequences for South Africa's estuaries. Their relative small size and low runoff make them extremely vulnerable to climatic and hydrological climate change stressors - stream flow reduction, temperature increases and associated evaporation. All the coastal regions will be subjected to extreme change under these projections. Under the far-future scenarios estuary mouth closure will become prevalent along the entire coastline with some systems not connecting to the coast on decadal scales. The occurrence of hypersalinity (>35) will become ubiquitous in most permanently open systems and a large number of open systems may close in the future. Some smaller estuaries may dry out in their entirety, while the estuarine lakes are likely to show extreme shifts in open water area on decadal scales. Thus, while trajectory is clear, much research still needs to be done to establish the extent to which individual systems will respond to such drastic change – making extreme prediction without more rigorous investigations will only be interpreted as alarmist.

3.6.3.3 Adaptation

The ability to predict the response of estuaries to climate change and to plan mitigation and adaptation strategies is still hindered by a lack of good prediction tools and the lack of a fundamental understanding of many of the effects of climate variability on the physical, chemical and biological characteristics of the aquatic domain (Meyer *et al.* 1999). We are limited by the availability of both data (e.g. long-term flow data, temperature data, mouth conditions, wave height, species data) and models (e.g. flow changes, linking hydrological regimes to ecosystem processes and large-scale ocean current changes). At the same time, this uncertainty around forecasting change should not be seen as an impossible obstacle to understanding and developing adaptive mechanisms to reduce the effects of climate change on estuarine resources. Increasing the ability or resilience of ecosystems to deal with extreme events such as droughts or floods is an important opportunity to adapt to future climate change. The resilience of an estuary is influenced by the intactness of its catchment and estuarine functional zone. The processes underpinning goods and services, such as the assimilation and cycling of nutrients in estuaries, also needs to be protected if resilience is to be maintained. For example, developments within the estuarine functional zone will reduce the resilience of the system to extreme flooding, as little lateral movement would be possible. A way to ensure resilience is the determination and implementation of the Estuarine Ecological Water Requirements (Reserve) and the protection and / or rehabilitation of the estuarine functional zone. Healthy estuaries equate to estuaries resilient to change (van Niekerk and Turpie 2012).

3.6.4 Health

3.6.4.1 Introduction

Human health is a key component of the South African Constitution (Act 108 of 1996) Section 24 of the Act is written as follows (RSA, 1996):

'Everyone has the right to (a) an environment that 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.'

Human health has been a key component of the Millennium Development Goals (MDGs) which were set following the Millennium Summit of the United Nations in 2000 (StatsSA, 2013) and subsequently adopted by the Johannesburg Plan of Implementation of the World Summit on Sustainable Development (WSSD) from 26 August to 4 September 2002 (UN, 2002). Through the MDGs it has been widely acknowledged that health and sustainable development are interrelated. Many, though not all, are strongly linked to the current health status of the country. The main concern about health in South Africa is that the country has a quadruple burden of disease with i) maternal and child health, ii) HIV and TB, iii) trauma and violence and iv) non-communicable diseases all contributing greatly to the national burden of disease (Sherry, 2015).

The mission of the Department of Health is 'to improve health status through the prevention of illnesses and the promotion of healthy lifestyles, and to consistently improve the health care delivery system by focussing on access, equity, efficiency, quality and sustainability.' (https://nationalgovernment.co.za/units/view/16/Department-Health)

Although the National Department of Health has the overarching responsibility for the health of the citizens of South Africa, many other departments and sectors also contribute, either directly or indirectly. For example, municipalities contribute through service delivery, e.g. through the management of sewage treatment works. Other national departments such as Department of Education, Water Affairs, Social Development, Human Settlements etc. all contribute to human health as indicated by the SDGs. Natural disasters may have health implications through injuries directly related to the disaster, as well as pollution of the environment following the disaster, and would require involvement of a variety of stakeholders at different levels. This may include the South African Weather Service, Disaster Management, and all levels of government.

3.6.4.2 Risks and Vulnerabilities

- South Africa has multiple risks that contribute to the overall burden of disease (i.e. the quadruple burden of disease), which currently puts stress on the health sector. This stress may make the sector as a whole more vulnerable to climate change due to the additional stress a changing climate may put on the system. South African does have health policies in place, but action is needed to implement these.
- The challenging burden of disease in South Africa may make people more vulnerable to the health impacts from climate change (e.g. through pre-existing conditions). However, the impact of pre-existing conditions on the resultant health impact from climate change in South Africa is not quantified.
- There is a lack of understanding on the linkages between climate and health in South Africa (e.g. quantitative link between high temperatures and mortality). Thus, the current impact of climate-related diseases is not quantified, nor is the vulnerability of communities to such risks. Without a better understanding of

the current health burden, it is not possible to understand how climate-sensitive health risks will change in a changing climate. A quantitative vulnerability and risk assessment for the health sector should be performed; this would help to identify the most important health risks, as well as begin to identify the most vulnerable populations or communities. Adaptation strategies can then be tailored to region or communities based upon their risks and vulnerability.

- A changing climate can have a myriad of impacts on the health sector, which can put the sector at risk if the future risks and vulnerabilities are not understood. Before the magnitude of the impact can be predicted, the current climate-health linkages must be quantified. Then the potential future risks can be quantified, and the potential risks can be prioritized for action to mitigate the health impacts.
- Decreasing the vulnerability of the sector to climate change depends on cross-sectoral cooperation and collaboration. All health risks can be mitigated or exacerbated by actions, policies, etc. by sectors outside of the health sector. South Africa does have many environmental and health policies and programs in place. However, there is a lack of formal and supported intersectoral linkages between health and the environment.
- The South African health system is vulnerable to the state of health and disease burden of people from neighbouring countries. For example, the majority of malaria cases in South Africa is not from local transmission.
- The potential impact on the health sector from climate change has both public and occupational health implications, and both of these aspects need to be considered in adaptation plans.

Table 3.6: Selected environmental and health risks in South Africa as highlighted in NCCHAP and LTAS (DoH, 2014, DEA, 2013)

Environmental Health Risks	Category	Example
Heat stress	Climate-sensitive	Increased temperature can have direct impact on public and occupational health
Natural disasters	Climate-sensitive	Natural disasters (e.g. floods, drought, fires) can have immediate and long-term impacts on health
Housing and settlements	Modifying factors	Housing, infrastructure and service delivery can be a modifying factor for many health risks (e.g. clean water supply can mitigate water-borne diseases, improved thermal comfort in houses can mitigate heat stress, etc.).
Communicable Diseases	Climate sensitive and modifying factor	Some communicable diseases (e.g. cholera) are climate sensitive; others can be pre-existing conditions that may make people more vulnerable to climate-sensitive diseases.
Exposure to air pollution and respiratory disease	Climate-sensitive	Ambient air pollution levels are climate-sensitive; changes in climate factors (e.g. temperature, relative humidity, rainfall) can impact pollutant emissions, transport and deposition.
Non-communicable Diseases	Modifying factor	For many climate-sensitive health risks, pre-existing condition can make a person more vulnerable (e.g. pre-existing cardiovascular disease have been found to make people more vulnerable to heat stress)
Vector and rodent-borne diseases	Climate-sensitive	Changes in rainfall and temperature may impact the geographical range of vectors
Food insecurity, hunger and malnutrition	Climate-sensitive	Agricultural and fisheries sectors are climate-sensitive, which can have an impact on malnutrition.
Mental illness	Modifying factor and potential for climate sensitivity	Adverse situations, such as natural disasters create a conducive environment for the occurrence of mental health problems

3.6.4.3 Adaptation

There has not been another census since the 2011 SNC. A census survey will indicate the growth in the proportion of sensitive people to climate change in terms of age and socio-economic conditions. In terms of other factors that do make people more vulnerable, it is known that the prevalence of non-communicable diseases is increasing and these existing diseases may render people more susceptible to the effects of climate change as mentioned earlier.

In their 2015 annual report, the World Bank stressed the importance of "healthy and productive ecosystems" as the backbone of development, as these systems not only provide the air, water and soil, but also acts as a buffer against climate change (WB, 2015, p 20). It is envisaged that the demand for food in sub-Saharan Africa will increase by about 60% in the next fifteen years (WB, 2015). At the same time, it is projected that if the temperature increases more than 2˚C due to climate change, a reduction in crop yield of up to 20%, is possible in the poorest regions (WB, 2015). Thus, in general, the health sector in South Africa is currently facing a wide-variety of challenges that may be exacerbated by climate change. Human health impacts due to climate change may put an extra burden on the public health system. It is therefore important to act pro-actively and implement the necessary changes and improvements in the system (Mayosi *et al.*, 2012).

International goals, such as the Sustainable Development Goals (SDGs) would have impact on climate change and health. For example, in order to improve integrated water resource management and to strengthen adaptation strategies to climate change, the objectives below were stated, which would have an impact on the potential risk to water-borne diseases:

- Universal access to safe drinking water and improved sanitation;
- Improved water quality and wastewater management;
- Water-use efficiency (Hemson, 2016).

In general, there are many policies covering climate and health linkages that could be leveraged to develop adaptation strategies for the sector, balancing opportunities and threats.

An important barrier to adaptation for the health sector in South Africa is the lack of data on climate-health linkages, and vulnerability and risk of communities to climate change (DEA; 2013; RSA, 2013; Gary *et al.*, 2013, Vogel, 2013). Without such data and linkages, it is not possible to begin to estimate the potential magnitude of climate change on human health in South Africa. Indeed, an important recommendation of the LTAS report was that a quantitative vulnerability and risk assessment for the health sector should be performed; this would help to identify the most important health risks, as well as begin to identify the most vulnerable populations or communities. Adaptation strategies can then be tailored to regions or communities based upon their risks and vulnerability (Gary *et al.*, 2013; Ziervogel *et al.*, 2014).

The key research needs for mitigating negative health impacts from climate change were outlined in Myers *et al.* (2011) and are summarized in Table 3.7 below. In general, these tasks are consecutive as they build upon the evidence and knowledge gained; in South Africa, there are gaps across research tasks.

Table 3.7: Research tasks for adapting to climate change in the health sector (taken from Myers et al. (2011), based on framework in McMichael, 2010)

Research Task	Examples of studies needed
Clarify relationships between climate variation and health outcomes	Incidence of heat-related illness in outdoor workers in plantation agriculture
Estimate, statistically, current burden of disease attributable to climate change	Use available secondary data to perform a comparative risk assessment of the burden of disease from climate change.
Seek evidence of actual current health impacts	Perform a study of deaths from diarrhoea among children under 5-yrs related to climate variables and climate variability.
Develop scenario-based modelling to project future risk (including handling complexity and uncertainty)	Use scenario-planning methods for high-level modelling and prediction of likely futures. These can include changes in climate factors and non-climate factors.
Estimate health co-benefits of actions to avert/reduce further environmental change	Estimate the health co-benefits of public transport systems (e.g. improvements in air pollution, more exercise)
Evaluate health-protecting actions	Evaluate the result of introducing a drought-resistant crop on rural malnutrition.
Monitor for unintended consequences of adaptation	Study effects of a new drought-resistant strain of crops on whether unintentional effects such as more (or different) chemical hazards to workers emerge.

3.6.5 Terrestrial Ecosystems

3.6.5.1 Introduction

This review integrates the key findings on vulnerability of terrestrial ecosystems to climate change as documented in the Long Term Adaptation Scenarios (LTAS), the National Biodiversity Assessment Report (NBA), Climate Change Adaptation Plan for South African Biome (DEA, 2015) and Strategic Framework and Overarching Implementation Plan for Ecosystem-based Adaptation (DEA, 2017). According to findings from these assessments, climate change will have a variety of impacts on South Africa's terrestrial ecosystems with evidence suggesting alterations in existing habitats as well as species distribution (DEA, 2013; DEA, 2015).

South Africa has a wealth of terrestrial biodiversity critical to its national heritage, supporting livelihoods and economic development (DEA, 2015). South Africa is home to three of the thirty-four internationally recognised biodiversity 'hotspots' which are the Cape Floristic Kingdom, the Succulent Karoo and the Maputoland-Pondoland-Albany region. These 'hotspots' contain high concentrations of endemic plant and animal species, in areas most threatened by human activity. South Africa's biodiversity is exposed to significant risks and the National Biodiversity Assessment (Driver et. al, 2012) found that 40% of terrestrial ecosystems are under threat and only 6.5% were reported in the SNC to have been afforded formal protection (DEA, 2011b).

The terrestrial ecosystems are delineated into nine biomes: Grassland, Fynbos, Succulent Karoo, Albany Thicket, Savanna, Nama Karoo, Desert, Forest and the Indian Ocean Coastal Belt. These biomes provide crucial ecosystem services such as soil production, water flow regulation, pollination, and natural fodder for dry-land livestock grazing. The Climate Change Adaptation Plan for South African Biomes (DEA, 2015) states that these biomes and the ecosystems services they provide are under severe threat from the effects of climate change and non-climatic drivers such as land-use change and invasions by alien species.

The future risks to the terrestrial ecosystems of the nine provinces in South Africa are assessed in this review by making use of provincial climate narratives (see Section 3.3.6 of the chapter). The adaptive capacity of the terrestrial ecosystems is assessed to determine their resilience and that of their inhabitants to climate change.

3.6.5.2 Risk and Vulnerabilities

The climate variability and change threats include rising average temperatures, more temperature extremes, changes in rainfall intensity and magnitude, a higher likelihood of extreme events (such as droughts, floods, heat waves, etc.) throughout South Africa, shifting rainfall season, sea level rise and rising atmospheric concentrations of carbon dioxide (CO_2). In addition, non-climatic conditions such as changes in the occurrence, seasonality and severity of fire and land-use change resulting from climate variability and change are also presented in this report. These threats vary in their importance between the biomes, increase over time through the 21st century, and increase with the level of greenhouse gas emissions globally.

Each of the nine biomes in South Africa has a specific climate envelope or a particular environment controlled by rainfall and temperature which is ideal for the biome to thrive. The changes in both temperature and rainfall as a result of climate change will influence the areas where the biomes will continue to thrive and as a result, the area suitable for one biome might become more suited to another, putting stress on the ecosystem and its inhabitants. In a situation where these climatic changes occur over long periods of time, the biomes are able to adapt and shift in response, but if the changes are accelerated, occurring over shorter periods of time, as a result of climate change for instance, the biome and the species might not be able to adapt of shift, resulting in species being lost. This is a big threat especially in biomes that are already degraded or fragmented (DEA, 2013a; Driver *et al.*, 2012).

The Phase I of the LTAS Biodiversity Report categorised Terrestrial Ecosystems (biomes and species) vulnerability to climate change impacts and land use change, taking into consideration both climatic and non-climatic factors. When combining the threats of land-use and climate change, the Grassland, Indian Ocean Coastal Belt, Fynbos, Forest, Nama Karoo and Succulent Karoo biomes were identified as the most vulnerable to both climatic and non-climatic threats and in need of strong protection, restoration and/or research to ensure adaptation benefits for vulnerable communities under future climate conditions.

The summary of the findings of the LTAS indicate that significant change and loss of habitat is projected for the grassland biome, due to climate change. This is likely to be related to the high altitude location of the biome and its susceptibility to warming effects, as well as the possible increase in tree cover due to a longer growing season and CO_2 fertilisation. The savanna biome, on the other hand, is projected to expand with its geographic range partly replacing grassland. However, an increase in woody cover could shift the structure of some areas of the savannah biome towards woodland and even forest.

This will increase the opportunities for bush encroachment and the invasion of woody plants (alien and indigenous) into the grassland biome with major implications for the delivery of ecosystem goods and services to people, notably water delivery from highland catchments and grazing. Such shifts have extremely important implications for conservation and ecosystem services delivery, as well as ecosystem processes such as wildfire. The projections of biome shifts under low, medium and high risk climate scenarios to approximately 2050 are illustrated in Figure 3.16.

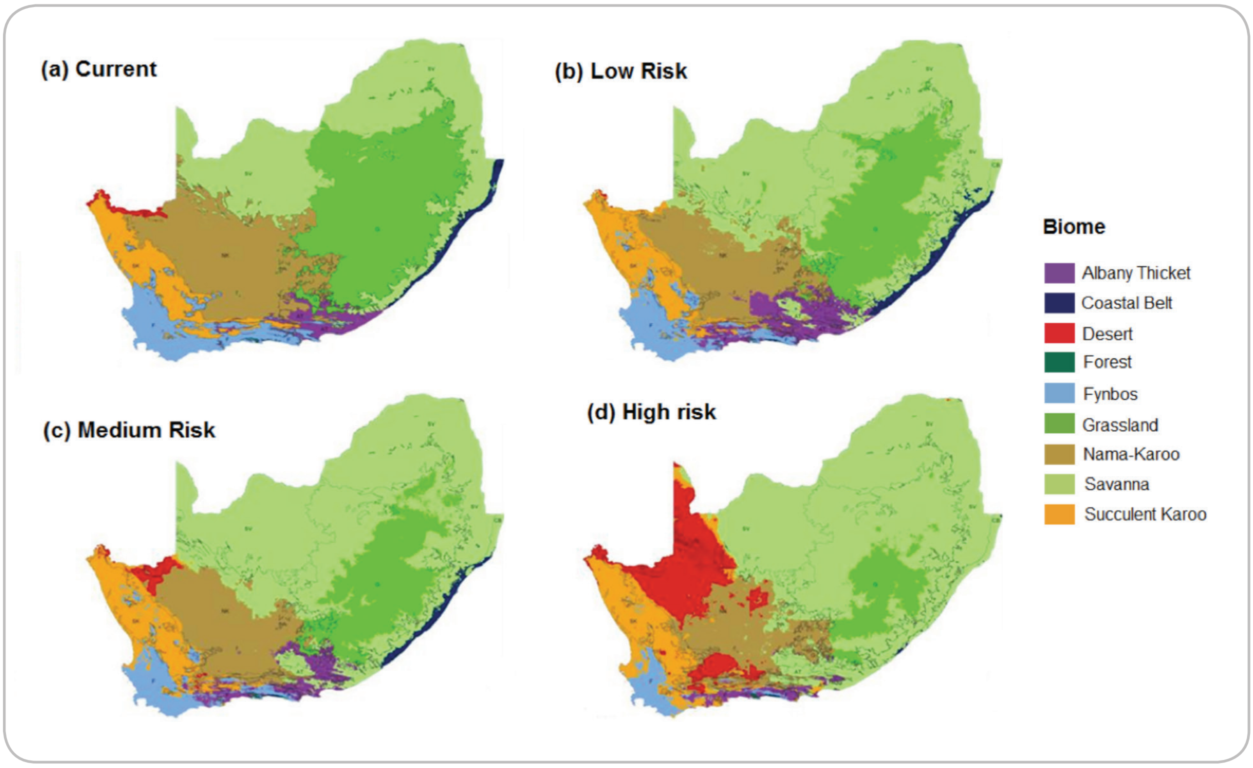


Figure 3.16: Predictions of biome climate envelopes under difference climate scenarios by 2050 as described by Driver et al. (2012). The future scenario is based on 15 downscaled global circulation models and the A2 emissions scenario

Climate change impacts on one biome can have impacts on various sectors of the economy of South Africa. Table 3.8 provides a summary of vulnerability of each biome to key climatic changes as well as the cross-cutting sectors that are impacted. The biomes presented are only those that have been identified and categorised by the LTAS to require the highest, high and medium action plan.

Table 3.8: Summary of each biome to key climatic changes as well as the cross-cutting sectors that are impacted

Priority Action	Biome	Climate risk	Cross-sector impacts
Highest	Grassland	Increased temperature and CO_2 will result in the invasion of savanna-like biome. Condition and major shrinkage of the spatial area of the biome Increased. Fire intensity and likely mega fires Increased temperature may limit livestock, and in particular dairy cattle More intense rainfall especially if coupled with overgrazing will intensify erosion	Agriculture
	Indian Ocean Coastal Belt	Potential invasion of savanna type vegetation Change in the proportion of forest versus grassland, linked to changes in fire regime and climate Extreme high temperatures will make domestic livestock raising unviable	Nature-based Tourism
High	Fynbos	Increased intensity and frequency of fires and more "out-of-season" fires Alien invasive species, especially grasses in lowland ecosystems Habitat transformation/fragmentation, particularly on the lowlands through agriculture and urbanisation	Tourism Agriculture
	Forest	Extreme high temperatures may increase destructive fires Heat intolerant Afrotemperate forests most at risk from temperature increase All forest types vulnerable to decreasing rainfall, with swamp forest and other water-table depth forest systems being vulnerable to changes in groundwater recharge	Biodiversity-based economy (e.g. Medicinal plants)
Medium	Nama Karoo and Desert	High temperatures exceeding comfort thresholds for most species of livestock, including wildlife management. High temperatures coupled with certain rainfall thresholds linked to increased pests and pathogens in particular areas Possibly higher frequency of extreme rainfall events implications for all sectors, including disaster management	Ecotourism Agriculture Water
	Succulent Karoo	Extreme high temperatures will place constraints on livestock productivity Higher temperatures could result in the range contraction of succulent plant species Reduced rainfall and increased drought frequency could result in a reduction in forage quality and quantity	Tourism Primary Livelihood (grazing) Biodiversity-based economy (e.g. game farming)

Priority Action	Biome	Climate risk	Cross-sector impacts
Medium	Savanna	Extremely high temperatures will make domestic livestock challenging and may lead to a sudden switch to other nature based ventures More summer rain and rising CO_2 will lead to an increase in bush encroachment and expansion of the savannah into grassland and Indian Ocean Coastal Belt biomes Rising CO_2 will also lead to high risk of alien woody plant invasion particularly in highly degraded rangelands	Tourism Water Game farming
	Albany Thicket	Extreme high temperatures will make domestic livestock raising unviable More summer rain and rising CO_2 will cause encroachment of savanna-like condition in the northeast More intense rainfall will cause soil capping, flash flooding, erosion and poor recharge	Agriculture

3.6.5.3 Adaptation

The following are broad categories of adaptive actions which can be taken to reduce the effects of climate change at biome level:

- Spatial-planning approaches which change the mix of activities in given biomes, including the possibility of abandoning some uses completely and introducing new ones;
- Management approaches that focus on adjusting the way in which the land uses are executed under a changing climate - for instance by changing the species used or the intensity of use;
- Ecosystem-based adaptation, which sets out to support the inherent ability of ecosystems, including their human inhabitants and organisms, to adapt to climate change, principally by reducing the other stresses which might impede that capacity, and restoring damaged ecosystem functions where necessary;
- Biodiversity stewardship programmes focussing on promoting sustainable land management and expanding protected areas on private land to form natural corridors that will enhance the adaptive capacity outside of state owned protected areas.

3.6.6 Urban and Rural Settlement

3.6.6.1 Introduction

Human settlements in South Africa face significant immediate and critical challenges even before the likely impacts and risks associated with climate change are considered (DEA, 2013; Linkd Environmental Services, 2013). Some of the current challenges include migration, urbanisation, poor spatial planning resulting from the legacy of apartheid, inequality, poverty, service provision complexities, limited local government capacity, and increased strain on aging infrastructure and reduced capacity for critical operations and maintenance of key infrastructure.

Historically climate change research has focussed on climate science and the associated biophysical impacts; whereas vulnerability assessments have tended to focus on rural areas and communities that are most directly impacted by climate change. In recent years, however there has been increased focus on assessing the potential climate change impacts and vulnerabilities of urban areas and cities (e.g. Bulkeley and Betsill, 2014; eThekwini Municipality, 2011; ICLEI, 2012; Roberts and O'Donoghue, 2013), particularly with regards to the potential for increasing disaster risk. The importance of incorporating climate change into normal development planning has been recognised as critical in terms of achieving broader development objectives through sustainable and climate-compatible development (DEA, 2013).

3.6.6.2 Risks and vulnerabilities

Different human settlement types and locations having varying vulnerabilities and capacities will experience the hazards associated with the present and future climate changes to an unequal extent. Higher vulnerability and lower coping capacity areas will have increased risk exposure to climate-related hazards; informal settlements and their population being the most exposed. Projected climate changes are likely to compound the impacts felt by the most-exposed populations and therefore building adaptive capacity in these areas should be a priority.

The current vulnerability of human settlements are determined by access to basic services, the type of dwelling, health and age, economic factors, land tenure status and social grants (DEA, 2013). Additionally, political and economic ideologies are considered to be the root causes of vulnerability as they influence the distribution and allocation of resources (van Huyssteen, *et al.*, 2013). In this regard, the long term implications of apartheid era planning in South Africa which created fragmented urban communities and increased vulnerabilities will be experienced both by the current generations as well as future generations.

Future risk will be subject to many of the present challenges but will be compounded by climate changes expected to increase exposure to both temperature and precipitation hazards, and water and heat related stresses. Adaptation strategies to reduce the risk must be effective not only for the current communities but also for the households in the future. Uncertainty inherent in climate modelling as well as the regarding emission pathway will require adaptation strategies that are applicable and resilient against a wide range of potential climate futures. The discord between much-needed economic development of a resource-rich country and the moral responsibility to mitigate climate change through the reduction of atmospheric emissions, creates a scenario where one goal may be prioritised at the expense of the other. Each of these paths will have implications for household vulnerability in the future.

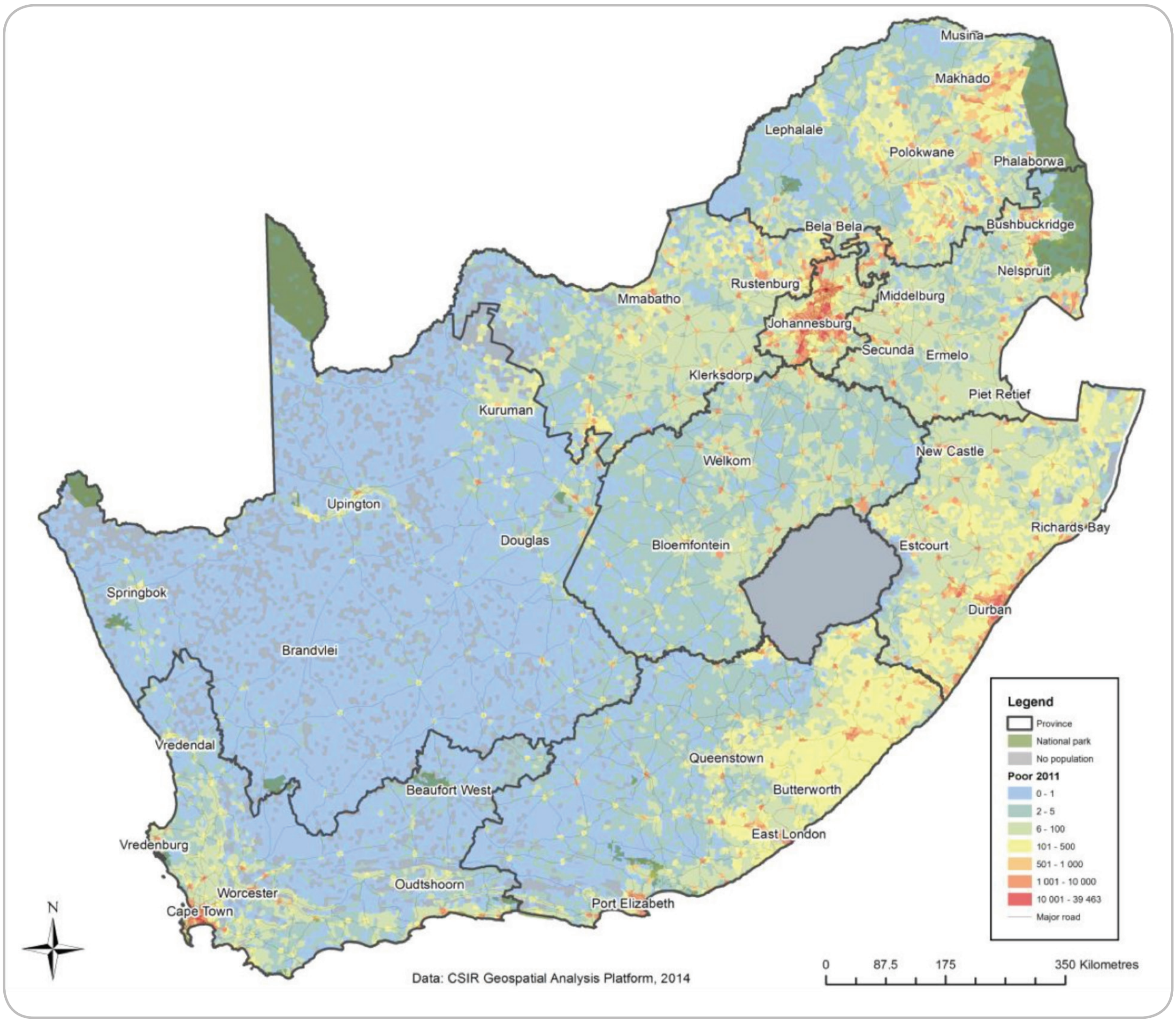


Figure 3.17: National Vulnerability (CSIR)

3.6.6.3 Cross-cutting impacts

There are several cross-cutting impacts between human settlements and other sectors such as the economy, human health, food security and water supply.

Economy

The development of human settlements is impacted by macro-economic factors such as unemployment, costs of building, inflation, income, access to credit and financial environments (DHS, n.d.). Building costs and businesses are impacted by increasing scarcity of raw materials. The cost of living for individuals will increase and consequently living standards will be forced to decrease. Weather events damage assets, equipment and fixed capital consequently impacting mining, manufacturing and construction industries. Increasing climate risks such as damage to infrastructure and assets by extreme weather events and ill health results in higher insurance prices and increased investment costs. Economic losses can result from decreased tourism, workday loss from ill health and decreased productivity. Climate change has changed the way the world views economic growth; because countries are held responsible for their carbon emissions, they are constantly exploring cleaner sources of energy (KZN PDP, 2011).

A review of the potential impact of climate change on the economy of South Africa noted that the greatest risk was from impacts to dry-land agriculture and transport infrastructure (DEA, 2015b; Cullis *et al.*, 2015). Consideration of the economic impacts in different parts of the country noted that it was in particular the rural areas that were most at risk from the potential economic impacts of climate change.

Health

Climate change alters the range and breeding season of disease vectors and can result in increased spread of diseases. Malaria is more common in rural areas (particularly to the north eastern part of RSA) whereas dengue fever and bilharzia is more common in urban areas, especially informal settlements because of poor water and waste systems. Increased temperature results in temperature inversions which trap pollution causing dry eyes, headaches, nasal congestion, fatigue, nausea, and respiratory problems. Urban residents are more prone to temperature-related illnesses due to the enhanced heat-island effect. Water-borne diseases will become more prevalent due to decreased water quality, as well as damaged water and sanitation infrastructure. Human health and mortality is affected by disaster response and emergency services already under strain (DEA, 2013).

Food security

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

Water Supply

Future water supplies are considered to be one of the greatest climate risks for human settlements (IPCC, 2012). South Africa, however already has a well-developed and highly integrated bulk water distribution system that has been designed to address the existing high spatial and temporal variability in water supply. For the major metropolitan areas, this existing water-supply infrastructure is considered to provide a reasonably high level of resilience in terms of future water supply provided that it continues to be managed correctly and planned accordingly (Cullis *et al.*, 2016). Of greater concern are the smaller cities and towns that are dependent on only a single source or do not have the capacity to efficiently manage and maintain existing and future water supply infrastructure (DWA, 2012). Increased variability in rainfall is also likely to have a greater impact on dry-land agriculture and hence on the potential economics of rural settlements (Cullis *et al.*, 2015). The link between water and energy (i.e. the water-energy nexus) also needs to be considered with regards to climate vulnerabilities for human settlements and possible adaptation options.

Embracing the concepts of water-sensitive urban design (WSUD) will be critical for reducing climate change vulnerabilities for human settlements in terms of increased resilience for future water supply. In addition, it is also an essential approach to reduce the risk from flooding and treatment of waste water which, in turn, will improve water quality, as well as reducing the energy requirements with associated benefits for climate change mitigation.

3.6.6.4 Adaptation

A deficit in infrastructure and provision of services in some areas acts as barriers to adaptation and increases vulnerability to climate change. This can be compounded by a lack of resources, unclear regulations and unexpected consequences resulting from previous mal-adaptation or poor development practices. Reducing capacity for necessary operation and maintenance is also contributing to the failure of critical infrastructure needed to mitigate the potential impacts and development risks associated with climate change.

Legislative progress has been made through the development of the National Climate Change-Response White Paper, the Long Term Adaptation Scenarios (LTAS) Research Program and the Disaster Management Amendment Act No.16 of 2015. These seek to assess and quantify the climate change risks to South Africa and provide the bases and legal mandate for adaption and mitigation actions to reduce the countries contribution and exposure to climate relates disasters in varying sectors, including human settlements.

Although it is important to continue to work on reducing the impact of human settlements in terms of climate change mitigation, it is also important to recognise that human settlements in Africa contribute only a very small percentage to the overall global greenhouse gas emissions. As such a priority for research should be on addressing the adaptation requirements in terms of planning and action frameworks for decision-making at a local community scale to strengthen resilience which will also support economic development.

Adaptation priorities should include disaster risk management principles to reduce the future climate change risks and building resilience to support future social and economic development. Furthermore mainstreaming of no-regret interventions while in the planning and development objectives will enhance general resilience to climate hazards. Adaptation responses and strategies must be tailored to differing settlement capacity and circumstances.

In terms of the development of human settlements in South Africa it will be important to consider alternative philosophies such as embracing the principals of water sensitive urban design (WSUD) and consideration for ecological infrastructure to replace or complement physical infrastructure.

The development of human settlements impacts on many other sectors such as transport, energy, water and food production and as such, a renewed focus on climate compatible development for human settlements will result in reduced climate change risks and vulnerabilities in these associated sectors.

3.6.7 Disaster Risk Management

3.6.7.1 Introduction

Climate-related disasters have come to dominate the disaster risk landscape to the point where they now account for upwards of 80% of reported disasters worldwide (CRED, 2015). Under climate change it is expect that there will be a significant increase in the risk of disasters not only due to increases in extreme weather events, but also due to increasing population growth, poor land use practices, and generally an increasing number of people living in high-risk areas particularly in Africa.

The National Climate Change Response (NCCR) White Paper highlights disaster management as a key area of development for the country, due to the expected increase in extreme climatic events. This commitment is illustrated by the fact that the national government's investment in disaster risk reduction and emergency response has risen from US$ 0.02 bn. to US$ 0.7 bn. between 2010 and 2015, as part of the total increase of investment in adaptation which rose from US$ 1.64 bn. to US$ 2.31 bn. (South Africa, 2015).

As the relationship between climate change and disaster risk become increasingly clear to both the public and private sector, actions are being seen on all levels. Smart (policy) choices and informed decision-making will be and are already delivering economic, environmental and social benefits locally and internationally, motivating more resilient and sustainable solutions in achieving everyday objectives.

The South African policy context has positioned the country to take a leading role in this regard, with the progressive national disaster management regulatory framework and incremental cross-sectoral support for practical disaster, risk and emergency management of which climate change response is acknowledged as a critical factor.

One of the most significant developments since the SNC, has been the Disaster Management Amendment Act No.16 of 2015. The Act now explicitly provides for the inclusion of climate change in disaster risk assessments through all spheres of government and mandates measures to reduce the risk of disaster through adaptation to climate change and the development of early-warning mechanisms.

3.6.7.2 Risks and vulnerabilities

Climate change will pose additional challenges for disaster risk management and the appropriate allocation of resources for disaster risk reduction. The frequency of extreme events as well as their spatial variability is likely to increase, which will alter and likely increase the number of communities located in hazard zones. The increased exposure combined with high levels of vulnerability, particularly with regards to poorer communities, will likely contribute to an increase in the overall levels of disaster risk.

Climate change will make it increasingly difficult to anticipate, evaluate, and communicate the variables that contribute to disaster risk. High degrees of uncertainty will make it less reliable to use the past as a precedent for the future, making development planning and allocation of resources increasingly complicated. This will have significant implications for the social and economic development of the country. Climate change could potentially prove a significant obstacle to maintaining and improving overall well-being, as responding to its impacts may continually demand resources to be redirected away from investments aimed at development.

In the context of disaster risk the priority hazards currently facing South Africa are floods, drought and wildfires. All of which can be either directly or indirectly exacerbated by climate change. Other disaster risks include lightning strikes, heat waves, hail damage, wind storms and sea level rise, as well as possible increases in health-related disasters, increased migration, and possible war and conflict that could be exacerbated by future uncertainties, including climate change.

Over the last two decades there have been 52 climate-related disaster declared in South Africa (EM_DAT, 2016) – see Figure 3.18. The key factor is not the increase in the occurrence of hazard events but rather a significant increase in human vulnerability as an ever-growing number of people are exposed to disaster risk. The main risk drivers include population growth, urbanization, the large portion of the population residing in informal settlements, and high levels of poverty and inequality (UNISDR, 2015).

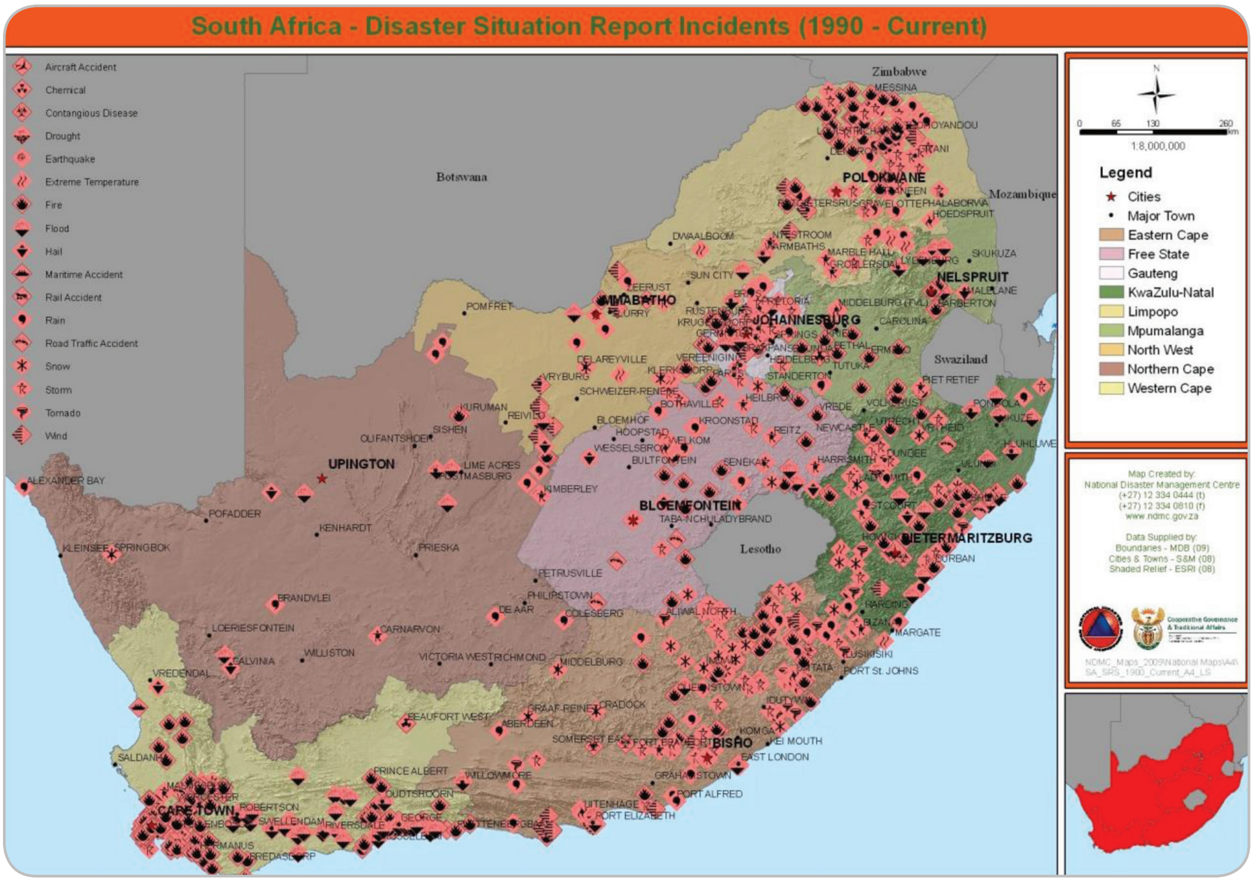


Figure 3.18: National Disaster Management Centre (NDMC) disaster situation report showing the extreme events incidents that have occurred across the country from 1990 to date (DEA, 2015a). (http://gisportal.ndmc.gov.za/StaticMaps.aspx)

The possibility of increased disaster risk is considered to be one of the most-concerning and potentially costly impacts of future climate change in South Africa (DEA, 2015a). Understanding these risks and identifying key areas of concern will be critical for developing suitable and sustainable adaptation policies and scenarios.

It is clear that climate change will be modifying hazard levels and exacerbates disaster risks in some locations and sectors of the country. The LTAS program provides initial quantitative estimates of future risks related to extreme events, based on provisional models of potential impacts under a range of possible climate futures. This informs adaptation scenarios for disaster risk reduction including droughts, floods, sediment and sea level rise that complements other studies in the LTAS Flagship program (DEA, 2015b).

Drought

Drought impacts stem from a combination of factors. Increasing rainfall variability is one aspect, but how this affects communities depends upon how well people, the economy and the environment can adapt.

Climate change projections show a significant increase in the frequency, duration and severity of droughts events in South Africa during the second half of the 21st century, with specific reference to the south-Western Cape (DEA, 2015b). In contrast, summer rainfall catchments, although less severe, will be experiencing increased drought risk from the beginning of 21st century.

Climate change impacts related to meteorological droughts appears to be manifesting over a longer time horizon compared to more acute impacts of hydrological droughts, with the winter rainfall regions experiencing impacts in the second-half of the century. This is an important factor when considering impacts. Crop yields can be severely affected by a single drought year, but can recover quickly if the drought is broken, even by a single good year. Water resources systems however respond much more slowly and it will take a number of years for the impacts of droughts to be felt particularly with regards to groundwater impacts (DEA, 2015b).

Flooding

Flooding events are primarily a natural occurrence, attributed to South Africa's already highly variable rainfall. Such events may then be exacerbated by dam and infrastructure failures related to inadequate design and maintenance, particularly in the case of storm-water infrastructure in urban areas, as well as poor land-use planning and a lack of early-warning systems. It is generally acknowledged that the South Africa's history of land use planning, largely developed under Apartheid has resulted in a significant increase in the risk and vulnerability of poorer communities particularly with regards to the location of informal settlements in high risk areas. In rural areas degradation of the natural environment, particularly with regards to overgrazing and poor land-use management practices, has also resulted in an increase in the flooding risk as well as increased soil loss and sedimentation.

The risk of flooding is also likely to increase in the future due to a combination of increasing climate risks as well as other socio-economic pressures resulting in changing land use and more people living in high risk areas. Possible future risks in terms of increased precipitation and flooding include (IPCC, 2014, DEA, 2014b):

- Large numbers of people exposed to flood events in urban areas, particularly in low-income informal settlements;
- Death, injury, and disruption of human security, especially among children, elderly, and disabled persons;
- Interaction of increasing frequency of intense precipitation, urbanization, and limits of insurance;

- Burden of risk management shifted from the state to those at risk leading to greater inequality,
- Eroded assets due to infrastructure damage, abandonment of urban districts;
- Creation of high risk / high poverty spatial traps; and limited ability to cope and adapt due to marginalization, high poverty, and culturally-imposed gender roles;
- Overwhelmed, aging, poorly maintained, and inadequate urban drainage infrastructure; and
- Increased demands on governmental attention to disaster risk reduction.

Wild-fire

Fire risk is strongly linked to weather and climate conditions, with factors such as wind and temperature being critical aspects of fire activity (CSIR, 2010). While climatic variables and natural causes play a significant role, human activity remains a main risk factor. Humans drive fire risk through activities such as land clearing and inadequate environmental and land management and the increased spread of invasive alien plants (IAPs), particularly pine, eucalyptus and wattles.

Recent years have seen a marked increase in veldfire risk across South Africa due to poor forestry practices, cyclical changes in weather patterns, altered population densities and distribution, the continued spread of alien invasive plants and constrained fire management resources (CSIR, 2010).

Observed and projected changes in climate are expected to increase the area at risk of wild-fire across South Africa. Bush encroachment and the increasing spread of invasive alien plants (IAPs), facilitated by increasing CO_2 in the atmosphere is also likely to increase the risks from fires in certain parts of the country. The potential for initiation of veld fires may also be increased due to increased risk of lightning strikes.

Sea-level rise

There are risks associated with increased severe storms, erosion, tidal influence and flooding impacts coastal settlements through the loss of property and damage to infrastructure (DEA, 2013; Taylor and Peter, 2014). Studies on sea-level rise have identified Saldanha Bay, Table Bay, northern False Bay, Mossel Bay to Nature's Valley, Port Elizabeth and the developed areas along the KZN coast as being the most vulnerable to the effects of sea level rise (Blake, 2010).

Although South Africa is not considered to be particularly vulnerable to the impacts of sea level rise, as compared to other countries such as Bangladesh or Mozambique (Dasgupta, 2007), there are specific local municipalities along the coast that have a relatively significant amount of land that is considered to be at risk from possible sea level rise and increased storm surges (DEA, 2015b). This does not include the possible additional impacts in terms of sea water intrusion into coastal aquifers that may impact some coastal communities and existing farming areas.

3.6.7.3 Adaptation

- Mainstreaming risk reduction, adaptation and management into development activities are important policy goals for responding to climate change and disaster risk and requires a shift in thinking towards more proactive risk reduction and adaptation planning from a current largely re-active system.
- The multi-sectoral nature of disasters means that effective implementation can only be achieved when disaster management institutions are integrated with other relevant institutions at all levels of administration within a country.
- Additional information on specific climate risks at the local level is necessary and this requires improvements in regionally downscaled climate models as well

as modelling of specific impacts at finer scale and at a more local level.

- In addition to further "top-down" modelling of potential climate change impacts for disaster risk reduction, it is also necessary to consider a "bottom-up analysis" of the specific climate risks and thresholds for disaster risk reduction and decision-making particularly with regards to future infrastructure planning.
- Consideration should be given to soft (i.e. institutional) as well as ecological interventions (e.g. buffer zones, wetlands, etc.) for disaster risk reduction and not only hard engineering solutions as these have multiple additional benefits.
- Consideration should be given to the global trend of moving away from a philosophy of risk reduction, to one of a managed approach to disaster risk.
- Investments should be made into improved forecasting and the development of early-warning systems and decision-support systems to manage and mitigate for the potential impacts of climate change and disaster risk.

3.6.8 Water Resources

3.6.8.1 Introduction

South Africa experiences extreme rainfall fluctuations. Consequently, the management of its water resources involves catchment and river systems management, water storage, water abstraction and return-flow management. In order to manage the variability of surface water runoff and to supply water to locations of economic activity, South Africa has built comprehensive water resources infrastructure that includes 794 large dams (i.e. dams with a wall height ≥15 m, or a wall height between 5 and 15 m and a storage capacity exceeding 3 million m^3). Their combined storage capacity is in the order of 31 billion m^3. More than two-thirds of the country's mean annual runoff (MAR), is stored in these dams.

Current usage is estimated to be between 15 and 16 billion $m^3.a^{-1}$, roughly split between agriculture (62%), municipal (27%), mining (3%), industry (3%), energy (2%) and afforestation (3%). An estimated 9.5 billion $m^3.a^{-1}$ is required to satisfy the total ecological reserve requirement. Rivers, lakes, wetlands and estuaries are some of the key ecosystems requiring protection. The human reserve is required to satisfy basic human needs by securing a basic water supply, for people who are, or who will, in the reasonably near future, be: (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource.

Current water usage already exceeds reliable yield and this translates into fairly large water restrictions during a drought year like the one the country is experiencing. Additional water resources need to be developed in order to provide for increased domestic water requirements. In future some Water Management Areas will need to develop additional local water resource bulk infrastructure.

Comprehensive water resource assessments (reconciliation studies), a primary tool for strategic water resource planning to the 2030 time horizon, in 13 key demand/economic areas, have been completed along with other water resource assessments, (the so-called All Towns Studies), in 905 towns. From these assessments, which do not make provision for climate change, it was found that 28% of the towns have inadequate water resources and are in need of urgent attention. Water resource actions were identified with water conservation and demand management (WC/WDM) identified as a key requirement. In spite of this, 50% of towns are not currently implementing WC/WDM. There are however no provisions for climate change in the water resources reconciliation studies, the primary tool for strategic water resource planning to at least 2030.

3.6.8.2 Risks and vulnerabilities

Water quantity:

South Africa already suffers from high-risk hydrology, with high levels of variability in rainfall from year to year, resulting in frequent floods and droughts. As a water-scarce country, the river systems and aquifers are highly used and developed, and many are already highly degraded. Under an unconstrained greenhouse gas emissions scenario, modelling results suggest a change that lies between a 20% reduction to a 60% increase. If global emissions are being constrained, the risk of extreme increases and reductions in runoff are sharply reduced, and the impacts lie between a 5% decrease and a 20% increase in annual runoff. While this is the picture at a national level, closer examination allows the division of the country into six distinct climatic zones, each of which will be impacted differently by climate change as illustrated below (Table 3.9):

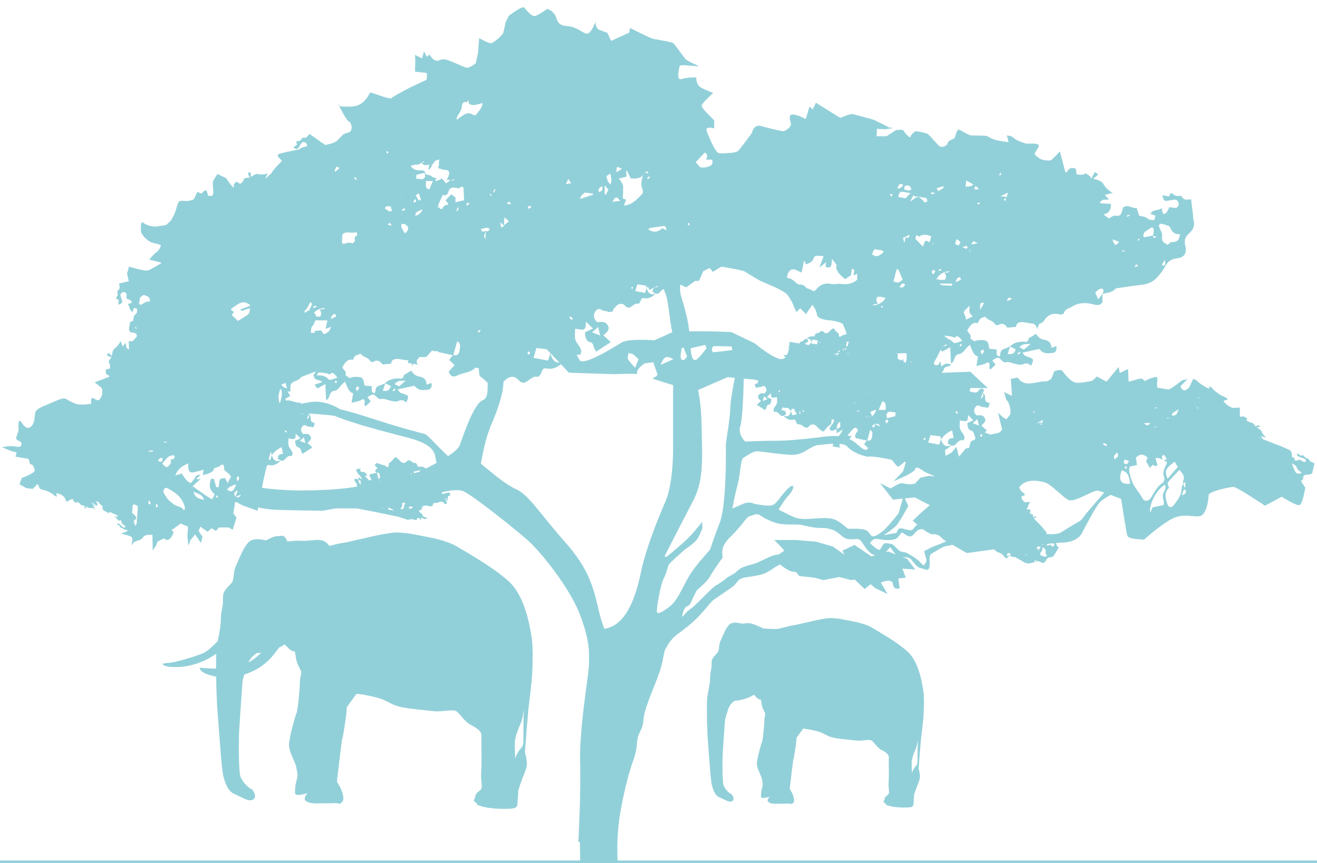


Table 3.9: Key climate change impacts in the six climate zones

Zone	Impacts
Zone 1: Northern Interior Irrigated agriculture, power and mining, urban and forestry, with dryland on the Highveld	• Likely reduction in rainfall, particularly in the summer rainfall period; • Significant increased temperatures, and thus evaporation; • Increase in water demand from agriculture; • Increase in demand for power generation; • Increase in domestic demand.
Zone 2: East Coast Rain-fed agriculture and subsistence farming	• Likely increase in summer rainfall, with increased large events (storms); • Moderate increase in temperatures due to proximity to ocean.
Zone 3: Central Interior Mining, industrial and domestic demand	• Highly uncertain future rainfall, with possible wetting or drying during the summer months; • Likely increase in storm activity and large rainfall events; • Significant increase in temperatures; • Increase in water demand from agriculture; • Increase in demand for power generation; • Increase in domestic demand.
Zone 4: West Coast and North-western Interior Intensive irrigation and groundwater use	• Uncertainty of rainfall patterns in the eastern parts, but with likely increased storm activity; • Likely drying in the arid western and coastal areas; • Significant increase in temperature expected; • Increase in water demand from agriculture; • Already a water scarce zone in the west, but is projected to become drier.
Zone 5: Southern Cape Large rural population with a high level of subsistence farming.	• Uncertainty in rainfall impacts in year round rainfall area, although likely drying in the west; • Likely increases in the summer rainfall in the western parts; • Moderate temperature increases; • Extreme events such as flooding might have an impact on the large rural population.
Zone 6: South Western Cape Large urban population and strong commercial agriculture	• Uncertain climate impacts on winter rainfall, but likely increase in orographic activity; • Possibly spread of rainfall beyond the historical winter rainfall period; • Moderate temperature increases compared to the rest of the country; • Increase in extreme events will affect vulnerable communities; • An increase in the demand for water for agriculture and domestic use.

Water quality:

The consequences of climate change on water quality are poorly understood and only beginning to be studied. This stems from the relatively scanty water quality monitoring network of the country. Nevertheless, there is evidence of deteriorating water quality of South Africa's major river systems, water storage reservoirs and ground water resources – the core water supply systems that underpin social and economic development in South Africa.

The country already faces an enormous task in dealing with the problems posed by key water quality issues such as acid mine drainage, eutrophication (or nutrient enrichment) and salinisation, coupled to the apparent ineffectiveness of many institutions to treat domestic sewage and industrial effluent to levels that are safe for discharge to rivers and streams.

Higher water temperatures will alter water-gas equilibria and increase the rates of microbial processes; these will in turn accelerate nitrification, denitrification, respiration and methanogenesis (the generation of methane by anaerobic bacteria). Floods and droughts will also modify water quality by direct effects of dilution or concentration of dissolved substances. Even if these facts are often inferred, few scientific works have been published until recently on the impacts of climate change on water quality modification. Moreover, climate change is not the only factor affecting water quality. Land use evolution, deforestation, urban spreading and area waterproofing may also contribute to water quality degradation. More often, water pollution is directly linked to human activities of urban, industrial or agricultural origin, and climate change could lead to degradation in surface water quality as an indirect consequence of these activities.

Climate change will affect water quality but in many areas the impacts may be masked by changes in land use, or compliance to effluent standards. Some of the impacts can be foreseen and can be mitigated by careful planning to include potential climate change in water quality management strategies.

3.6.8.3 Adaptation

South Africa is experiencing severe capacity challenges that impede the successful implementation of its water policy, legislation and various strategies. This translates into the slow establishment of CMAs, difficulties at several local authorities in discharging their water-related duties, as well as a shortage of technical staff in DWS national and regional offices. The water services sector is highly criticised for the inappropriate maintenance of its water services infrastructures. This poses a threat to the effective functioning of water institutions in South Africa.

Despite the government's vision for a comprehensive formalised system of water governance, water management in South Africa, and in particular in rural South Africa, tends towards plural legal systems. The complex set of institutional relationships that govern the water sector involve a myriad of organisations fulfilling different roles and functions. Hence, problems and challenges experienced in the sector are in part a consequence of these multiple institutional layers and the associated risks of performance failure by any one party. Their effective alignment and good inter-governmental relations will be a critical part of ensuring effective adaptation to climate change across the water value chain. The water-related policies and legislation are also not always aligned.

Table 3.10: Summary of the vulnerability of key socio-economic sectors in South Africa to climate change

	Sensitivity analysis	Exposure Analysis			Adaptation priorities
Sector	*Current stresses to the systems*	*Change in climatic driver (top priority)*	*Potential future consequences*	*Geographical Area*	*Actions required to cope*
Agriculture and Forestry	• Land use and change • Water stress • Invasive alien plants	↓ rainfall	Reduction in yields	KZN, Mpumalanga, Western Cape	• Climate Smart Agriculture • Conservation Agriculture
		Δ rain distribution	Impact crop production	All 9 provinces	
		↑ heat waves	Increase pressure on water resources	All 9 provinces	
Coastal zone	• Direct wave impacts, coastal flooding and inundation, and erosion and under-scouring • Land use change	Provinces with a coastline: • Intrusion of saltwater • Loss of or changes to coastal wetlands • Higher (ground)water levels and limited soil drainage • Flooding of low-lying areas and resultant damage erosion of beaches and bluffs			• Land use planning • Designation of flood areas/ high risk areas and development - free zones • Construction of dykes, groynes, bank protection, sea walls • Beach nourishment, dune protection
Health	• Quadruple burden of disease in SA and people from neighbouring countries • Poor housing, infrastructure and service delivery • Change in geographical distribution of diseases e.g. Malaria might spread southward. New diseases might develop. • Water supply, agriculture, catastrophic events may have short and long term effects on the health of the population. It would be essential to include these contributing factors and their health impacts in the sensitivity analysis.	• A changing climate can have a myriad of impacts on the health sector • There is a lack of understanding on the linkages between climate and health in South Africa (e.g. quantitative link between high temperatures and mortality)			• Cross-sectoral cooperation and collaboration • Tailored Adaptation strategies to regions or communities based upon their risks and vulnerability • Measuring / monitoring the effects of climate change on health will be very important. This will assist us to develop data and information on vulnerability as we go. The data could inform future plans.
Terrestrial Ecosystems	• Habitat fragmentation • Land use change • Invasive alien plants	• Rising temp • Temp extremes • Dec/increase in rain amount • Rising CO_2 • Changes in fire	• Climate change will lead to changes across the biomes through the alteration of existing habitats, seasonal rainfall, species distribution, and changing ecosystems functioning. • Threats vary in importance between the biomes, increase over time, and increase with the level of GHG.		• Land use planning • Land management • Ecosystem-based adaptation • Mainstreaming of stewardship programmes • Monitoring and evaluation
Urban and Rural Settlements	• Deficit in infrastructure and provision of services	• Different human settlement types and locations having varying vulnerabilities and capacities will experience the hazards • Informal settlements and their population being the most exposed			• DRM • Mainstreaming of no-regret interventions • Principals of water sensitive urban design (WSUD) and consideration for ecological infrastructure
Water Resources	• High water demand: current water usage already exceeds reliable yield • High levels of variability in rainfall from year to year, resulting in frequent floods and droughts • Deteriorating water quality of major river systems, water storage reservoirs and ground water resources (e.g. acid mine drainage)	↓ rainfall	• Increase in water demand from agriculture, power generation, settlements		• National water policies, plans and funds mainstream climate change adaptation • Monitoring and information needs to be appropriately designed • Infrastructure development, operation and maintenance • Groundwater needs to be protected by preventing groundwater degradation and unwise exploitation
		↑ intense rainfall	• Increased erosions and sedimentation of dams and rivers		
		↑ temperature	• Increase evaporation loss from dams • Affect biological and microbiological processes		

3.7 Towards a National Adaptation Plan

The National Climate Change Response Policy (NCCRP) recognised the need for the country to implement adaptation actions in order to respond to climate change. This would specifically involve changes to policy and process responses that need to be taken so that the country is able to best moderate or benefit from climate change.

South Africa will finalise its National Climate Change Adaptation Strategy in 2018. This document will be used as the National Adaptation Pan (NAP) for the country which will prioritize the key activities to co-ordinate and prioritise the country's climate change adaptation needs.

This section reports on the progress made by South Africa in the adaptation space since the SNC. In particular, South Africa's readiness to effectively develop, implement, monitor and improve (through continuous learning) effective climate change interventions is discussed.

3.7.1 Responses at a national level

South Africa has indicated its commitment to responding to climate change challenges through the development of the National Climate Change Response Policy (NCCRP) in 2011. However, the country is a developmental state that seeks to develop its economy and reduce the levels of inequality and poverty. It is recognised that climate change is likely to impact on the ability to meet these development goals. As such the country has presented its commitment to tackle climate change through the development of its Nationally Determined Contributions (NDCs). The NDC outlines the overall aspirations for adaptation and provides the timelines and levels of investment needed to achieve these goals. Whilst the NDC represents the broader vision for adaptation planning that is aligned with the National Development Plan, significant progress has already been made with respect to developing the adaptation response strategies that are aligned to short-to-medium term policies and strategies.

The National Adaptation Strategy (NAS) which is being developed concurrent to the National Climate Change Act outlines the key strategic goals and outcomes that are needed to respond to climate change, in terms of adaptation, emphasising the inter-linkages between climate change resilience and development goals. Using the NCCRP and NDCs as a basis, the NAS outlines the vision and strategic goals, while outlining strategic outcomes for the period of 2017-2025 and expanding on the strategic interventions that need to be implemented to achieve these outcomes (DEA, 2017).

3.7.2 Adaptation planning within key socio-economic sectors

At a sectoral level, adaptation plans have been developed for the key socio-economic sectors identified in the NCCRP as being vulnerable to climate change. In the Water Sector, for example, the Climate Adaptation Strategy for the sector outlines a number of strategic adaptation actions for addressing climate change impacts. These options range from planning for new dams to developing new groundwater sources and further highlights the need to improve flood-warning systems and to ensure that water allocation is sufficiently flexible to cope with climate change. Importantly, the strategy also highlights the need to protect water allocations to poor and marginalised communities, particularly under drought conditions. In the case of Agriculture, Forestry and Fisheries, sector-related climate change strategies have also been initiated which includes a Climate Change Sector Plan and a Climate Change Adaptation and Mitigation Plan that addresses agriculture and forestry. Climate Change Adaptation Plans have also been developed for South Africa's Biomes, presenting potential adaptation responses to guide current and future decision-makers in protecting South

Africa's natural ecosystems and biodiversity in the face of climate change. A climate change adaptation plan has been developed for the Health Sector that focusses on nine health and environmental risks and further seeks to improve health systems-readiness to climate change. The NAS, which provides guidance as to the minimum information required within sectoral strategies, will provide guidance for 2019/2020 sector plans (DEA, 2017).

Adaptation planning within South African cities is occurring alongside the need to address the problems of poor spatial and development planning inherited from the apartheid era. Human settlement typologies in the country are diverse, each with its own set of developmental challenges and potential to be impacted by climate change. A Climate Change Adaptation Sector Plan for Rural Human Settlements has been developed to support the creation of sustainable livelihoods that are resilient to climate change. This plan calls for access to climate-resilient services and infrastructure in rural areas to be promoted through climate-resilient rural housing programmes that include rainwater harvesting, solar water heaters and off-grid/mini-grid electrification, as well as environmentally-friendly and socially-acceptable sanitation solutions. In addition to this plan, policies that impact on human settlement design and development require the inclusion of climate change considerations. For example, spatial planning and land-use management legislation requires incorporating environmental requirements such as climate change. The Integrated Coastal Management Act 24 of 2008 also requires that coastal provinces and municipalities develop management programmes that allow for potential climate change impacts to be taken into account in all coastal planning and management. Further to this, amendments to the country's disaster risk management legislation require all organs of state to not-only indicate how it will invest in disaster risk reduction but also climate change adaptation.

3.7.3 Adaptation planning at provincial and local level

The NCCRP (2011) clearly mandates the development of dedicated provincial climate change strategies, while requiring local municipalities to integrate climate change into municipal planning tools. The importance of provincial and local government planning is echoed in one of the aspirational goals of the NDC and the NAS, where it is noted that climate considerations also need to be taken into account in sub-national policy frameworks. All nine provinces have made progress towards this end since the SNC, with a number of district, local and metropolitan municipalities following suit as shown in Figure 3.19.

The NAS (DEA, 2017), recognises that provincial and local governments would have different resources available to implement national priorities, and recommends that the adaptation priorities should be interpreted within the spatial area of the relevant authority, with the minimum information as stipulated for sectors, being applied as appropriate.

3.7.4 Monitoring and Evaluation (M&E)

It is critical to measure and monitor climate change responses so that decisions can be based on accurate, current and complete information to reduce risk and ensure that interventions are effective. The needs of the Monitoring and Evaluation (M&E) system for the country is outlined in the NCCRP that specifically calls for the monitoring of climate change impacts and the establishment of an M&E system for gathering information and reporting progress on the implementation of adaptation and mitigation actions. To this end, the country has embarked on developing an M&E-system for mitigation and adaptation aimed at providing an evidence-base of the impact of climate change in South Africa and the associated responses.

The aim of the adaptation component of the M&E system developed by the Department of Environmental Affairs (DEA) is to track the country's transition to a climate-

Provinces	District Municipalities	Metropolitan Municipalities	Local & Metropolitan Municipalities
Eastern Cape	Amathole Alfred Nzo Chris Hani	Buffalo City Nelson Mandela	Not applicable
Gauteng	Sedibeng West Rand District	City of Johannesburg City of Tshwane Ekurhuleni	Mogale
Western Cape	Eden West Coast	City of Cape Town	Bergrivier
KwaZulu Natal	uMgungundlovu	eThekwini	KwaDukuza
Mpumalanga	Nkangale	Not applicable	Mbombela
North West	Bonjanala Platinum	Not applicable	Not applicable
Limpopo	Capricorn	Not applicable	Thulamela
Free State	Not applicable	Mangaung	Not applicable
Northern Cape	Namakwa	Not applicable	Sol Plaatje

Figure 3.19: Overview of provincial and municipal climate change plans or strategies

resilient society (DEA, 2015). It is therefore built upon the work that is being undertaken with respect to climate information; climate risks, impacts and vulnerability; and climate-resilience response measures. These aspects form the three key building blocks of the structured approach proposed for a M&E system for adaptive capacity and response measures (DEA, 2015). The indicators for understanding the progress made toward the transition to a climate resilient South Africa are based on the number of policies/plans and strategies that integrate climate change; the number of stakeholder platforms on climate change adaptation-related activities; the number of monitoring systems and networks to monitor climate and atmospheric parameters and the number of monitoring systems and networks to monitor climate change impacts. This type of information facilitates tracking progress in the implementation of climate-resilient responses and assessing the effectiveness of such responses in enhancing adaptive capacity and addressing climate change vulnerability.

Among the challenges associated with tracking the transition to a climate-resilient society is that the effectiveness of adaptation responses may not be evident for many decades. This, coupled with the long timescales associated with climate change and its impacts, along with the multi-sectoral and multi-stakeholder nature of adaptation, make it challenging to track the transition to a climate-resilient society. The difficulties in trying to attribute cause-and-effect and the lack of agreed metrics for adaptation are also acknowledged as challenges to M&E for adaptation (DEA, 2015). However, the system will serve to provide a useful platform for gathering information and reporting progress on the implementation of actions that will ultimately assist in understanding how the country's vulnerability and adaptive capacity is changing.

3.7.5 Implementation of Climate Change Projects

The initiation of the National Climate Change Response Database (NCCRD) in 2009 provides an important resource to the M&E-system discussed above. Adaptation activities are emerging across the South African landscape. Project-based responses are developed and implemented by a variety of actors, ranging from the private sector and parastatals to Non-Governmental Organisations (NGOs) and local government. The NCCRD was developed by the DEA as a means to provide easy access to this landscape[7]. The database came as a response to the scattered nature of information on implementation of climate change interventions, recognised as a non-conducive setting for an "efficient, effective, integrated and cohesive climate change response" in South Africa (Dlamini, no date: slide 6). The database thus provides the natural source of information for this review, aimed at providing a sense of South Africa's adaptation implementation landscape in the years since the SNC.

While not claiming to provide an exhaustive overview of South African adaptation projects, the NCCRD is understood to be the largest existing South African database for adaptation projects. However, as noted by the DEA, the gathering of information kept by a large number of stakeholders is extremely time- and labour-intensive, with information difficult to find at times and with some information holders suspicious of the intention of these database (Dlamini, n.d.). An update of the database was underway at the time of this review (in the first few months of 2016. While updating information in the database is an ongoing process, the majority of the 125 adaptation projects listed have been implemented over the last 4-5 years[8].

7. *http://nccrd.environment.gov.za/deat/*

8. *A total of 23 of the projects were deemed to be operational at the time of the review, of which ten were scheduled for completion in 2016, five were scheduled for completion in 2017 and the completion of the remaining eight were spread relatively evenly between 2018/19/20. Just over half of the projects, 75, had already been completed, with a large portion of these, 24 projects, completed in 2015, and approximately ten projects were completed each year from 2011 through 2014. Insufficient data meant that it was not possible to get clarity on 27 of the projects.*

The NCCRD provides an overview of three types of projects, termed Adaptation, Mitigation and Research projects. For each project it provides a number of set categories of information, including description, funding organisation, host organisation and project start and end year[9]. A list of all adaptation projects was downloaded from the database[10], and amended[11], resulting in a list of 125 projects. Analysis of the 125 projects included categorisation of implementing agents, funders and the focus of the projects, as well as mapping the geographic spread of the projects.

Government, in the form of national and provincial governments and district, local and metropolitan municipalities, are the implementers of around half of the 125 projects (Table 3.11). Out of the government actors the metropolitan municipalities are the major implementers, responsible for approximately half of the 64 government-implemented projects. As was highlighted in Section 3.7.3 all eight South African metropolitan municipalities have a climate change plan or strategy, either completed or in process, and research has found evidence of adaptation being integrated into the plans and practices of metros (Ziervogel *et al.*, 2014). South African metros can thus to some extent be seen as being at the forefront of adaptation planning and implementation, likely in part due to their municipalities being better capacitated.

Implementers that are more indirectly regarded as government actors are included in the Parastatals & National institutes/ councils/ agencies/ foundations category. These include, for example, Eskom, the South African National Biodiversity Institute (SANBI) and the National Agricultural Marketing Council (Table 3.11). Following on from government and government-related actors, South African NGOs are the most dominant, with international and regional actors almost negligible. Only two of the projects in the database are implemented by university-based groups, which is not surprising considering that universities are generally focussed on research, rather than on implementing actions.

9. Note that not all the projects provide information for each category, and these cases are recorded in the analysis as "not specified."

10. The list of projects was downloaded from the database 05 April 2016.

11. The database download presents projects that have a number of different geographical implementation areas as separate projects, with one project per implementation area. These were reorganised to each represent one project, with multiple implementation areas.

Table 3.11: Project implementers and funders

Project Implementers[12]	
National Government	12
Provincial Government	12
District Municipalities	5
Local Municipalities	2
Metropolitan Municipalities	33
National institutes/councils/agencies/ foundations & parastatals	17
South African Non-Governmental Organisations (NGOs)	21
University based groups	2
Private sector	5
International NGO/ agency/ networks	6
Regional networks, initiatives & institutes	6
Not specified	5

Project Funders[13]	
National Government	14
Provincial Government	10
District Municipalities	1
Local Municipalities	0
Metropolitan Municipalities	34
National institutes & parastatals	3
South African trusts, funds and Non-Governmental Organisations (NGOs)	10
Private sector	5
Foreign Governments & Development Agencies	4
International trusts, funds, agencies, institutions and NGOs	39
Regional programmes & initiatives	3
Not specified	8

Overall, the projects presented in the database are largely South African-led in terms of implementation, with a minor part played by international actors. However, international actors play a greater role in terms of funding. International trusts, funds, agencies, institutions and NGOs fund the largest number of projects, with South African Trusts, Funds and NGOs playing a minor role. South African government actors still play a central role when it comes to funding, with metropolitan municipalities again the most dominant. However, as many projects list several funders without reference to the proportion contributed by each, it was difficult to get a more detailed understanding on the proportion of funding provided by the different actors.

Metropolitan municipalities dominated, with half of the projects being implemented in metropolitan municipalities in Tshwane, Cape Town or eThekwini. Hence, the Western Cape (45), followed by Gauteng (25) and KwaZulu-Natal (25), have the most projects being implemented in their province. The Northern Cape has a relatively high number of projects (16), followed by 12 projects in Eastern Cape. The remaining provinces, Limpopo and Mpumalanga have comparatively few projects, with the Free State and North West having only two and one project/s respectively. The North West and the Free State also display the least climate change strategies and plans of all the provinces, indicating that both planning and implementation

12. Note that one project has more than one implementer, hence the numbers presented here total to more than the 125 projects presented.

13. Note that many projects have more than one funder, and so the numbers here total to a lot more than the 125 projects presented.

in the two provinces may be lagging behind other South African provinces.

The NCCRP clearly identifies water, agriculture and forestry, health, biodiversity, human settlements and disaster risk management as the sectors that require particular attention for the immediate future. While sectoral planning is well underway at the national level, as outlined in Section 3.7.2, this project review provides an opportunity to reflect on the extent to which general adaptation projects map to these sectors. The projects were thus categorised according to the NCCRP priority sectors, with the addition of a coastal zone and a cross-sectoral category, based on the project descriptions provided.

As illustrated in Table 3.12, close to half the projects relate to the Terrestrial Ecosystems Sector. Included in this sector are projects focussed on sustainable land-use management; wildlife, biodiversity, soil and water conservation; restoration; alien clearing; rehabilitation; stewardship; biodiversity corridors; protected areas; ecological resilience; and ecosystem-based adaptation. A large number of these also have linkages and cross-benefits with other sectors, for example alien clearing can link to water resources and restoration to disaster risk management. However, the projects were largely framed around the natural systems, and were thus categorised accordingly. Further research is required to fully understand this large weighting towards terrestrial ecosystems projects. Though it can be theorised that the no-regrets nature of such projects, whatever the extent of future climate change, as well as the strong and long-standing South African conservation movement, could be playing a role.

The cross-sectoral category holds the second-largest number of projects. While not a sector as such, this category was included for projects that did not speak to any sector, but rather address aspects such as general policy dialogue, partnerships, collaborations and information sharing, training, sharing of tools and strategizing climate change responses. These can generally be considered to be enabling projects, focussed on planning and capacity and knowledge-building.

While it is the category with the third-most projects, the Agriculture and Forestry Sector features an unexpectedly low number of projects. Agriculture is a priority sector in all of the provincial plans, and could be expected to feature more prominently given its central role in food security and given the large number of South African subsistence farmers. Water Resources, Urban and Rural Settlements and DRM, and the Coastal Zone have fewer projects, with the Health Sector having the least number of projects. While analysis of a broader range of projects and a more up-to-date database is required to fully understand the landscape, there are indications that South African adaptation projects are thus not well spread across the country's priority sectors.

Table 3.12: Sectoral focus of projects[14]

Agriculture & Forestry[15]	Terrestrial Ecosystems	Water Resources	Urban and Rural Settlements & DRM	Coastal Zone	Health & CC	Cross-sectoral	Not clear
19	51	9	9	12	2	31	4

14. Note that for several projects more than one sector has been ticked, and so the numbers here total to more than the 125 projects presented.

15. Projects focussing on fisheries were also included here.

3.7.6 Climate Adaptation Financing

Central to the adaptation planning and implementation process is the issue of finance, i.e. the provision of funding. As highlighted in the NCCRP (2011), South Africa will need domestic resources to be complemented by international resources in order to build a climate-resilient society. This will require a range of actions, ranging from mobilisation to co-ordination to new market-based instruments, to financial reforms. This section aims to first provide a brief overview of adaptation finance in South Africa by reporting on the progress made since the SNC in terms of overarching governance and mechanisms for climate finance, and by outlining the main national and international sources of adaptation finance. Past investments (over the last five years) toward climate change adaptation are presented in Section 3.7.6.2.

3.7.6.1 Funding sources

In 2011 the NCCRP called for the development of a climate-finance strategy and architecture, as well as a climate-finance co-ordination mechanism. The Development Bank of Southern Africa (DBSA) conducted investigations on behalf of the DEA in this regard, looking at the most effective setup and structure of a climate-finance co-ordination mechanism. DBSA developed the prototype presented in Figure 3.20 and proposed a more South Africa-driven investment programme aimed at growing ownership and increased integration (Montmasson-Clair, 2012).

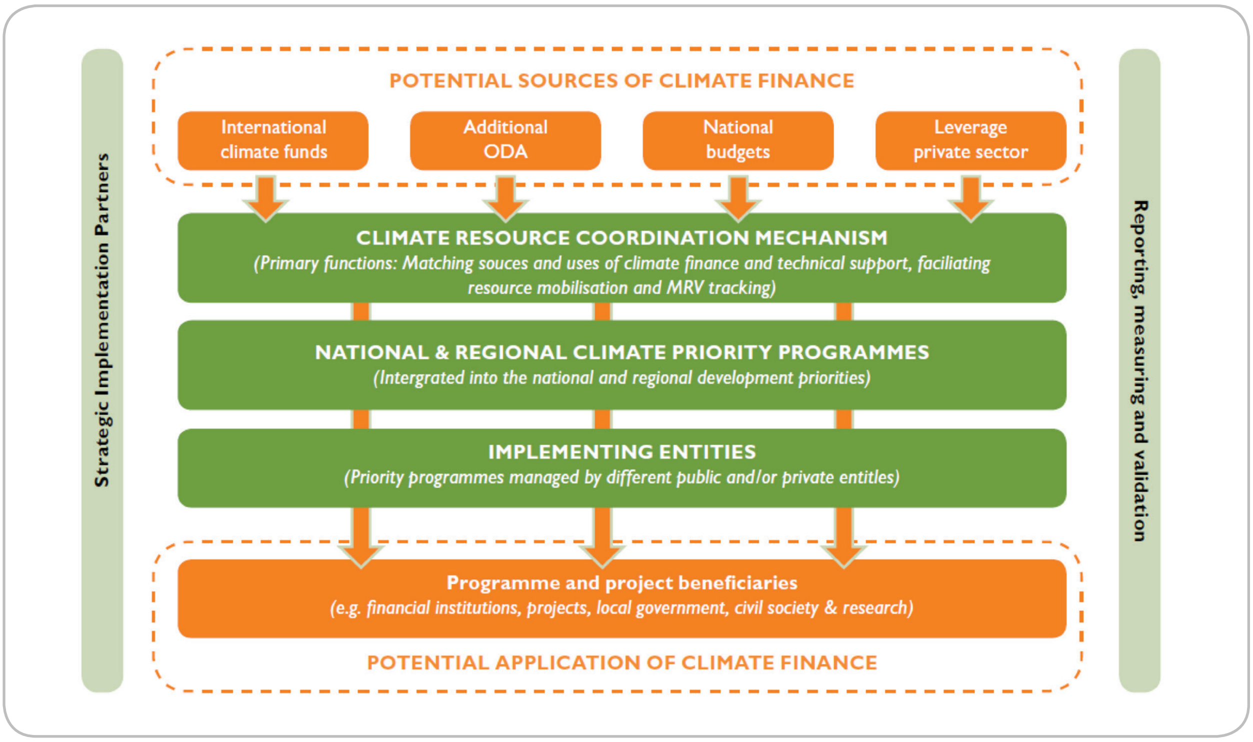


Figure 3.20: Prototype for climate co-ordination for South Africa (RSA, 2011c)

Potential sources of climate finance, as outlined in Figure 3.20 include international climate funds, additional official development assistance, national budgets and private sector. As illustrated in recent global figures, which show that in 2014 only 17% of public climate finance went to adaptation (Buchner *et al.*, 2015), mitigation tends to dominate. This is set to shift with the 2015 Paris agreement as pledges were made to move towards a more equal focus towards mitigation and adaptation.

In South Africa, a number of international and national funds have, to varying degrees, been funding adaptation action over the past 4-5 years. The majority of these have become operational in South Africa in the years since the SNC and are briefly discussed here.

The Global Environmental Fund (GEF), established in the 1990s, is the financial mechanism for a number of conventions, including the UN Convention on Biological Diversity and the UNFCCC. Climate change adaptation is a minor part of that, and the majority of GEF-funded climate change-related projects in South Africa so far have been mitigation-related.

The Adaptation Fund (AF) came about in the 2000s and is dedicated to funding climate adaptation and resilience activities. Funding can be accessed through accredited Implementing Entities, including Multilateral Implementing Entities such as the African Development Bank, UNDP and UNEP. A South African National Implementing Entity (NIE), the South African National Biodiversity Institute (SANBI) was accredited in 2011. The SANBI NIE issued a call for project concepts towards the end of 2013, which, after following a long multi-step selection and concept- and proposal-development process, led to the approval of two South African projects in October 2014. These two projects, the uMngeni Resilience project and the Small Grants Facility project, have a total of $10 million from the AF, and are currently in the implementation stage.

More recently, in 2010, ***the Green Climate Fund (GCF)*** was formally established. This fund, over time, is committed towards a 50:50 balance between adaptation and mitigation investments. The GCF provides a variety of financial instruments beyond grants, including equity, sub-ordinated debt and concessional loans. As with the AF, access to the GCF financial instruments requires accreditation. Accreditations have been awarded since 2015, and the first South African entity to be accredited to access GEF funds was the Development Bank of South Africa (DBSA) in March 2016. Two other South African entities are currently waiting for the final accreditation: Nedbank and SANBI. As opposed to the AF, where the NIE's access to funding is capped at $10 million, the GCF has no such caps and single projects can be up to the size of $250 million. The GCF thus has the potential to bring large amounts of climate finance into South Africa over the next few years. It is still too early to say to what extent this will be adaptation-focussed, but at least one of the entities, SANBI, will be focussed on projects that are either a combination of adaptation and mitigation projects, or that are solely adaptation-focussed.

South Africa has also set up national arrangements for finance, one of which is the ***South African Green Fund,*** whose inception was confirmed early in 2012. The Fund is managed by DBSA, on behalf of DEA, who initially set aside R 800 million for the establishment of the Fund. Aiming to catalyse the transition towards a green economy, the Fund offers financial support in the form of grants, loans and equity. Since 2012 the Fund has concluded several public requests for proposals, funding projects within the following funding windows: green cities and towns; low carbon economy; and environmental and natural resource management. While not explicit, adaptation aspects are entangled in the last and, to some extent, first of the three funding windows.

The Drylands Fund is another South African initiative, formally constituted in 2011. It came about following South Africa's ratification of the United Nations Convention to Combat Desertification (UNCCD), and was established as a mechanism to house, manage and utilize contributions to fund the country's UNCCD National Action Programme. While not directly a climate finance mechanism as such, the Fund's focus on sustainable land-use management and on people living in areas vulnerable to environmental degradation, implies that actions financed through this fund tend to implicitly also address climate-related vulnerabilities. Initially housed within the DBSA, this fund has in more recent times moved to SANBI, and a strategy for the way forward for the fund is currently in process.

3.7.6.2 Investments in adaptation for the period 2010-2015

The NDC provides an overview of past investments, made from 2010-2015, that were based on annual reports on expenditure of different departments of the South African government. In the approach undertaken to estimate these investments as part of the NDC, activities that met the criteria or definitions of adaptation technologies, or were regarded as technology transfer for the adaptation sector were considered (CSIR, 2015).

In the Water Sector, for example, the country has invested in numerous projects to make this sector more resilient through investments into new desalination plans, and the development of bulk water-supply infrastructure and maintenance thereof, as well as the development of new water storage facilities. In the past five years significant investment has also been made in terms of operational climate monitoring and operation climate prediction under the foresight of the South African Weather Services (SAWS) (CSIR, 2015). In addition to these investments during this five year period, it was found that various programmes have been undertaken that are relevant to climate change adaptation in the Water Sector. These include the Environmental Protection and Infrastructure Programme, that created 99 548 work opportunities during 2012/13, while 13 613 were created in the first half of 2013/14. Programmes such as the Working for water (WfW), Working on fire (WoF) and The Working for Wetlands programme have not only supported the rehabilitation, protection and sustainable use of natural resources but also provided for employment and training of men and women from marginalised communities. The DBSA as the implementing agent for the Green Fund in 2013/2014 further approved 22 projects in South Africa (CSIR, 2015).

It has been estimated that the capacity for domestic investment into climate change adaptation increased from US$ 0.26 million to US$ 1.1 million from 2011 to 2015. The implementation investment increased from $US 0.71 bn $ US 1.88 bn from 2010 to 2015. The breakdown per year for some of these key investments is shown below in Table 3.13.

Table 3.13: Summary of investments made in adaptation in South Africa (CSIR, 2015)

Years	2010	2011	2012	2013	2014	2015
US$ Million						
Environmental Protection	84 955.8	54 279.7	113 623.9	84 889.6	81 738.3	88 006.8
WfW and WoF	62 496.7	88 944.3	110 758.4	144 621.0	15 0645.4	183 175.3
Green Fund	0	0	8 877.4	2 5000.0	2 5000.0	3 000.0

Based on the existing investments that the country has made, the investments that will be needed in the future for adaptation was estimated and included in the country's INDC. These investments were scaled up with the range[16] 5% - 15% increase per annum to the years 2020, 2025 and 2030, with the total investments increase to R 29.5 bn - R 46.5 bn, R 37.6 bn – R 93.5 bn and R 48.0 bn – R 188.0 bn respectively (CSIR, 2015).

3.7.7 Concluding remarks

The review presented in this section of the chapter highlights that an enabling environment for climate change governance has been created at the national and, to a certain extent at the provincial level, through the establishment of sectoral and provincial climate change response strategies respectively. Whilst the country has made progress, there are still gaps that exist around financial resources, capacity and research. Specifically, dedicated financial resources for climate change adaptation planning and implementation are needed at a provincial and local government level, with guidance needed on how to access international and national funds available to them. Other critical knowledge gaps highlighted in previous studies (e.g. Ziervogel *et al.*, 2014) relate to the need for cross-sectoral approaches and integrated assessments. These are vital for creating a better understanding of cross-sectoral linkages and regional/landscape vulnerabilities, and for developing adaptation measures that are of benefit to various sectors and communities.

16. The range represents uncertainty in the estimates

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4 South Africa’s Measures Undertaken to Mitigate Climate Change

4 South Africa's Measures Undertaken to Mitigate Climate Change

4.1 Introduction

South Africa has a comprehensive approach and suite of measures to mitigate climate change. The context for such mitigation activities is well established. South Africa's participation in concluding the recent landmark climate change agreement, reached by world leaders at the 21st Conference of the Parties in Paris in late 2015, attests to the country's commitment to reducing its national emissions. South Africa's climate change commitments are part of the global effort to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

South Africa's *Nationally Determined Contribution*, submitted to the UNFCCC before the 21st Conference of the Parties, outlines the country's pledge to transition to a lower-carbon economy. South Africa's *Nationally Determined Contribution* was informed by the findings of the Intergovernmental Panel on Climate Change (IPCC), which warns that early and increased mitigation efforts are required to reduce unavoidable climate change impacts around the world. Such measures will lessen the required adaptation investments. Accordingly, the *Nationally Determined Contribution* (RSA, 2015, p. 1) acknowledges that:

Near zero emissions of carbon dioxide (CO_2) and other long-lived greenhouse gases (GHG) are needed in the second half of the century to avoid even greater impacts that are beyond adaptation capability.

South Africa's ongoing efforts in this regard are reflected in the range of implemented mitigation activities. The country's mitigation plans and strategies compliment the national adaptation plan, and these represent critical pillars in the country's response to climate change. Since the SNC, the country has made progress in developing and implementing a comprehensive range of policies and measures. Of note are the promulgation of the *National Climate Change Response White Paper* (which was in draft when the SNC was published) in 2011; the updated South African N*ational GHG Inventory: 2000-2010* (published in 2014), as well as the potential emission reduction trajectories developed during the course of the *Mitigation Potential Analysis*, a landmark study on South Africa's mitigation options, also published in 2014. These documents are seminal achievements in South Africa's response to climate change and represent government's most current positions on the matter.

For this communication, the climate change mitigation policies and measures have been arranged according to the sectors defined by the *Mitigation Potential Analysis*[17], published in 2014. Table 4.1 maps the various IPCC categories against the sectors used in the *Mitigation Potential Analysis*.

17. The sectors are energy, industry, transport, waste and agriculture, forestry and other land use.

Table 4.1: Reference table for grouping of the mitigation potential analysis sectors into IPCC categories (DEA, 2014b, p. 10)

Mitigation Potential Analysis			IPCC Category
Key Sector	Sector	Subsector	
Energy	Non-Power	Other Energy Industries	Energy
		Petroleum Refining	
		Coal Mining	
	Power	Electricity and Heating	
Transport	Road	Road	
	Rail	Rail	
	Aviation	Aviation	
Industry	Mining	Surface and Underground Mining	
	Other	Pulp and Paper Production	
	Buildings	Residential	
		Commercial/ Institutional	
	Metals	Primary Aluminium Production	Industrial Processes and Products Use
		Ferroalloys Production	
		Iron and Steel Production	
	Minerals	Cement Production	
		Lime Production	
	Chemicals Production	Chemicals Production	
Waste	Municipal Solid Waste	Municipal Solid Waste	Waste
Agriculture and Forestry and Other Land Use	Agriculture and Forestry and Other Land Use	Agriculture and Forestry and Other Land Use	Agriculture and Forestry and Other Land Use

The policies and measures included in this chapter represent the high level national activities currently in progress, with a focus on reporting on new developments subsequent to the SNC. In addition, the progress on policies and measures in this national communication are contained in South Africa's biennial update reports (which are also submitted to the UNFCCC). The biennial update reports typically contain more detailed descriptions of the various activities, and also include initiatives lead by the private sector as well as upcoming policies and measures.

This chapter also includes a description of the systems and institutions tasked with monitoring and evaluating the progress of the country's mitigation measures and policies. South Africa's overarching mitigation strategy is based on a peak, plateau and decline GHG emissions trajectory range, as communicated in the SNC. According to this course, South Africa's emissions will range between 398 and 614 Mt CO_2e by 2025 and 2030 respectively. The emissions are expected to plateau for about a decade and then decline in absolute terms thereafter. The *Mitigation Potential Analysis* is the most recent comprehensive study that outlines South Africa's future emission reduction potential and opportunities. *The National GHG Inventory for the period of 2000-2010* and *the Long Term Mitigation Scenarios (LTMS)* have served as the departure point for the development of the *Mitigation Potential Analysis*.

The *Mitigation Potential Analysis* has been used as the basis for the documentation of future emission projections which are outlined in this chapter. It also guides the technology and financial needs analyses of key future mitigation scenarios outlined in this chapter, which led to the development of marginal abatement cost curves and national abatement pathways.

The chapter is concluded with an account of the country's sequestration potential. In addition, various potential mitigation project briefs are presented. These components provide a comprehensive summary of mitigation efforts in South Africa today, which inform mitigation plans for the future.

4.2 Policies and Measures to Mitigate Climate Change

South Africa's high level approach to mitigation is characterised by continuous endeavours to balance the national developmental priorities with the global necessity to reduce GHG emissions associated with energy and industrial activities.

Although the Department of Environmental Affairs is the lead agency for climate change response in South Africa, climate change is cross cutting and therefore requires intense coordination with other government departments and institutions. Key national policies drive mitigation efforts, which in turn drive the country's mitigation framework. These policies are championed at a strategic level by Government and prioritised in various high level measures. These measures drive the numerous activities, actions, programmes, initiatives and studies undertaken by the public and private sectors that catalyse or result in the reduction of GHGs and other co-benefits.

In the context of this communication, policies are the high level, national frameworks set in place to guide government and the private sector in the fulfilment of the country's goals to reduce its carbon or carbon equivalent emissions. Measures are considered to be the instruments that government puts in place to create an enabling environment for mitigation measures, in which these interventions can be effectively and efficiently implemented. Policies and measures are policy instruments implemented by government and applied across the economy, over a wide range of sectors, in order to help South Africa achieve its emission reduction goals. The policies and measures may include regulatory instruments (specifically legislation, regulations and standards), economic instruments (for example, incentives and taxes), government procurement programmes or direct and indirect investment by government. These may be cross-cutting (across more than one sector) or specific to individual sectors or subsectors – and may achieve abatement through action by government, or induce action by others.

4.2.1 Policies and measures per sector

The *Constitution* (RSA, 1996) is the supreme law that governs South Africa. Among other objectives, it sets out the various rights and duties of its citizens. In the context of this National Communication to the UNFCCC, the rights related to the environment are especially relevant because they provide the background and foundation with regards to South Africa's policies and related measures to mitigate climate change. The *Constitution* states:

24. Everyone has the right -

a) to an environment that is not harmful to their health or wellbeing; and

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

All of South Africa's subsequent laws and policies should align with the *Constitution.* South Africa has consequently developed, in conjunction with the private sector and civil society, key policies and measures which guide the country's efforts to stabilise GHG emissions. The *National Climate Change Response Strategy* (2004) was one of the first formal policy provisions relating to climate change in the country. It aimed to integrate national government objectives, sustainable development and climate change.

The focus on sustainable development frequently reoccurs in South African policies and strategies, positioning the country's response to climate change in this context. The *National Development Plan* 2030, published in 2010, is one of South Africa's landmark policies in this regard. The Plan considers various opportunities to building environmental sustainability and enhance the resilience of people, and the economy, to climate change. It recognises the need to reduce GHG emissions and improve energy efficiency. Specifically, the country needs to implement the 2010 *Integrated Resource Plan* (DoE, 2011) which mandates the procurement of at least 20 000 MW of electricity from renewables: 17 800 MW from solar photovoltaics, concentrated solar power and wind, and 2 609 MW from imported hydro. By displacing electricity from grid (primarily generated from fossil fuels), renewables will assist in reducing carbon emissions from the electricity industry from 0.9 kg per kilowatt-hour to 0.6 kg per kilowatt-hour. In addition, the *National Energy Efficiency Strategy* considers improvements of 15% in the energy efficiency of mining and mineral processing by 2030.

The *National Development Plan* also outlines various other climate change mitigation goals and proposed actions to meet the country's environmental sustainability and resilience needs. These include:

– Achieve the peak, plateau and decline trajectory for GHG emissions, with the peak around 2025;
– By 2030, an economy-wide carbon price should be entrenched;
– Zero emission building standards by 2030; and
– Absolute reductions in the total volume of waste disposed to landfill each year.

Furthermore, the *National Development Plan*'s co-benefit[18] goals include increasing energy security and enhancing socio-economic and environmentally sustainable growth.

The *New Growth Path* (RSA, 2011) is another of the country's seminal policies that was published after the Second National Communication (SNC), and which aims to enhance growth, employment creation and equity. The policy's principal target is to create five million jobs over the next 10 years. This framework reflects government's commitment to prioritising employment creation in all economic policies. It identifies strategies that will enable

18. Within the context of this report, co-benefits are advantages that are additional to the benefits related to climate change.

South Africa to grow in a more equitable and inclusive manner while attaining South Africa's developmental agenda. The *New Growth Path* also mandates the development of the 'Green Economy', where clean manufacturing and environmental services are projected to create 300 000 jobs over the next decade. This policy represents a key development in South Africa's strategic response to climate change within the context of the country's industrial growth.

The *National Climate Change Response White Paper* (DEA, 2011a) is South Africa's most current, overarching climate change policy, which was promulgated after the publication of the SNC. The White Paper guides the development of response measures across all sectors. It represents the country's vision for an efficient climate change response and the long-term, just transition to a climate-resilient and lower-carbon economy and society. Given the socio-economic context of the country, the White Paper focusses on the effective management of climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity. It states that mitigation actions in the country shall: (DEA, 2011a)

- Be needs driven and customised to meet the relevant circumstances, with specific; emphasis on developing the more vulnerable communities and members of society;
- Promote GHG-reducing technologies, practices and processes;
- Be cost effective and provide substantial GHG emission reductions; and
- Result in economic growth and job creation or benefit public health and alleviate poverty.

Government has made significant investments in research and mitigation activities in order to fulfil the national climate change goals. One such example is the Department of Science and Technology's Ten-Year Innovation Plan for South Africa, which encompasses the Global Change, Society and Sustainability Research Programme. Furthermore the Department of Environmental Affairs' LTMS (*Long Term Mitigation Scenarios*) study undertaken during 2005-2008 is another notable achievement. The LTMS featured prominently in the SNC, as it represented the country's most progressive deliberations on the national emissions trajectories at that time. The study included extensive stakeholder engagement with academia, the private sector and civil society. The research found that, without constraints, emissions in South Africa will quadruple by mid-century. The research team explored a broad range of detailed mitigation actions and proposals for four strategic options that South Africa can pursue. The study resulted in the adoption of the peak, plateau and decline trajectory (which would subsequently become upheld in the *National Climate Change Response White Paper*). In Copenhagen in December 2009, South Africa internationalised this pledge by committing to reducing emissions by 34% below the business as usual trajectory by 2020, dependent on international support and funding mechanisms being in place.

The *Mitigation Potential Analysis* was founded on the LTMS study. The *Mitigation Potential Analysis* subsequently developed marginal abatement cost curves for the key economic sectors under investigation. These curves provide an estimate of mitigation potential and marginal abatement cost for a broad range of mitigation measures. The importance of the *Mitigation Potential Analysis* lies in its potential to guide climate change policies and subsequent measures. While the *Mitigation Potential Analysis* is one of the landmark South African studies in this regard and is possibly the key reference document used in this chapter, it represents a snapshot in time. Mapping South Africa's climate change trajectory and related projection scenarios is an iterative process which the Department of Environmental Affairs continues to drive.

Considering these further studies to mitigate climate change in the country, South Africa is actively driving future mitigation measures to respond to climate change. The Draft Carbon Tax Bill is a notable example, which was released in 2015 for public comment and hence is a new development since the publication of the SNC in 2011. The aim of the Carbon Tax Bill is to provide for the implementation of a tax on GHGs (in CO_2 equivalent) and to provide for the related matters. The development of a carbon offsets mechanism is incorporated under the tax and is currently in development. The carbon tax is expected to be implemented in 2017.

The development of desired emission reduction outcomes (DEROs) and company level carbon budgets are additional key anticipated activities under development since the SNC was published. These programmes will support the country's emission reduction objectives and will also form part of South Africa's official mix of mitigation measures. The DEROs represent the overarching sector mitigation goals for the country, of which company-level carbon budgets form a part.

In addition to the cross cutting policies and measures presented above, the country has implemented many sector specific climate change initiatives. A selection of these is categorised below, using the sector categories outlined in the *Mitigation Potential Analysis* report.

4.2.1.1 Energy sector

South Africa's primary energy sources are mainly coal (65.7%) and crude oil (21.6%). Renewable energy sources and waste (7.6%), natural gas (2.8%), nuclear (1.9%) and hydro (0.2%) make up the remainder of the supply. South Africa's liquid energy consumption is comprised of petrol (47%); diesel (36%); jet fuel (9%); liquefied petroleum gas (3%); paraffin (3%) and fuel oil (2%) (DEA, 2014a, pp 70-71).

CO_2 is the major GHG arising from South Africa's energy sector, with large volumes typically resulting from stationary combustion facilities (e.g. power plants and refineries). Power generation accounted for 65% of all energy-related emissions in 2009.

Due to the carbon content of the country's primary energy sources, the South African Government has prioritised the development of mitigation opportunities in the sector, for example, those related to energy efficiency activities. For example, the passive design of buildings is a particularly effective way of reducing energy consumption for heating and cooling.

Coal fired power stations account for around 90% of South Africa's electricity supply. The national utility, Eskom, generates approximately 95% of the electricity used in South Africa and about 45% of the electricity used on the continent. Eskom's total nominal capacity is just over 45 GW, the vast majority of which is generated from coal sources (Eskom, 2016).

Other sources of emissions in the energy sector include those related to fugitive emissions, industrial processes and indirect emissions from the consumption of electricity. Fugitive emissions, which escape without combustion (for example, leakage of natural gas and the emissions of methane during coal mining and flaring during oil/gas extraction and refining), are material sources which accounted for 8% of emissions in the energy sector in 2009. Process emissions arise from production processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel (DEA, 2014b).

Emissions from the energy sector make up the bulk of the country's *national GHG inventory*. The Department of Energy is the leading government department driving climate change mitigation approaches and activities in this sector, as mandated by key enabling policies and measures.

Policies and measures to mitigate climate change in this category broadly aim to:

– Provide financial support for mitigation actions in energy sector;
– Diversify electricity generation sources;
– Diversify liquid fuel sources;
– Facilitate carbon capture and storage;
– Promote energy efficiency;
– Reduce emissions in the transport sector; and
– Reduce coal bed methane.

The key policies and measures in the energy sector are outlined in Figure 4.1 and discussed further. These policies and measures have been developed in the context of the National Climate Change Response Policy (2011), the *New Growth Path* (2011) and the *National Development Plan* (2010).

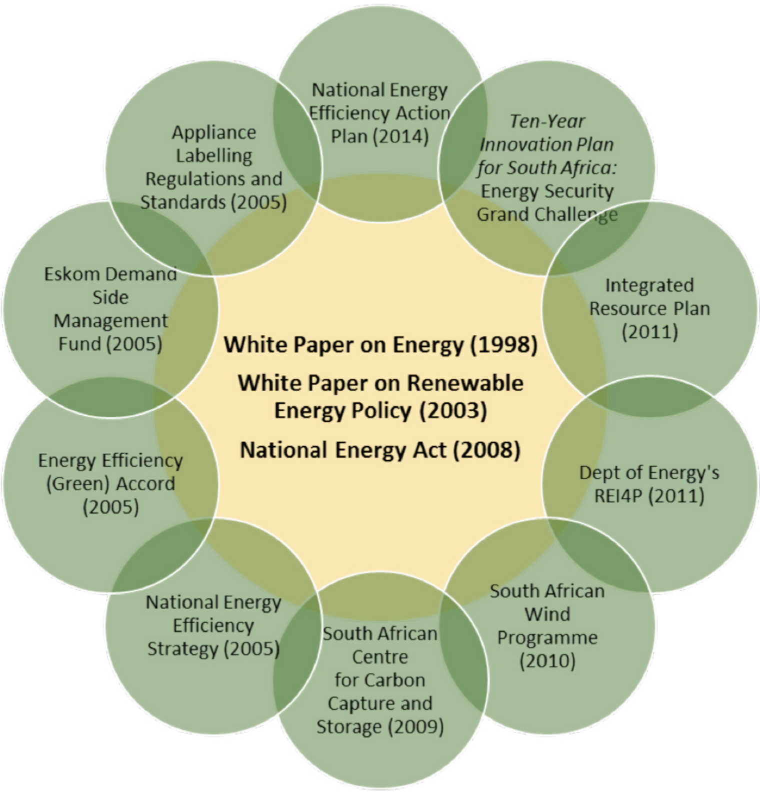


Figure 4.1: Energy policies and measures

The *White Paper on Energy Policy* (DME, 1998) was one of the first policies in the South African energy sector to address the country's exposure and response to climate change. The *White Paper on the Renewable Energy Policy of the Republic of South Africa* (DME, 2003) was promulgated thereafter and its purpose is to provide a range of measures to integrate renewable energies into the mainstream energy economy. The White Paper informs the renewable energy strategy for the country, notably the development of an independent power producer subsector. The sources of renewable energy considered include biomass, solar, small-scale hydro and wind.

The *White Paper on the Renewable Energy Policy* sets out a target of 10 000 GWh (0.8 Mtcoe) renewable energy contribution to the country's final energy consumption by 2013 (approximately 1 667 MW). Co-benefits include the creation of new jobs and stimulation of the green economy; contribution to water savings and increased government revenues.

To give effect to the climate change goals outlined in these White Papers (and other cross-cutting guiding documents), government has initiated many activities and programmes on national, regional and local levels. At the core of these key documents is the objective of transitioning to a low-carbon energy sector through the transformation of the future energy mix. This sentiment is echoed strongly in South Africa's *Nationally Determined Contribution*, which considers the stimulation of activities in the renewable energy and energy efficiency sectors as key climate change priorities.

Responses to climate change in South Africa are set within the context of socio and economic development. The main policies driving this agenda are the New Growth Plath and the *National Development Plan*. The *New Growth Path* recognises that bottlenecks in the provision of energy are constraining growth in South Africa, and it prioritises the development of initiatives in this regard. New Development Plan contains a number of actions for the energy sector, including the development of a carbon price, building standards, vehicle emission standards and municipal regulations. The purpose of these actions is to achieve scale in stimulating renewable energy and in retrofitting buildings (RSA, 2012, p. 57).

The national *Energy Efficiency Strategy of the Republic of South Africa* (DME, 2005) is a key guiding document developed by government to support the implementation of energy efficiency measures in South Africa. It was the first strategy to focus explicitly on energy efficiency in South Africa and sets a national energy efficiency target (12% improvement by 2015) to be achieved through various enabling instruments and interventions. Administered by the Department of Energy, the strategy takes its mandate from the *White Paper on Energy Policy* (published in 1998) and is set within the context of social sustainability. The strategy therefore links the development of the energy sector with national socio-economic development plans and other government departmental initiatives.

The *Draft National Energy Efficiency Strategy Review* was released in 2012. It lays out the steps required to review the sector targets and measures required to achieve reductions in energy intensity, which were applicable up to the end of 2015. The 2012 review takes a longer-term view, reflected in the "aspirational targets" set forward by the Government. The review recognises that energy efficiency is one of the most cost-efficient climate mitigation measures available and proposes clear, quantifiable targets for the major demand sectors, as well as the leading supply sector. It also provides a comprehensive list of voluntary and regulatory measures for each sector that will support the achievement of the sectoral targets.

The country's industrial, transport and residential sectors are high energy-use sectors. The strategy's key target is an overall, voluntary energy intensity reduction of 12%, relative to the projected national energy usage in 2015. The detailed targets, set to culminate in 2015, include a final energy reduction of 15% in the industry and mining sectors; an interim reduction of 15% in "parasitic" electrical usage within the power generation sector and final energy demand reductions of 15%, 10% and 9% in the commercial/public building; residential and transport sectors respectively. Various enabling instruments and interventions to this effect have been implemented.

The strategy also fuelled the development of the Energy Efficiency (Green) Accord, signed in 2005, which marked a collaborative effort between the public and private sectors. The Energy Efficiency Leadership Network was initiated under the Accord by the National Business Initiative and other key stakeholders. Its purpose is to improve energy efficiency in the South African business sector. The Network consists of more than 40 companies, government departments/ agencies and business associations which participate on a voluntary basis.

The development of appliance labelling regulations and standards in 2005 was an activity driven by the strategy to manage performance and enforce energy efficiency labelling of domestic appliances. This activity was jointly implemented by the Department of Energy and Department of Trade and Industry, with support from South African Bureau of Standards and the National Regulator for Compulsory Specifications. Other support mechanisms and instruments that could be employed to achieve the strategy's goals include certification and accreditation; education, information and awareness campaigns; research and development programmes for energy efficiency undertaken through the South African National Energy Development Institute (SANEDI); new regulations; energy audits and energy management systems.

Additional measures to support the realisation of the strategy include the *National Energy Efficiency Action Plan* (2014), which summarises the current and planned actions to support the *National Energy Efficiency Strategy* for the period 2013-2015. Its aim is to assist and guide all stakeholders and sectors achieve their energy efficiency objectives by providing a comprehensive account of the short-term actions being taken by government to implement the country's long-term needs. The account facilitates the prioritisation of future activities/policies and the timely identification of challenges or barriers. The monitoring of the *National Energy Efficiency Action Plan* is scheduled to be undertaken on an annual basis and updated at least every three years, to reflect progress made, new information and changing conditions.

The *National Energy Efficiency Strategy* also considers the use of subsidising energy efficiency projects through the Eskom Demand Side Management Fund. Eskom's programme covers a range of funding and awareness initiatives, which promote energy efficiency and load management. The programme has expanded the implementation of energy efficiency technologies by providing rebates through the following:

– Energy Efficiency Demand Side Management;
– Energy Management Programme;
– Solar Water Heating Programme;
– Energy Conservation Scheme; and
– Demand Response Programme.

The Eskom Demand Side Management programme was initiated in 1991 with research and pilots studies and has grown into a concerted national effort targeting three market sectors – residential, commercial and industrial.

The national *Energy Efficiency Strategy* (DME, 2005) covers all energy-using sectors and is implemented in phases through Sectoral Implementation Plans. The strategy is currently under review and a monitoring system is being used to assess the progress of the various goals.

In 2014 the Department of Energy implemented an Energy Efficiency Target Monitoring System to monitor the country's progress with regards to the implementation of the *National Energy Efficiency Strategy*. The system is based on analyses of the residential sector, the commercial and public sector and the industry and mining sector. Efficiency improvements between 2000 and 2012 resulted in a fall in consumption of 28% relative to a baseline projected from 2000, significantly above the *National Energy Efficiency Strategy* sector target of a 10% improvement by 2015.

Overall, the report found that there was an increase of 236 PJ in final energy consumption between the years of 2000-2011. This was made up of:

– 837 PJ increase due to increased activity levels;
– 57 PJ decrease due to structural change; and
– 544 PJ decrease due to efficiency improvements.

The Department of Energy is one of the key government department driving climate change interventions in South Africa. The Department is responsible for the country's energy plans, as per the *Integrated Resource Plan for Electricity* 2010 to 2030 (promulgated in 2011 and currently being revised).

The *Integrated Resource Plan* (DoE, 2011) is the primary guiding document informing the development of the South African electricity sector. It identifies the preferred generation technologies (and assumed energy efficiency demand side management interventions) required to meet expected electricity demand up to 2030. The plan is being updated to reflect changing macroeconomic realities as well as the technological progress of electricity generation and energy efficiency options and a new *Integrated Resource Plan* is expected to be released shortly.

The *Integrated Resource Plan* (DoE, 2011) is the driver of all new generation capacity development in South Africa and also directs the decommissioning of various large coal units. The plan recommends additional analyses on the potential of extending the life of the existing coal fleet to establish the costs involved, which must be weighed up against the environmental impacts. Alternatives to extending the life of these plants include new coal-fired generation which is more efficient and with lower emission rates, or zero-emission alternative energy resources under more aggressive climate mitigation objectives. The proposed decommissioning strategy is in line with the country's *Nationally Determined Contribution*, which advocates the replacement of South Africa's fleet of ageing coal-fired power plants with clean technologies to reduce national GHG emissions (RSA, 2015).

Since the publication of the SNC, Government has also invested in numerous national energy related mitigation programmes and activities, many of which are clustered under the various energy related Flagship Programmes. The Department of Energy's Renewable Energy Independent Power Producer Procurement Programme (REI4P) is a key example, which has stimulated private sector investment in the programme by R194.1 billion since its inception in 2011 (DoE, 2015b).

The REI4P is a competitive procurement programme, where prospective power producers submit bids to supply Eskom with renewable energy. The Department of Energy adjudicates the bids according to various criteria, the price being the most critical. A total capacity of 5 243 MW has been contracted to date, with another 6 300 MW under consideration. The *Integrated Resource Plan* makes provision for the generation of 17.8 GW of renewable energy by 2030, to be commissioned under the REI4P. A Small Projects REI4P (for projects between 1 MW - 5 MW) was also launched recently and the preferred bidders were announced under the first Bid Window in 2015. The aim of this programme is to generate 100 MW from small scale producers (DoE, 2011).

As of the second quarter of 2016, around 79 projects had been approved in four Bid Windows under the Large Projects Programme, with further windows expected in the next few years. Further windows are also expected in the Small Projects Programme.

In addition to generation under the large and small REI4Ps, the *Integrated Resource Plan* recommends that the Department of Energy develops a standard offer approach in which an agency, similar to a Single Buyer Office, purchases energy from embedded generators at a set price in order to support small scale distributed generation.

The South African Wind Energy Programme also falls under the Renewable Energy Flagship Programme (which was initiated subsequently to the SNC). Its aim is to assist diversify Eskom's energy mix and contribute to South Africa's objective of meeting 42% of the country's power demand with renewable energy sources by 2030. The wind programme includes the development of the 100 MW Sere Eskom Wind (operational since 2015) in the Western Cape as well as a facility in Nelson Mandela Bay Metropolitan Municipality (operational since 2010). The Atlas has also been developed to improve knowledge and quality of wind resource assessment methods and tools.

The development of the South African Centre for Carbon Capture and Storage in 2009 is one such key measure that the country is supporting in its efforts to investigate innovative clean technological applications that address climate change. The pilot storage project is scheduled for initiation in 2017 and commercial operation is expected in 2025.

The Department of Science and Technology is also actively involved in developing measures in the energy sector that reduce the country's emissions. The Ten-Year Innovation Plan for South Africa which encompasses the Global Change, Society and Sustainability Research Programme is one such an endeavour. The programme aims to bring about social, economic, political, scientific and technological benefits in a ten-year timeframe (2008-2018). Five 'Grand Challenges' in science and technology have been identified as areas which could stimulate multidisciplinary thinking and challenge the country's researchers to answer existing questions, create new disciplines and develop new technologies. One of the five challenges is 'Energy security: provide for safe, clean, affordable and reliable energy supplies', which supports the reduction of emissions in the energy sector.

There are significant numbers of national interventions currently being implemented in South Africa, which aim to give effect to the policies outlined above. These include regulatory and economic instruments, government procurement programmes and various investments by government. For the purposes of this report, however, Table 4.2 represents a summary of only the high level policies and measures in the energy sector, as discussed above.

Table 4.2: Policies and measures in the energy sector

Name of Policy or Measure	Objective and/ or activity affected	GHG	Type of Instrument	Status	Implementing entity
White Paper on the Renewable Energy Policy of the Republic of South Africa (DME, 2003)	Provide a range of measures to bring about the integration of renewable energies into the mainstream energy economy. The White Paper informs the renewable energy strategy for the country.	CO_2	Regulatory	Implemented	Department of Energy
National *Energy Efficiency Strategy of the Republic of South Africa* (DME, 2005)	Outlines how an overall energy intensity reduction target of 12% could be reached by 2015. The strategy is being reviewed and a monitoring system is under development to assess the progress of the strategy's goals.	CO_2, CH_4, N_2O	Voluntary	Implemented	Department of Energy
Energy Efficiency (Green) Accord and the Energy Efficiency Leadership Network. (EDD, 2005)	Fuelled by the *National Energy Efficiency Strategy*, the objectives of the Accord and the Leadership Network include enhancing energy security by making better use of existing and new generation capacity, as well as improvement of South Africa's global competitiveness through reduced energy costs. Improving global competitiveness contributes to job creation.	CO_2, CH_4, N_2O	Voluntary	Implemented	Department of Energy and private sector
Integrated Demand Management Programme (Eskom, 2017)	Promote the implementation of energy efficiency technologies by providing rebates. The programme covers a range of funding and awareness initiatives, which promote energy efficiency and load management.	CO_2, CH_4, N_2O	Economic	Implemented	Department of Energy and Eskom
Integrated Resource Plan for Electricity 2010 to 2030 (DOE, 2011), promulgated in 2011 and currently being revised	Directs the generation expansion and demand-side intervention programmes to meet electricity demand. The plan specifically makes provision for increased electricity generation from renewable and nuclear energy sources. It also informs the REI4P. The Plan is to be regularly updated by the Department of Energy. The next update is expected soon, and may include increased scope for renewable energy.	CO_2	Voluntary	Implemented	Department of Energy

Name of Policy or Measure	Objective and/ or activity affected	GHG	Type of Instrument	Status	Implementing entity
The South African Centre for Carbon Capture and Storage, 2009	The South African Centre for Carbon Capture and Storage is responsible for the implementation of a roadmap for evaluating the potential for carbon capture and storage, as well as a testing and demonstration plant to store the process emissions from an existing high carbon emission facility.	CO_2	Research	Implemented	Department of Energy in partnership with SANEDI
REI4P (2011)	The Renewable Energy Independent Power Producer Procurement Programme is a competitive procurement programme, where prospective power producers submit bids to supply renewable energy to the national grid.	CO_2	Economic	Implemented	Department of Energy
South African Wind Energy Programme, 2010	Facilitate the implementation of wind power in South Africa e.g. wind resource assessment, capacity building and strengthening of institutions. Projects under this programme include the 100MW Sere Wind Farm Facility.	CO_2	Voluntary	Implemented	Department of Energy
Ten-Year Innovation Plan for South Africa 2008-2018: Global Change, Society and Sustainability Research Programme	Bring about social, economic, political, scientific and technological benefits in ten-year timeframe. Five 'Grand Challenges' in science and technology have been identified. All of the Grand Challenges incorporate the country's purpose to climate change in some manner. The Energy security grand challenge is the measure most applicable to this chapter on mitigation.	CO_2	Voluntary/ research and development	Implemented	Department of Science and Technology

The development of renewable or low emission energy interventions in the energy sector represents only one of the approaches that South Africa is pursuing in order to mitigate emissions in the energy sector. Energy efficiency is another key area in which South Africa could realise emission reduction opportunities. The *Integrated Resource Plan* recommends that the Department of Energy formalise funding for energy efficiency demand side programmes and secure the appropriate mandate to facilitate these programmes (possibly with targets on electricity intensity of the economy). These measures are of specific relevance to South Africa's industrial sectors.

4.2.1.2 Industry sector

Emissions under the industry sector account for 8.1%[19] of South Africa's total emissions (DEA, 2014a, p. 37). The sources of these emissions include industrial processes that chemically or physically transform raw materials. CO_2 is the dominant GHG produced in this category, although smaller quantities of CH_4, N_2O and PFCs are also emitted. South Africa's metal industries are the largest sources of emissions in this sector and accounted for 86.3% of the total emissions in 2010. Ferroalloys and cement production make up the rest of the emissions. Emissions from these and other related industries are tied to the performance of the respective businesses which are in turn linked to the performance of the general economy. The key policies and measures relating to climate change mitigation in this sector are outlined in Figure 4.2 and are discussed further.

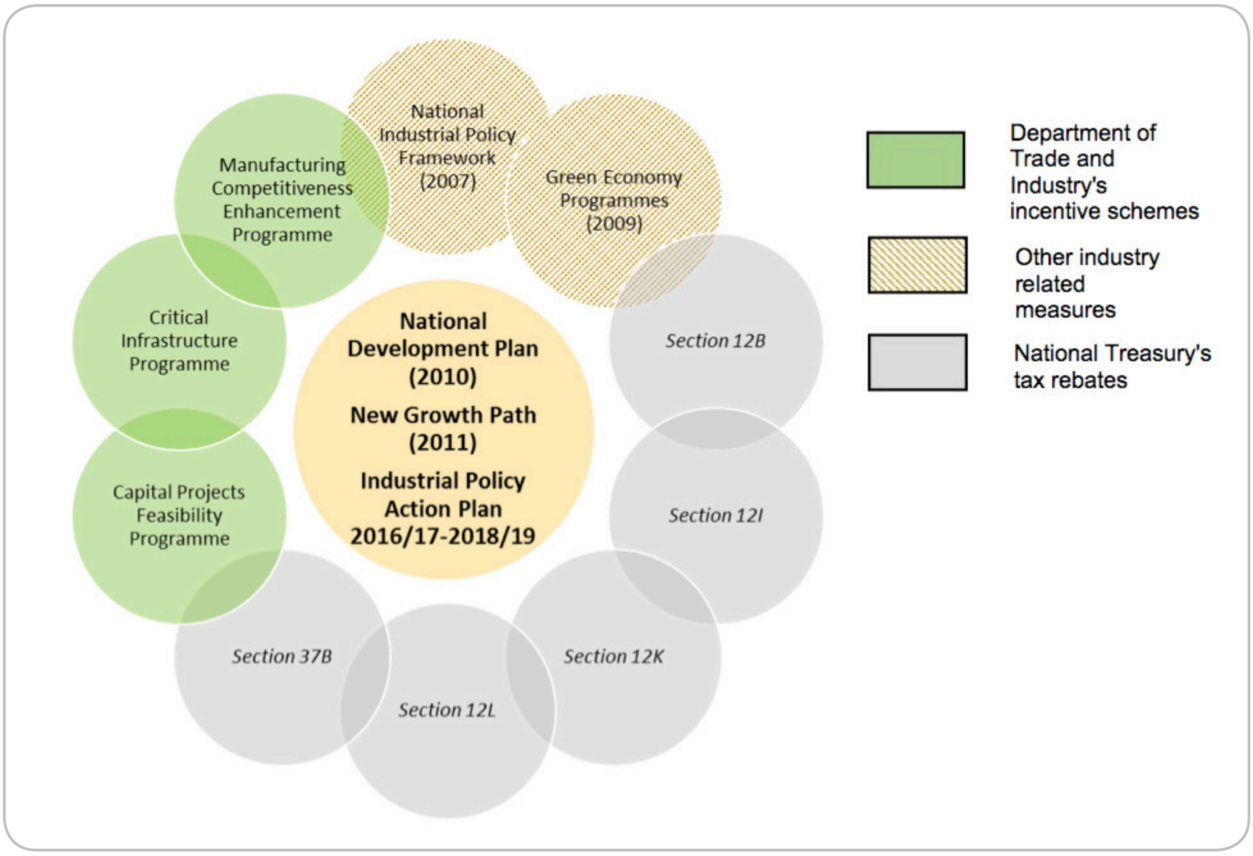


Figure 4.2: Industry policies and measures

19. This figure is based on the total inventory for the country excluding the Forestry, Other Land Use category. If emissions from this category are included, the contribution of the industry category emissions increases to 8.55% of the total emissions.

The *National Development Plan* (2010) and the *New Growth Path* (2011) are the key overarching policies driving the industry sector. The *New Growth Path* encourages government to stimulate stronger investment by the private and public sectors to grow employment-creating activities rapidly, while maintaining and incrementally improving South Africa's core strengths in various sectors, including green technologies. Jobs drivers are identified in these green economies, where there are new opportunities to leverage knowledge and develop skills (RSA, 2011). The Department of Environmental Affairs' Green Economy Programmes represent another example of active mitigation measures being undertaken in the country as part of addressing the *New Growth Path* imperative. The aim of the nine key programmes is to implement green economy programmes in conjunction with the private sector, civil society and all levels of government. The programmes cover a wide range of applications including initiatives in green buildings, waste, transport, clean energy and energy efficiency. The co-benefits of such measures lie in increased investments in renewable energy technology; diversification of the energy mix; and related improvement in global competitiveness which will, in turn, contribute to job creation.

The *National Development Plan* outlines a wide range of actions needed to develop South Africa's industrial economy. One of the actions, within the context of climate change, is the consideration of carbon-pricing mechanisms, supported by a wider suite of mitigation policy instruments to drive energy efficiency.

The National Industrial Policy Framework (DTI, 2007) represents the broad framework governing all industrial policy interventions in South Africa. The National Industrial Policy Framework is the basis from which South Africa's Industrial Policy Action Plan emanates. This Plan is a product of the Economic Cluster of Government and is updated annually. The most recent revision for 2016/17-2018/19 was released in May 2016 and provides updates on the key focus areas, of which green industry investments is one. Achievements from the 2015/16 period include the Department of Energy's REI4P and investments in solar and wind. New developments in own- and co-generation of electricity in the country were also highlighted, as were ground-breaking initiatives regarding the development of fuel cell technology.

The Department of Trade and Industry has also been instrumental in mitigation efforts in this sector through the provision of various incentives related to the development and use of green technologies. These include the Capital Projects Feasibility Programme; the Critical Infrastructure Programme and the Manufacturing Competitiveness Enhancement Programme.

National Treasury also supports mitigation initiatives that use lower-carbon technologies through the provision of various tax rebates in the Income Tax Act of South Africa:

- Section 12B allows companies to deduct, from their taxable income, the cost incurred from investing in assets that are used directly for the production of renewable energy;
- Section 12I offers support for both capital investment and training related to Greenfield (new) and Brownfield (expansions or upgrades) projects within South Africa's manufacturing sector. Qualifying projects are called "Industrial Policy Projects". The window period for applications under this programme closes 31 December 2017;
- Section 12K provides for tax exemptions on proceeds gained from the disposal of certified emission reductions derived from activities registered with the Clean Development Mechanism. The tax window runs up to 31 December 2020, in-line with termination of the second commitment period of the Kyoto Protocol;

- Section 12L provides for a tax incentive as a result of the implementation of efficiency initiatives; and
- Section 37B allows companies to deduct the costs, incurred due to expenditures on environmental pollution control and monitoring equipment and/or disposal sites, from their taxable revenues.

The Department of Energy, through the Designated National Authority, is also actively driving the development of lower-carbon initiatives in industry. South Africa's Designated National Authority was established in 2004 and is mandated to oversee the operation of the Clean Development Mechanism in South Africa. South Africa is a host party to 56 registered projects and 35 registered programmes of activities. These projects and activities are registered under various key scopes including chemical, manufacturing and energy industries; energy demand; fugitive emissions from fuels and metal production.

Thirteen low-carbon projects in South Africa are also registered with the Voluntary Carbon Standard, under similar scopes including chemical industry; fugitive emissions from industrial gases energy (renewable/non-renewable) and transport. Table 4.3 represents a summary of these selected key policies and measures in the Industry sector.

Table 4.3: Policies and measures in the industry sector

Name of Policy or Measure	Objective and/ or activity affected	GHG	Type of Instrument	Status	Implementing entity
Green Economy Programmes, 2009	Implement green economy programmes in conjunction with the private sector, civil society and all levels of government.	CO_2, CH_4, N_2O	Economic/ Information/ Voluntary	Implemented	Department of Environmental Affairs
National Industrial Policy Framework (2007)	Articulates South Africa's overarching approach to industrial development. Aims to support invest in South Africa's innovation and technology capabilities.	CO_2, CH_4, N_2O	Regulatory	Implemented	Department of Trade and Industry
Industrial Policy Action Plan 2016/17-2018/19	Outlines the National Programme of Action that has been put in place to implement South Africa's industrial policy objectives. Investment in the local green industry is one of the Plan's key focus areas.	CO_2, CH_4, N_2O	Voluntary	Implemented	Department of Trade and Industry
The Department of Trade and Industry's Incentive Schemes	Drive growth, foreign direct investment and promote competitiveness in the manufacturing sector, in line with the Industrial Policy Action Plan and the National Industrial Policy Framework.	CO_2, CH_4, N_2O	Economic	Implemented	Department of Trade and Industry
Sections 12B, 12I, 12L, 12K and 37B of the Income Tax Act	Provision of financial incentives to promote the use of lower-carbon technologies. The tax rebates include Section 12B; Section 12I; Section 12K; Section 12L and Section 37B.	CO_2, CH_4, N_2O	Fiscal	Implemented	South African Revenue Service

4.2.1.3 Transport sector

While renewable and energy efficiency policies and measures are material to the country's mitigation responses to climate change, transport related measures are also prioritised by government. Measures in this sector are material not only on account of their potential to reduce GHGs, but also because they provide a range of socioeconomic and developmental benefits.

Emissions from the transport sector arise directly from the combustion of fuels, and indirectly from the production of electricity or other energy carriers. Emission sources include civil aviation; road transport; railway and water-borne navigation.

The Department of Transport is responsible for the policies and measures that would reduce the demand of liquid fuels and in turn reduce emissions in the transport sector. The majority of emissions come from road transportation. It is for this reason that the policies and measures prioritized in this sector are aimed at reducing emissions by this mode of transport. The mitigation opportunities identified for the country fall under the following broad categories: modal shift; demand reduction measures; more efficient vehicle technologies; more efficient operations and alternative lower-carbon fuels (DEA, 2014a, p. 68). The key policies and measures relating to climate change mitigation in this sector are outlined in Figure 4.3 and are discussed further.

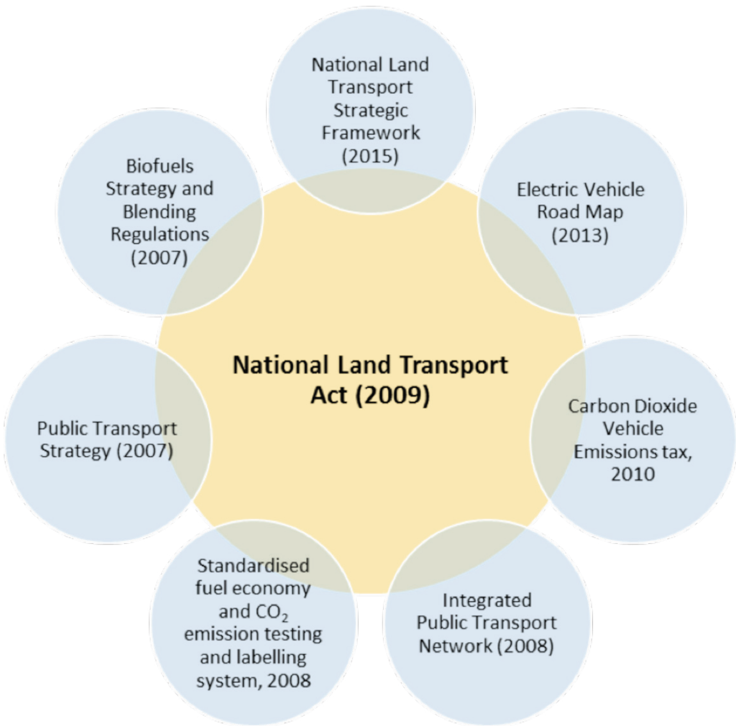


Figure 4.3: Transport policies and measures

The *Biofuels Industrial Strategy of the Republic of South Africa* (DME, 2007) outlines Government's approach to policy, regulations and incentives for the development of a biofuel sector in the country. The strategy proposes a 2% penetration level of biofuels in the national liquid fuel supply (400 million litres per annum), within five years of its publication. While the biofuels strategy is an important component of South Africa's response to climate change, the strategy focuses on creating employment in the biofuels value chain, particularly in underdeveloped areas.

In support of the strategy, regulations were published in 2012 relating to the mandatory blending of bio-ethanol or biodiesel with petroleum petrol and petroleum diesel, respectively, to produce a biofuel blend that may be sold in South Africa. In particular, the regulations address the purchase process; specify the blending ratios for both types of biofuel and list the type of records to be kept by licensees. The Regulations allow for the blending of biofuels to the effect that the allowed minimum concentration of the biofuel in the final blended biofuel complies with (i) the minimum concentration to be allowed for biodiesel blending, mainly 5% by volume; and (ii) the permitted range for bio-ethanol blending, namely from 2% by volume up to 10% by volume.

The *Public Transport Strategy* (DOT, 2007) has two key thrusts: Accelerated Modal Upgrading and Integrated Rapid Public Transport Networks. Accelerated Modal Upgrading refers to the current initiatives to transform bus, taxi and rail service delivery in the short to medium term. Integrated Rapid Public Transport Networks covers the integration of urban public transport, including Bus Rapid Transport, Metro buses and minibus taxis. The programme includes dedicated lanes for public transport, an inner-city distribution, integrated ticketing, and pedestrian and bicycle facilities. The co-benefits of the programmes include reduced highway congestion and commuter time. It also creates employment in the service, assembly and infrastructure sectors.

Policies and measures have advanced in the transport sector since reporting in the SNC. For example, the National Land Transport Strategic Framework (DOT, 2015) is another key initiative, and is a legal requirement in terms of the *National Land Transport Act* (DOT, 2009). It embodies the overarching, national five-year (2015 to 2020) land transport strategy, which guides transport planning and land transport delivery by national government, provinces and municipalities. The Framework also supports the aims and priorities outlined in the *National Development Plan*, recognising its holistic view to encouraging sustainable development. The Framework is committed to reducing GHGs through the support of green technology and clean fuels and encourage a shift towards sustainable transport modes, among others.

In addition to initiatives driven by the Department of Transport, there are a number of other government departments responsible for mitigation measures in this sector. In further support of activities in this sector, the Department of Energy, in conjunction with the South African Automotive Industry, implemented the standardised fuel economy and CO_2 emission testing and labelling system in 2008. This measure allows comparison of power and performance indicators of different vehicle models.

The Carbon Dioxide Vehicle Emissions Tax (NT, 2010), administrated by National Treasury, is an additional measure directed at making South Africa's vehicle fleet more energy efficient and environmentally friendly.

Furthermore, the *Electric Vehicle Road Map* (DTI, 2013) is one of the mitigation elements that have arisen out of the Industrial Policy Action Plan and marks a significant progression in the country's climate change strategy since the publication of the SNC. The Road Map looks to develop a local electric vehicle industry in South Africa through the application of several strategic new technology interventions. The long term plan proposes an incentive package for manufacturers that produce electric vehicles and also considers possible incentives to encourage South Africans to buy electric vehicles.

Table 4.4: Policies and measures in the transport sector

Name of Policy or Measure	Objective and/ or activity affected	GHG	Type of Instrument	Status	Implementing entity
Biofuels Industrial Strategy for the Republic of South Africa, 2007	Aims to create a market for biologically produced fuels for use as blending components in the production of petrol or diesel. It sets a short term target of 2% penetration of biofuels in the national liquid fuel supply, which is the equivalent of 400 million litres per annum.	CO_2, CH_4, N_2O	Voluntary	Approved	Department of Energy
Public Transport Strategy, 2007	Focuses on Accelerated Modal Upgrading and Integrated Rapid Public Transport Networks. Accelerated Modal Upgrading is the programme to transform bus, taxi and rail service delivery in the short to medium term. Integrated Rapid Public Transport Networks covers the integration of urban public transport, including Bus Rapid Transport, Metro buses and minibus taxis.	CO_2, CH_4, N_2O	Voluntary	Implemented	Department of Transport
Standardised fuel economy and CO_2 emission testing and labelling system, 2008	Allows comparison of power and performance indicators of different vehicle models.	CO_2,	Voluntary	Implemented	Department of Energy, in conjunction with the South African Automotive Industry
Carbon Dioxide Vehicle Emissions tax, 2010	A CO_2 emissions tax is applicable to new passenger motor vehicles. The main objective of this tax is to influence the composition of South Africa's vehicle fleet to become more energy efficient and environmentally friendly. The tax rate was set at R100/gCO_2/km in 2016.	CO_2	Fiscal	Implemented	National Treasury
Electric Vehicle Industry Road Map and Key Action Plans, 2013	Mitigate the impact of harmful gases on the environment while promoting investment and job creation in the electric automotive industry.	CO_2, CH_4, N_2O	Economic, research	Implemented	Department Environmental Affairs and the Department of Trade and Industry
National Land Transport Strategic Framework (DOT, 2015)	Framework for Transport Planning effectively for all tiers of Government. It sets the overarching goals, vision, and objectives for each element of the transport system which would be reflected in the Provincial Land Transport Frameworks and Integrated Transport Plans.	CO_2, CH_4, N_2O	Voluntary	Implemented	Department of Transport

4.2.1.4 Agriculture, forestry and other land use sector

This sector comprises the production as well as the removal of emissions. The subsectors include livestock, aggregated sources and non-CO_2 emissions on land, land and harvested wood products. The land and harvested wood products components are considered sinks. The sequestration potential of the land subsector tends to vary quite widely over the years depending on the changes in carbon stocks in forest lands and land use changes in crop lands in particular.

Emissions typically occur as a result of the livestock and the aggregated sources and non-CO_2 emissions on land components. CH_4 emissions contribute the most to the agriculture, forestry and other land use sector emissions. Enteric fermentation (from the livestock component) accounted for 93% of the CH_4 emissions (DEA, 2014a, p. 154).

The *South African GHG Inventory* (2000-2010) indicates that emissions from the agriculture subsector (i.e. excluding forestry and other land use) account for 9.5% of the country's total emissions. The inclusion of the forestry and other land use subsectors reduces the total figure to 5% (DEA, 2014a).

The key policies and measures relating to climate change mitigation in this sector are outlined in Figure 4.4 and are discussed further.

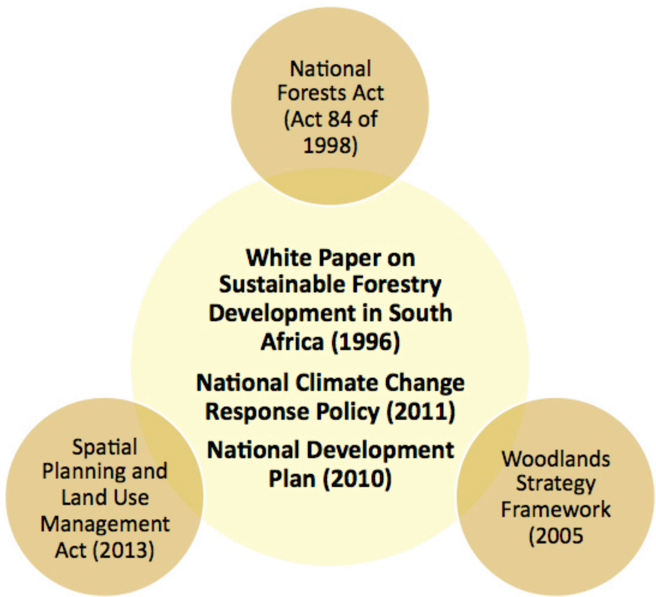


Figure 4.4: Agriculture, forestry and other land use policies and measures

The *National Climate Change Response White Paper* (DEA, 2011a) considers the agriculture and forestry as sectors that need particular attention in the near future. The New Development Plan (2010) sets a target to protect about 7.9 million hectares of land, and considers putting in place a regulatory framework for land use, to ensure the conservation and restoration of protected areas. The Department of Agriculture, Forestry and Fisheries is the institution responsible for this sector.

The *White Paper on Sustainable Forestry Development in South Africa* (DWAF, 1997) and the National Forests Act (Act 84 of 1998) (DWAF, 1998) are the main guiding documents, specific to this sector. Developed prior to the *National Climate Change Response White Paper*, they do not specifically allude to climate change measures but do support activities that are likely to sequester GHG emissions, especially activities relating to sustainable management, conservation and protection of natural forests and woodlands.

The *Woodlands Strategy Framework* (DWAF, 2005) is better aligned with the *National Climate Change Response White Paper* and outlines mitigation principles for the sector. Woodlands are distributed across more than 30% of the national land surface area. They therefore have a significant relation to climate change due to their fire adaptation potential as well as their potential as carbon sinks or sources.

While not focussed on climate change per se, the *Spatial Planning and Land Use Management Act* (DRDLR, 2013) is an instrumental piece of law with regards to the agriculture, forestry and other land use sector. The Act aims to develop a new framework to govern planning permissions and approvals, sets parameters for new developments and provides for different lawful land uses in South Africa. This information is relevant for reporting purposes, particularly with regards to updating the agriculture, forestry and other land use emissions profile in the national GHG inventories.

Table 4.5 represents a summary of these selected key policies and measures in the agriculture, forestry and other land use sector.

Table 4.5: Policies and measures in the agriculture, forestry and other land use sector

Name of Policy or Measure	Objective and/ or activity affected	GHG	Type of Instrument	Status	Implementing entity
White Paper on Sustainable Forestry Development in South Africa, 1996	Intended to provide the Forestry Industry and the general public with a clear view of the policies regarding conservation forestry, commercial forestry and community forestry.	CO_2, CH_4, N_2O	Regulatory	Implemented	Department of Agriculture, Forestry and Fisheries
The National Forests Act, No. 84, 1998	Promotes the sustainable management and use of forests and woodlands in South Africa.	CO_2, CH_4, N_2O	Regulatory	Implemented	Department of Agriculture, Forestry and Fisheries
Woodlands Strategy Framework (2005)	Provides a practical outline for the implementation of woodlands related measures as directed by the White Paper on Sustainable Forestry Development in South Africa (1996).	CO_2, CH_4, N_2O	Regulatory	Implemented	Department of Agriculture, Forestry and Fisheries
Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries (2013)	Addresses institutional arrangements, vulnerabilities and mitigation and adaptation measures in the Agriculture, Forestry and Fisheries sector.	CO_2, CH_4, N_2O	Regulatory	Planned	Department of Agriculture, Forestry and Fisheries

4.2.1.5 Waste sector

Emissions from the waste sector represent the smallest contribution to the *national GHG inventory* with 3.7%[20]. The two sources of emissions in this sector are solid waste disposal and wastewater treatment and discharge. Emissions from solid waste dominate, accounting for 82.75% of the total emissions in this sector (DEA, 2014a).

The *South African GHG Inventory* (2000-2010) notes that there are significant mitigation opportunities in the waste sector. The key policies and measures relating to climate change mitigation in this sector are outlined in the following figure and are discussed further.

20. This figure is based on the total inventory for the country excluding the forestry, other land use subsectors. If emissions from these subcategories are included, the contribution of the waste sector emissions increases to 3.8% of the total emissions.

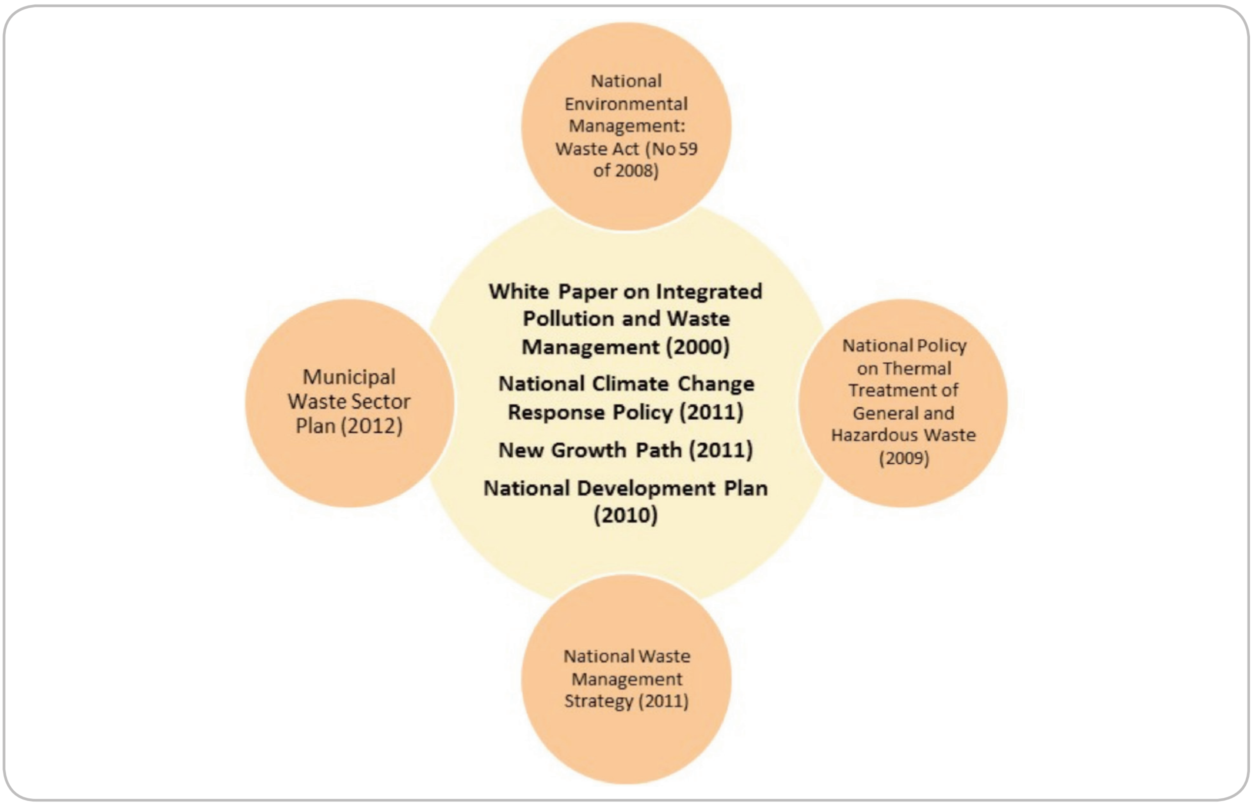


Figure 4.5: Waste policies and measures

The *White Paper on Integrated Pollution and Waste Management* (2000) sets out the vision, principles, strategic goals and objectives that government uses for integrated pollution and waste management in South Africa. The White Paper considers these elements in the context of growing concerns regarding climate change in conjunction with the need for development in South Africa. The National Climate Change Response Policy (DEA, 2011a) outlines the South African Government's vision for an effective climate change response and the actions required to drive this vision in the waste sector. The *New Growth Path* (2011) and the *National Development Plan* (2010) are other overarching policies guiding the waste sector. One of the *National Development Plan*'s objectives is to ensure environmental sustainability and resilience in South Africa and includes the goal of absolute reductions in the total volume of waste disposed to landfill each year (RSA, 2012, p.57).

The *National Environmental Management: Waste Act* (No 59 of 2008) and the National Policy on Thermal Treatment of General and Hazardous Waste (2009) are the main policies specific to the waste sector, and they both recognise the significance of mitigating climate change.

The *National Waste Management Strategy* (2013), a legislative requirement of the *National Environmental*

Management: Waste Act, 2008 (Act No. 59 of 2008), is well aligned with the *National Climate Change Response White Paper*. The Strategy was promulgated after the SNC, and marks a progression in the country's approach to climate change in that it addresses emission reduction opportunities specific to the waste sector. The Strategy's main purpose is to achieve the objectives of the Waste Act, where it promotes waste minimisation, re-use, recycling and recovery. The Strategy has eight priority goals and accompanying objectives. It sets out the indicators to measure the achievements against targets which are to be met within a five-year time-frame. One of the key outputs is the reduction of GHG emissions to mitigate climate change and improve air quality.

The achievement of these objectives is further supported at local government level by the *Municipal Waste Sector Plan* (2012) is another development since the publication of the SNC. It aims to fast track waste-related service delivery in South Africa and reduce backlogs in this regard. The Plan highlights waste reuse and recycling as well as the flaring or recovery of landfill gas.

Table 4.6 represents a summary of these selected key policies and measures in the waste sector.

Table 4.6: Policies and measures in the waste sector

Name of Policy or Measure	Objective and/ or activity affected	GHG	Type of Instrument	Status	Implementing entity
White Paper on Integrated Pollution and Waste Management (2000)	Sets out the vision, principles, strategic goals and objectives that government uses for integrated pollution and waste management in South Africa.	CH_4, N_2O	Regulatory	Implemented	Department of Environmental Affairs
National Environmental Management: Waste Act (No 59 of 2008)	Regulates waste management to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation. Also aims to secure ecologically sustainable development.	CH_4, N_2O	Regulatory	Implemented	Department of Environmental Affairs
National Policy on Thermal Treatment of General and Hazardous Waste (DWEA, 2009)	Provides the framework for the environmentally sound management of general and hazardous waste in South Africa. It does so through the integration of a range of complementary waste management options, in line with the waste management hierarchy and internationally accepted principles of best environmental practice.	CH_4, N_2O	Regulatory	Implemented	Department of Environmental Affairs
National Waste Management Strategy (DEA, 2011b)	Achieve the objectives of the National Environmental Management: Waste Act. One of the key outputs is the reduction of GHG emissions to mitigate climate change and improve air quality.	CH_4, N_2O	Regulatory	Implemented	Department of Environmental Affairs
Municipal Waste Sector Plan (DWEA, 2012)	Assist in eliminating service delivery backlogs in South Africa. The Plan features waste reuse and recycling as well as flaring or recovery of landfill gas.	CH_4, N_2O	Regulatory	Implemented	Department of Environmental Affairs

The information in the sections above represents key government lead policies and measures to mitigate climate change to date, as well as an indication in some instances of imminent future activities in this regard. These sectoral highlights are by no means a complete picture of all the activities undertaken in the country. South Africa's various biennial update reports also contain reports of policies and measures, many of which are led by the private sector. These activities and the reporting thereof are iterative in nature. Initiatives in the sectors are ongoing and the related activities build on prior bodies of knowledge.

To understand their impacts, these activities require monitoring and evaluation to track their progress or guide interventions. Work is therefore continuing to quantify the effect that individual (and grouped) policies and measures have on emission reductions. The outcome of this work is expected to be available for reporting in the next reporting cycle of National Communications.

4.2.1.6 Monitoring and evaluation of policies to reduce GHGs

The *National Climate Change Response White Paper* is the policy that commits South Africa to manage inevitable climate change impacts effectively, while making a "fair contribution to the global effort to stabilise GHG concentrations in the atmosphere" (DEA, 2011a, p.11). The *National Development Plan* 2030 is the policy that prioritises the setting up of a national monitoring, reporting and verification of climate change information system in South Africa (RSA, 2012, p. 208).

In line with these policies, South Africa has initiated development of the National Climate Change Response Monitoring and Evaluation System Framework, which is planned for official endorsement in 2016. The overarching objective of the system is to track the country's transition towards its long-term vision of a climate-resilient and lower carbon economy and society. The system will provide an evidence base to inform effective climate change response planning and implementation. It is envisaged that the system will provide evidence on the effectiveness of policies and measures, as well as gauge mitigation and adaptation actions and their effects, including technical and financial support provided.

Monitoring and evaluation mitigation efforts in South Africa will be integrated into a national data-collection system which will provide detailed, complete, accurate and up-to-date emissions information. The *National GHG Inventory* and the Monitoring and Evaluation System will support the analyses of the impacts of mitigation measures. The collective outcome of all South Africa's climate change mitigation interventions will be monitored and measured against the national emissions trajectory range.

Under the leadership of the relevant national sector government department, each significantly emitting economic sector, or sub-sector, will be required to formulate mitigation and lower-carbon development strategies. These strategies will include measurable and verifiable indicators for each programme and measure, the implementation and outcome of which will be monitored. Indicators may include those related to implementation, local sustainable development benefits and the impact of programmes and measures on emissions.

4.2.1.7 Monitoring and evaluation system framework design

South Africa's overall climate change monitoring and evaluation system will be composed of two primary complementary systems as shown Figure 4.6.

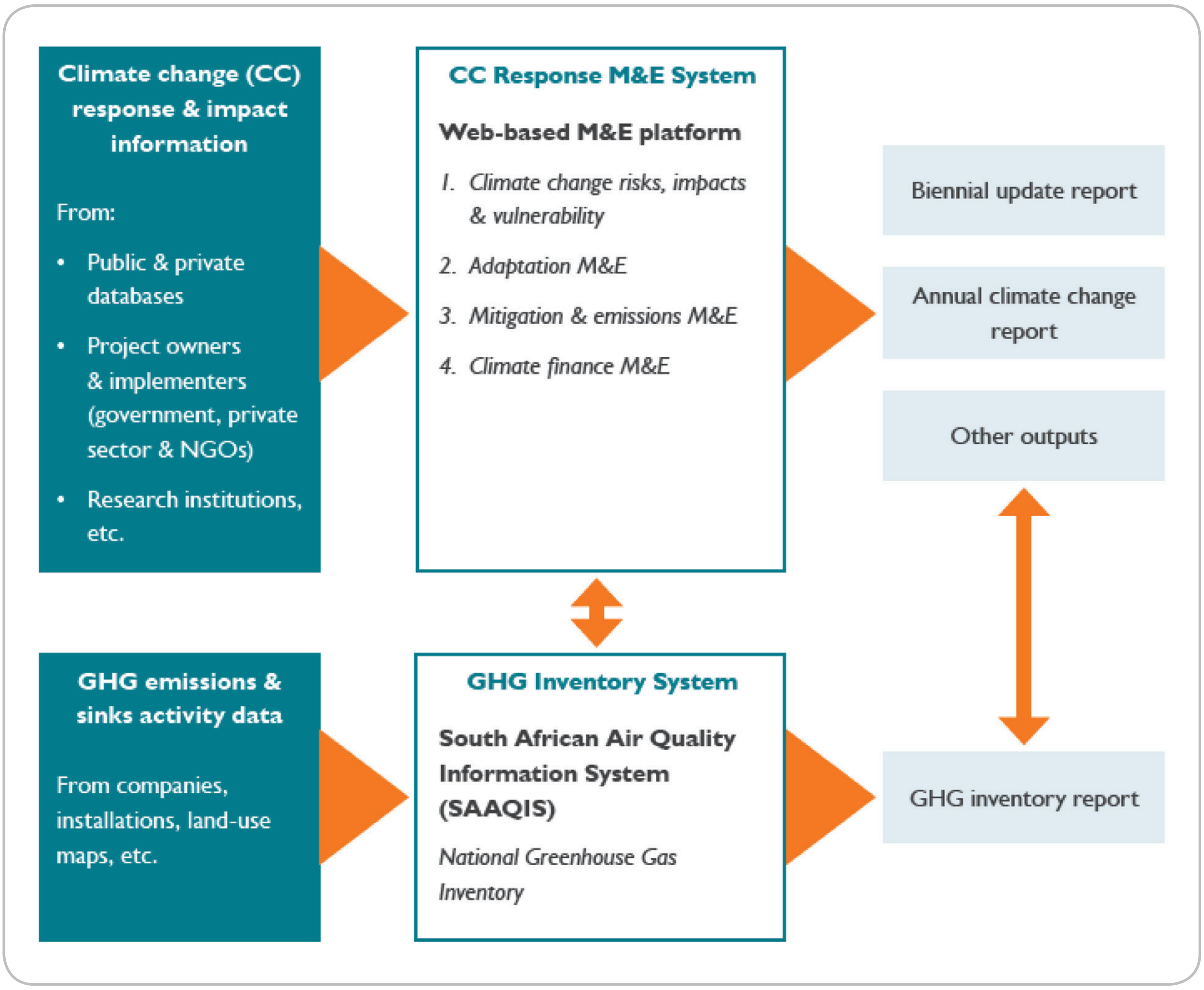


Figure 4.6: Summary of the overall monitoring and evaluation system for climate change South Africa (DEA, 2016, p. 10)

The Monitoring and Evaluation System will cover all other aspects of climate change monitoring and evaluation, and will make use of the *National GHG Inventory* as one of its primary information sources. The *National GHG Inventory*, which delivers the *GHG Inventory Report* as the main output, will use the South African Air Quality Information System as its web-based database.

4.2.1.8 *Progression of the South Africa monitoring and evaluation system*

The monitoring and evaluation framework represents a milestone in South Africa's climate change response, subsequent to the publication of the SNC. The South Africa Monitoring and Evaluation System has been in development since 2009. The system will be autonomous, institutionalised with a statutory mandate to capture, analyse and publish information about climate change response measures. This information may be used as an evidence base to inform further policy and decision making. The system will be coordinated by the Department of Environmental Affairs. The process for implementation of the system is ongoing and is planned for completion in 2017. Table 4.7 details the development of the South African Monitoring and Evaluation system.

Table 4.7: Progression of South Africa's monitoring and evaluation system

2007	The concept of monitoring, reporting and verification is introduced at COP13, at which South Africa actively participates. The Bali Action Plan calls for enhanced action on mitigation of climate change, including consideration of measureable, reportable and verifiable nationally appropriate mitigation actions.
2009	• The Department of Environmental Affairs commissions a study to help better understand the status of climate change response interventions and emissions impacts in South Africa; • The National Climate Change Response Database is developed and showcased at COP 15.
2010	Launch of the International Partnership on Mitigation and Monitoring, Reporting and Verification (South Africa, Germany and South Korea) to support climate change mitigation-related activities and monitoring, reporting and verification practices through capacity building and knowledge management.
2011	• South Africa participates in the WRI's Measurement and Performance Tracking programme which aims to enhance national capacity in developing countries to measure GHG emissions and track performance toward low-carbon development goals; • South Africa publishes its *National Climate Change Response White Paper* which authorises the development of a Climate Change Response Monitoring and Evaluation System.
2012	• South Africa begins structuring a system for monitoring and evaluation of climate change; • South Africa hosts the first technical workshop for the International Partnership on Mitigation and Monitoring, Reporting and Verification which analyses existing UNFCCC frameworks and identifies options and requirements for system plans and implementation in developing countries; • The Department of Environmental Affairs contracts entities to research monitoring, reporting and verification topics. The following reports are published: - *Measurement, Reporting and Verification in South Africa* - *A Draft Climate Change Response Monitoring and Evaluation System (Interim Report)* • The following are published through the Measurement and Performance Tracking programme: - *South African Approaches to Measuring, Reporting and Verifying: A Scoping Report;* - *MRV across Multi-Level Governance: National, Provincial and Municipal Institutions in South Africa*

2013	• The National Climate Change Response Database is updated to cover most mitigation and adaptation actions in South Africa, together with their respective emission reduction potentials; • The Department of Environmental Affairs updates the national GHG Inventory (2000-2010) and compiles the first *Biennial Update Report*.
2014	• South Africa submits its first *Biennial Update Report* to the UNFCCC; • Setting-up phase (Phase 1) of the Monitoring and Evaluation System is initiated.
2015	• A Technical Analysis of the first *Biennial Update Report* is conducted and published by the UNFCCC; • The web-based monitoring and evaluation platform is initiated; • The *GHG Emissions Reporting Regulations* are published for public comment (Gazette NO. 38857)
2016	• Development of the architecture and design of the web-based Monitoring and Evaluation System, which detail how the system will handle information on mitigation, adaptation and climate change finance. The system will be the central depository and portal of climate change information in South Africa.

4.3 South Africa's Projections to Mitigate Climate Change

In 2012, following on work reported on in the SNC, the Department of Environmental Affairs established a Technical Working Group on Mitigation which comprised of stakeholders from government departments, business, civil society and academics. The role of the Technical Working Group was to provide technical inputs and assist in identifying mitigation options on both sectoral and national levels for the *Mitigation Potential Analysis* work. Mitigation measures at both the sectoral and national level were evaluated in terms of cost of implementation, amount of emissions that could be abated, time required for implementation, social impacts and the realistic amount of emissions that could be mitigated by the measure in the event that it is implemented (DEA, 2014b, p. 2). The result of the study was a report entitled South Africa's GHG *Mitigation Potential Analysis*, published in 2014.

At the time of writing the mitigation chapter, the *Mitigation Potential Analysis* represented the most current research undertaken at a national level on mitigation. The *Mitigation Potential Analysis* required reference data as a baseline for the projection scenarios. The *Mitigation Potential Analysis* therefore used the *National GHG Inventory*: 2000-2010 as the departure point for the projection scenarios (DEA, 2014b, p. 1) because it was the latest available inventory in the public domain at the time of research related to the *Mitigation Potential Analysis*. The national inventory has subsequently been updated to include data up to 2012, but was not publicly available at the time of writing the mitigation chapter and was therefore not used as a basis for the projections in this chapter.

In the first projection scenario outlined in the *Mitigation Potential Analysis*, projections were modelled on gross domestic product (GDP) growth estimates based on the application of a macroeconomic growth model, derived from economic growth data in the *National Development Plan*. Using this economic growth data, three economic growth trajectories were considered to illustrate projections based on socio-economic factors. The departure point for the projections was based on a moderate economic growth rate. The moderate economic growth scenario was compared to two additional economic growth trajectories: one in which high economic growth occurred while another in which a low economic growth trajectory occurred.

A second projection scenario was based on the mitigation potential that could potentially be realised within South Africa per each projected time period. Three projection trajectories are used to illustrate this scenario: without measures (WOM), with existing measures (WEM) and with additional measures (WAM). The WOM trajectory is based on the premise that South Africa's total emissions volume will continue to grow from the 2010 *National GHG Inventory* volume without any measures to reduce the emissions generated. The WEM trajectory factors in emissions reductions technologies and measures that have been implemented, up to the point in time that the *Mitigation Potential Analysis* was completed. The WAM projection trajectory includes emissions reductions initiatives that have been earmarked for implementation across all the sectors considered. The WAM trajectory contains four implementation pathways which reflect the level of implementation of the technologies. These range from 25%, 50%, 75% and 100% levels of implementation.

Projections were made for three time periods: 2020, 2030 and 2050. The projected GHG emissions trajectories were categorised according to the following five sectors: Energy; Transport; Industry; Agriculture, Forestry and Other Land Use; and Waste.

4.3.1 Baseline

Subsequent to the work reported on in the SNC, a credible baseline was established and published in 2014 in the form of the South African *National GHG Inventory*: 2000-2010. The importance of this document lies in the potential to project future emissions from the data therein. The *National GHG Inventory*: 2000-2010 emissions data were presented per sector and each sector's relevant subsectors. Emissions data sets were taken as a combination of both emissions sources and sinks. The total GHG emissions per year could thus be allocated to each individual sector and allow major emitting subsectors within each subsector to be identified.

Across the entire period evaluated in the *National GHG Inventory*, the energy sector accounts for the majority of emissions. The emissions vary between 79% and 82% of the total annual GHG emissions between 2000 and 2010.

Approximately 80% of the emissions originate from the energy sector (DEA, 2014a, pp. 75 - 76). Emissions associated with the electricity generation subsector of the energy sector vary between 44% and 46% of the total annual GHG emissions. This is followed by petroleum refining and manufacture of solid fuels, manufacturing and construction, and the transport subsectors which individually account for approximately 8% of the total emissions per annum.

The annual emissions associated with the Industry sector account for approximately 10% of the total emissions while the agriculture, forestry and other land use and waste sectors make up the remainder of the emissions at an average of 6% and 3% of the total emissions per annum respectively.

The total GHG emissions figure in 2000 was 425 220 tCO_2e. In 2010 the total GHG emissions increased to 518 239 tCO_2eq. The total GHG emissions in South Africa thus rose by 22% over a 10 year period (DEA, 2014a, p. 37).

4.3.2 Projected emission reductions

Multiple emissions reductions scenarios were developed in the *Mitigation Potential Analysis* to ensure that sufficient provisions are made for South Africa to meet its emission reduction objectives. Two broad emission reduction scenario categories were developed: 1.) socio-economic projection scenarios which reflect the company's growth potential (based on various scenarios) and 2.) the mitigation projection trajectories (based on the various technological interventions that could be feasibly implemented in the country). These two scenario categories are discussed in the following subsections.

4.3.2.1 Socio-economic projection scenarios

The use of a socio-economic indicator enables the development of multiple projection scenarios based on the future growth trajectories. The growth trajectory of South Africa's GDP, was used as the basis to develop scenarios in the *Mitigation Potential Analysis* (DEA, 2014b, pp. 11 - 17).

The *Mitigation Potential Analysis* defines the mitigation potential of a measure as the quantified amount of GHG that can be reduced, as measured against a baseline (DEA, 2014b, p. viii). Three distinct mitigation trajectories were developed for South Africa's economic growth path: low economic growth; medium economic growth and high economic growth (DEA, 2014b, p. 17). All three growth trajectories were projected from the same baseline; the *National GHG Inventory*: 2000-2010. The 2010 emissions from which the trajectories are projected was 518 239 t CO_2eq.

The low economic growth trajectory was forecast to have an annual increase economic growth rate of 3.8% in both the medium term and long term. The low economic growth trajectory was assumed to originate from limiting socio-economic factors such as technical skill shortages, lack of required infrastructure required for economic growth and low global growth rates. For the medium economic growth trajectory, a moderate economic growth rate was forecast at 4.2% per annum for the medium term (2015 – 2020) and 4.3% per annum over the long term (2021 – 2050) (DEA, 2014b, p. 13). The high economic growth trajectory was forecasted to have an annual economic growth of 4.8% over the medium term and 5.4% over the long term (DEA, 2014b, p. 17).

The projections for the low, medium and high growth trajectories, between the years 2000-2050, are presented in figure 4.7. These emissions increase steadily. The totals per trajectory, up to the year 2020 do not vary significantly. For the medium economic growth trajectory, the total emissions volume is estimated to be 663 270 kt CO_2e (DEA, 2014b, p. 16). Taking the medium economic growth trajectory as the benchmark for comparison between trajectories, the differences in the total projected emissions for the low economic growth trajectory and the high economic growth trajectory are 3% lower and 3% higher respectively. These differences are depicted in Figure 4.7:

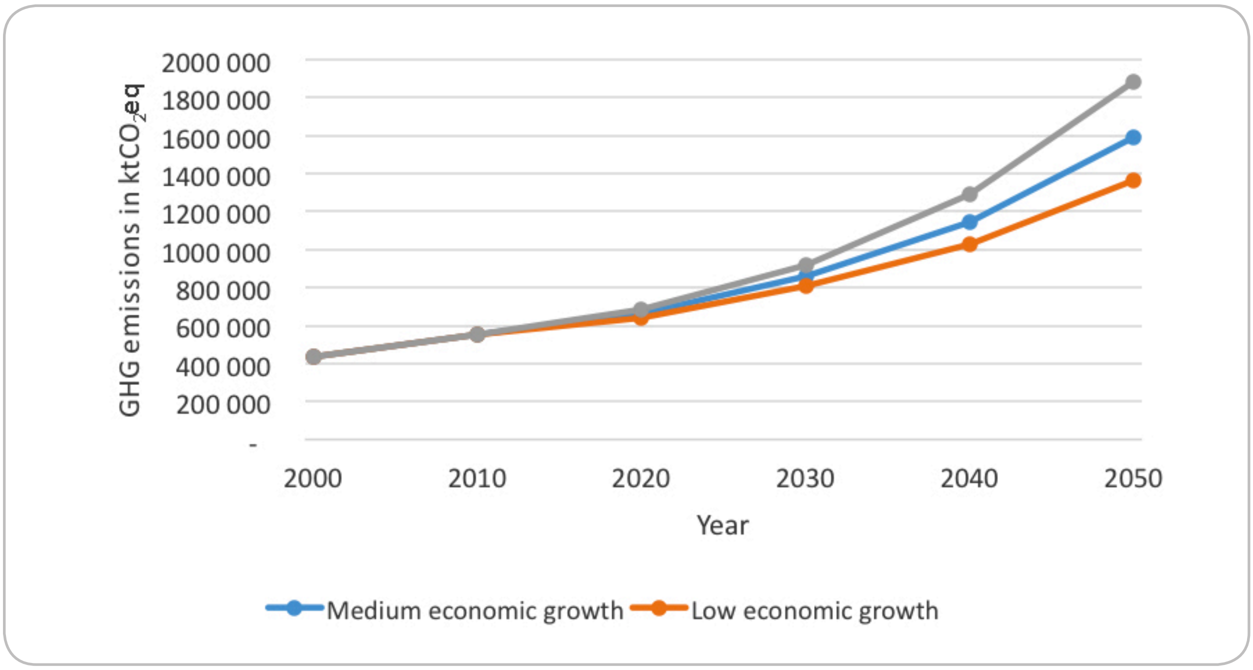


Figure 4.7: Socio-economic growth trajectories for South Africa's GHG emissions

When considering the difference in projected emissions volumes in 2050, the low economic growth trajectory's total GHG emissions of 1 360 526 kt CO_2e is 15% lower than that of the medium economic growth of 1 592 605 kt CO_2e. The high economic growth trajectory's total emissions volume amounts to 1 882 323 kt CO_2e which is 18% greater than that of the medium economic growth trajectory (DEA, 2014b, p. 19).

The increase in emissions in the high economic growth trajectories occurs predominantly in the energy and industry sectors. Similarly, there is a decrease in the emissions in the low economic growth trajectory. Comparing the high economic growth trajectory's emissions volume for the energy sector in 2030 to that of the medium economic growth trajectory, indicates that the emissions generated in this sector are 7% higher than that of the medium economic growth trajectory. The low economic growth trajectory displays the opposite behaviour, as the emissions originating from the energy sector in 2030 is 5% lower than that of the medium economic growth trajectory. As emissions from the energy sector account for approximately 67% of the total emissions of South Africa, it is clear that economic growth trajectories greatly influence the emissions projections.

A similar trend is seen when evaluating the industry sector's emissions. As this sector accounts for approximately 23% of the total emissions in South Africa, an increase or decrease in the economic growth of this sector would significantly influence the national GHG emission volumes. Comparing the high economic growth trajectory's emissions volume for industry in 2050 to that of the medium economic growth trajectory, the emissions generated in the sector are 33% higher than that of the medium economic growth trajectory. The low economic growth trajectory displays the opposite behaviour as the emissions originating from the sector in 2050, are 23% lower than that of the medium economic growth trajectory.

The transport sector was not adjusted for the high economic growth or low economic growth trajectories in the *Mitigation Potential Analysis*, as the effects of economic growth on the transport sector's emission trajectories were included in the energy sector.

The waste sector's emissions remain relatively constant in all three projection scenarios. The sector accounts for approximately 4% of the total emissions volume. When comparing the high economic growth trajectory's emissions volume for the waste sector to that of the medium economic growth scenario, the emissions volume increases by 0.3%. The low economic growth trajectory displays the opposite behaviour to that of the high economic growth trajectory. Under the low economic growth trajectory, emissions decrease by 2% when compared to that of the medium economic growth trajectory. The waste sector's emissions thus do not vary significantly according to the economic growth trajectories mapped for South Africa (DEA, 2014b, p. 19).

The agriculture, forestry and other land use sector was not adjusted for the high economic growth or low economic growth trajectories in the *Mitigation Potential Analysis*, as future agricultural production and land-use projections were covered in other studies. One such study is the the South African National Terrestrial Carbon Sinks Assessment (DEA, 2015c). The sequestration potential for the respective agriculture, forestry and other land use subsectors is discussed in detail in the National Carbon Sinks section of this chapter.

4.3.2.2 Projections based on mitigation potential

The country's mitigation potential was addressed in the research studies undertaken for the *Mitigation Potential Analysis*. A multi-criteria decision analysis model allowed the combination of a range of evaluation criteria in a decision-making framework. The resulting ranking of measures was thus based on more than merely the consideration of abatement potential and marginal abatement cost. The three projection trajectories (the WOM, WEM and WAM) were determined based on different weightings of the main criteria in the multi-criteria analysis framework utilised in the *Mitigation Potential Analysis*. The framework allowed the assessment of the socio-economic and environmental impacts of the various mitigation options that were identified in the study.

Various projections and related costs were subsequently developed and outlined in the *Mitigation Potential Analysis*. South Africa's projection trajectories, based on emissions reduction measures and interventions implemented for each of the projected time periods are presented in Figure 4.8.

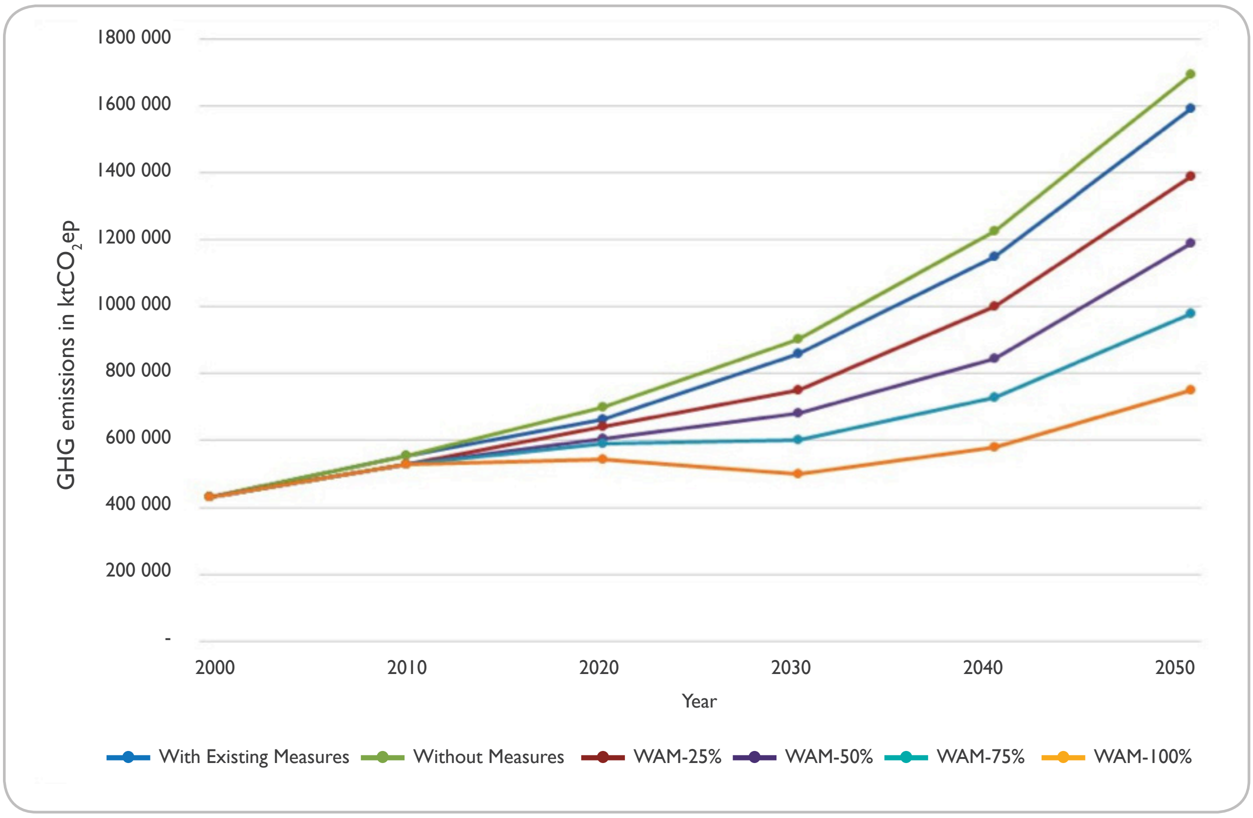


Figure 4.8: Influence of emission reduction measures and interventions on South Africa's GHG emissions projections

The WOM trajectory is extrapolated directly from the 2010 *National GHG Inventory*. This trajectory does not include any emissions reduction measures and interventions, and assumes that none will be implemented until 2050. The total emissions volumes in 2020 and 2050 are 699 300 ktCO_2e and 1 692 472 ktCO_2e respectively.

The WEM trajectory includes emissions reduction measures and interventions that had been included up until the date that the *Mitigation Potential Analysis* was published. The existing measures include projects and interventions such as the coal to gas feedstock change, the natural gas conversion, Eskom's Demand Side Management projects and Clean Development Mechanism projects implemented within South Africa. When comparing the total emissions volume of the WEM trajectory to that of the WOM trajectory, it can be seen that the emissions are lower in both 2020 and 2050. In 2020, the WEM trajectory had a total emissions volume of 663 270 ktCO_2e (5% lower than the WOM trajectory) while in 2050 the total emissions volume amounted to 1 592 605 ktCO_2e (6% lower than the WOM trajectory). This information illustrates that the emissions reduction measures and interventions, implemented to date, have already reduced the total South African GHG emissions.

The WAM projection trajectory includes multiple emissions reduction measures and interventions that could be implemented to reduce South Africa's national GHG emissions. The WAM trajectory is broken up into various pathways, which assume different levels of implementation of the national mitigation potential (100%, 75%, 50% and 25%). These four pathways have different emissions associated with them, the higher the level of implementation of measures, the higher the potential emission reductions. The emissions reduction measures and interventions span across all five sectoral categories and their respective subcategories. These measures were evaluated based on a marginal abatement cost.

4.3.3 Emissions quantified per GHG

For the current inventory, data was gathered for the following gases: CO_2, CH_4 and N_2O. Certain HFCs and PFCs were reported on in the IPPU sector and NOx and CO were also estimated for biomass burning emissions. Discussions are under way to estimate SF6 emissions from power generation. Progress on this initiative will be reported in the next inventory submission. SF6 is therefore not included in South Africa's national inventory.

The energy sector generates the largest quantity of CO_2 emissions. Throughout 2000 to 2010, the energy sector accounts for approximately 95% of the annual CO_2 emissions. The remainder is allocated to the industry sector while the agriculture, forestry and other land use sector reduces the net quantity of CO_2 per annum by approximately 6%, through carbon sinks.

The majority of the CH_4 emissions originate from the agriculture, forestry and other land use and waste sectors. In 2000, approximately 70% of CH_4 emissions could be allocated to the agriculture, forestry and other land use sector, 25% to the waste sector and the remainder distributed between the energy and industry sectors. In 2010, the portion of CH_4 emissions originating from the agriculture, forestry and other land use sector reduced to approximately 57% of the total CH_4 emissions. In the same period, CH_4 emissions originating from the waste sector increased to 37%, with the majority of the remainder allocated to the energy sector. CH_4 emissions under agriculture, forestry and other land use remain relatively constant throughout the period (with minor fluctuations) while the waste sectors's CH_4 emissions increase each year.

N_2O emissions originate mainly from the agriculture, forestry and other land use sector. When considering the trend of the N_2O emissions between 2000 and 2010, approximately 85% of the N_2O emissions originated from the agriculture, forestry and other land use sector with the remainder split between the other sectors.

The two ozone depleting substances, HFCs and PFCs, originate from only one sector: industry. When considering the trends of these two emissions between the 2000 and 2010 period, PFCs reduce significantly. In 2000, the total PFCs emissions were 982 kt CO_2e while in 2010 the volume reduced to 138 kt CO_2e. The HFCs emissions increase significantly between 2005 and 2010. In 2005, the HFCs emissions amounted to approximately 126 kt CO_2e. These emissions volumes increased further to 800 kt CO_2e in 2010.

4.4 Mitigation and Financial Needs Assessments

There are different mitigation opportunities in South Africa to reduce GHG emissions. These opportunities have varying degrees of costs associated with them, as identified in South Africa's GHG *Mitigation Potential Analysis*. The financial assessments relate to the potential mitigation options in marginal abatement cost curves (MACCs). The MACCs present the costs and potential for emissions reduction from different measures, ranking them from the cheapest to the most expensive, to demonstrate the marginal costs of achieving incremental levels of emissions reduction (DEA, 2014b, p. 21).

The *Mitigation Potential Analysis* uses a bottom-up sectoral approach in the development of the MACCs and determining the overall national and sectoral mitigation potential. The country's mitigation potential, defined as technological potential (DEA, 2014b, p. 20) , has been compiled for the period 2010-2050, following the methodology described in Figure 4.9.

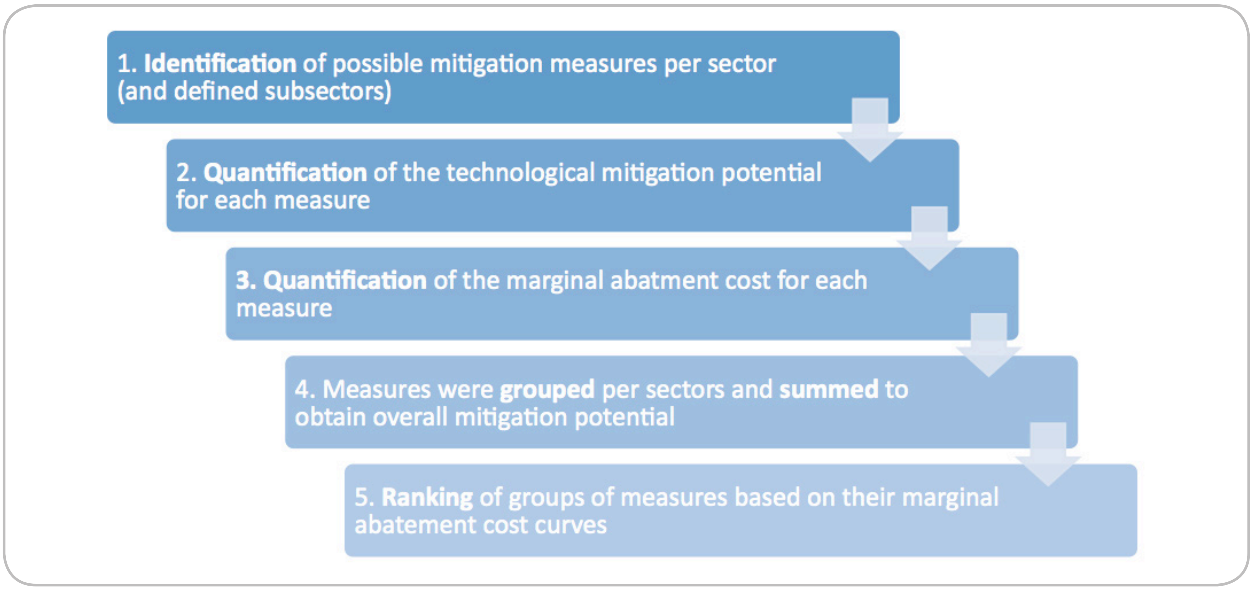


Figure 4.9: Bottom-up sectoral approach used to identify South Africa's mitigation potential (DEA, 2014b, p. 20)

21. *Technological potential refers to the amount by which it is possible to reduce GHG emissions or improve energy efficiency by implementing a technology or practice that has already been demonstrated.*

4.4.1 Identification of possible mitigation measures

The mitigation measures described in the *Mitigation Potential Analysis* are categorised according to five key sectoral categories: energy; industry; transport; waste and agriculture, forestry and other land use. These sectoral classifications are different to the traditional IPCC categories (energy; industrial processes and product use; agriculture, forestry and other land use; waste; and other) as well as the Standard Industrial Classification used by a number of government departments within South Africa.

In the *Mitigation Potential Analysis* approach, the energy key sector comprises exploration and exploitation of primary energy sources; conversion of primary energy sources into more useable energy forms in refineries and power plants; and the transmission and distribution of fuels. Energy for transport purposes is depicted in the independent transport key category. The industry key category includes emissions from industrial process emissions and from combustion activities in manufacturing industries and construction.

Under South Africa's 2010 *National GHG Inventory*, energy supply and consumption (which includes energy for transport and energy used during the course of industrial processes) account for about 83% of South Africa's GHG emissions. Therefore the national approach for mitigating climate change puts more efforts on measures in this sector. All of the country's mitigation efforts are however developed and implemented with the aim of balancing reductions of GHG emissions with the need to maintain economic competitiveness and align with other sustainable development priorities. The *National Climate Change Response White Paper* is the guiding policy in this regard. The White Paper focusses on aligning South Africa's climate change mitigation measures with interventions that build and sustain the country's social, economic and environmental resilience and emergency response capacity. In this way, the country seeks to realise it's developmental goals while harnessing the economic opportunities that accompany the transition to a lower-carbon economy (DEA, 2014b, p. 39).

4.4.2 Quantification of mitigation potential

The *Mitigation Potential Analysis*' reference GHG emissions were developed using a moderate projected future economic growth rate, as defined by National Treasury. Two reference emissions scenarios were created: without measures (WOM) and with existing measures (WEM). The WOM scenario assumes that no mitigation actions have taken place since the year 2000 and will remain likewise until 2050. The WEM scenario incorporates mitigation options implemented up to 2010; these correspond mainly with industry implemented measures and future reductions expected by the implementation of alternative sources of energy, as mandated by the *Integrated Resource Plan for Electricity* 2010-2030 (DEA, 2014b, p. 15).

The national GHG emissions under the reference case WOM and WEM projections are presented below in Figure 4.10. Emissions under the energy sector are by far the greatest contributors to the GHG emissions total.

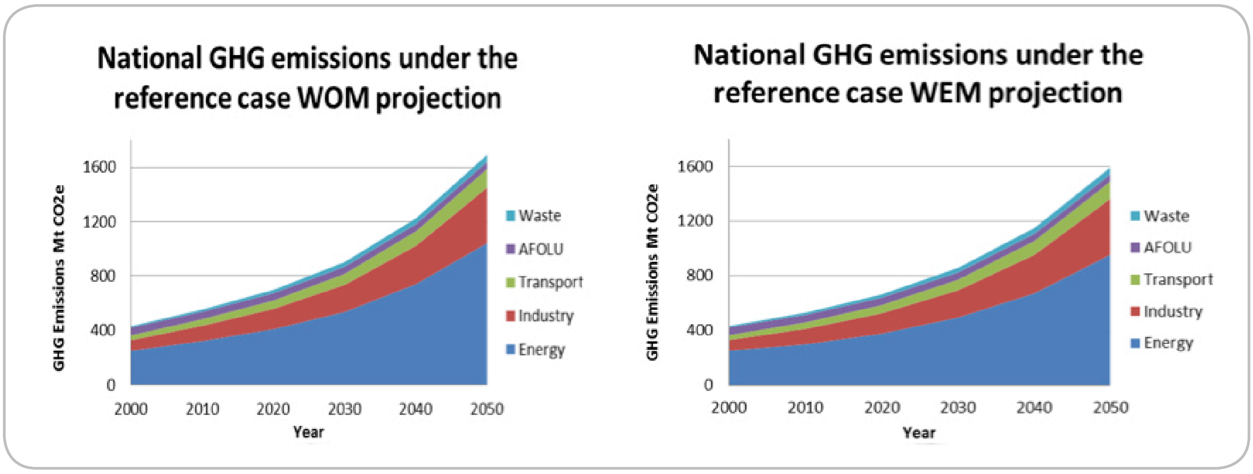


Figure 4.10: National GHG emissions under the reference case WOM (left) and WEM (right) projections, showing a breakdown per sector (2000–2050) (DEA, 2014b, pp. 14-15)

For estimation of potential mitigation, all the proposed measures are assumed as implemented and evaluated against the WEM scenario. Under this "with all measures" scenario (WAM) the national mitigation potential has been estimated at 100 Mt CO_2e in 2020, 340 Mt CO_2e in 2030 and 852 Mt CO_2e in 2050 (see figure 4.11) (DEA, 2014b, p. xviii). When compared with the WEM reference case, this represents a reduction of 15%, 40% and 54% for the years 2020, 2030 and 2050 respectively (DEA, 2014b, p. 19).

Under this scenario, the largest contributor to abatement in 2050 is the power sector (which falls under the energy category) with 416 Mt CO_2e abated, or 26% reduction of emissions relative to the WEM reference scenario. The entire energy sector has a potential for mitigation of 21% and 31% of the total emissions for the years 2030 and 2050 respectively. The second highest significant contributor to the national mitigation potential is the industry sector, with a 16% reduction for the year 2050 (DEA, 2014b, p. 88). However, the WAM assessment concluded that even if all identified mitigation measures were implemented, South Africa will not see GHG emissions below the 2010 levels.

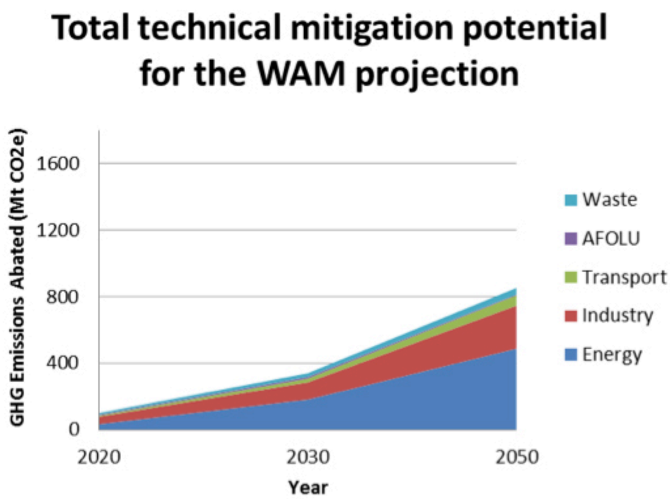


Figure 4.11: Total technical mitigation potential for the WAM projection (in Mt CO_2e) (DEA, 2014b, p. 31)

These totals under the WAM projection are a great indicator of mitigation potential. However each measure faces drivers or challenges not only of economical type, that may accelerate, delay or limit its implementation. Therefore the formulation of pathways is necessary to investigate the scope of the implementation of the measures, in different proportions. This is done by grouping the mitigation measures, assuming a varying proportion of implementation over time.

4.4.3 Financial needs assessment

The GHG abatement potential and the marginal abatement cost for each mitigation measure are listed under the five key sectors. The marginal abatement cost is an indicator of the net cost required to implement a given technical measure to abate a unit of CO_2e.

The MACCs therefore show the costs and potential for emissions reduction from different measures or technologies, ranking them from the cheapest to the most expensive to represent the marginal costs of achieving incremental levels of emis¬sions reduction. These analyses are presented for the periods 2020, 2030 and 2050.

Relative to the WEM emissions reference projection, the MACCs show the GHG mitigation abatement potential, for each abatement technology, along the horizontal x-axis (in t CO_2e abated) and the marginal abate¬ment cost of implementing the measures along the vertical y-axis (in R/t CO_2e abated). An overview to the complete national marginal abatement cost curves for the year 2020 is presented in Figure 4.12. The bars showing a negative value in the y-axis represent the proportion of mitigation potential which can be implemented, at a negative marginal abatement cost. A negative marginal abatement cost indicates that the 'low carbon option' is cheaper than the 'business-as-usual' option; however for implementation, there are other non-financial barriers to consider.

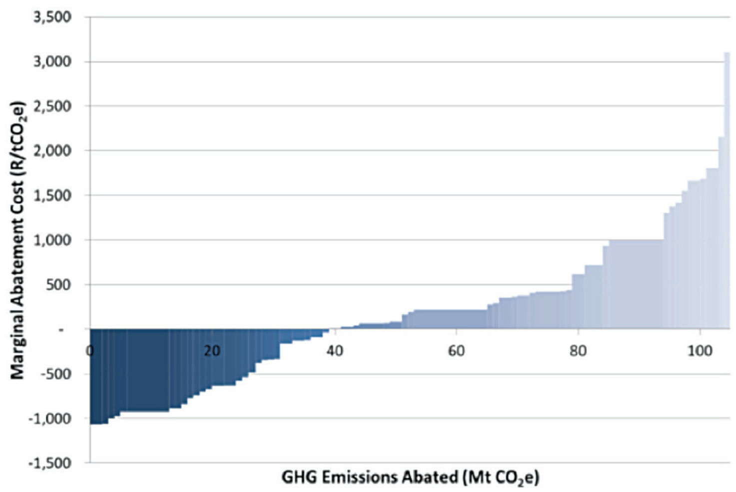


Figure 4.12: National marginal abatement cost curve per measure for the year 2020 (DEA, 2014b, p. 84)

The curves illustrate that with increasing targets for national emissions reduction, implementation of mitigation potential will become harder as measures become increasingly costly, with more substantially negative social and environmental impacts and also as the limits of technological possibilities are reached.

A MACC is a tool for understanding the level of emissions abatement that can be delivered by a specific measure, at a given point in time. It provides an understanding of the relative cost of each measure which is useful for ranking investment or prioritising decisions for implementation. The total cost of delivering an emission reduction is represented by the area under the MACC. However, this is static information - a snapshot in time - for the particular year of the assessment.

It is not possible to derive the required capital investment cost for the assessed measures purely from the MACCs. Each MACC has a set of underpinning analyses that influence the overall result. These may include a discount rate, lifespan of the measure, operational expenses, savings compared to the use of the traditional technology and penetration rate (DEA, 2014c).

The findings from the *Mitigation Potential Analysis* have been used to estimate the cost of delivery of the emission reduction also denominated as net annual cost (NAC) of implementing a measure (see Equation 1). The NAC is given in R/year, in present value, which should be interpreted as an additional burden/relief on the economy in a given year, for delivering the indicated abatement.

Equation 1. $$MAC\left[\frac{R}{tCO_{2e}}\right]*TER\left[\frac{tCO_{2e}}{year}\right]=NAC\left[\frac{R}{year}\right]$$

As referred to above, marginal costs can be positive or negative. Measures with a negative value usually imply that during their lifetime, the savings obtained surpass the capital and operation cost of the traditional technology. As the intention of this document is to indicate as close as possible, the real financial needs for national mitigation, only the measures whose marginal abatement costs were above zero have been considered. This does not imply that all measures with negative marginal cost will be implemented, as "cost" is not the only driver for implementation and there may be other barriers that were not considered in the scope of the studies undertaken for the *Mitigation Potential Analysis*.

4.4.3.1 Key sectors in the mitigation potential analysis

The graph below presents the South Africa's MACC for the year 2020, 2030 and 2050, for all the measures in the five key sectors as grouped in the *Mitigation Potential Analysis*. The energy and transport sectors have the greatest potential for abatement; however these opportunities come at higher costs. Opportunities for emission reductions with a negative marginal cost are available in the industry sector. Most of these opportunities are located in the metals subsector.

The national MACCs for the year 2020, per sector, are outlined in Figure 4.13.

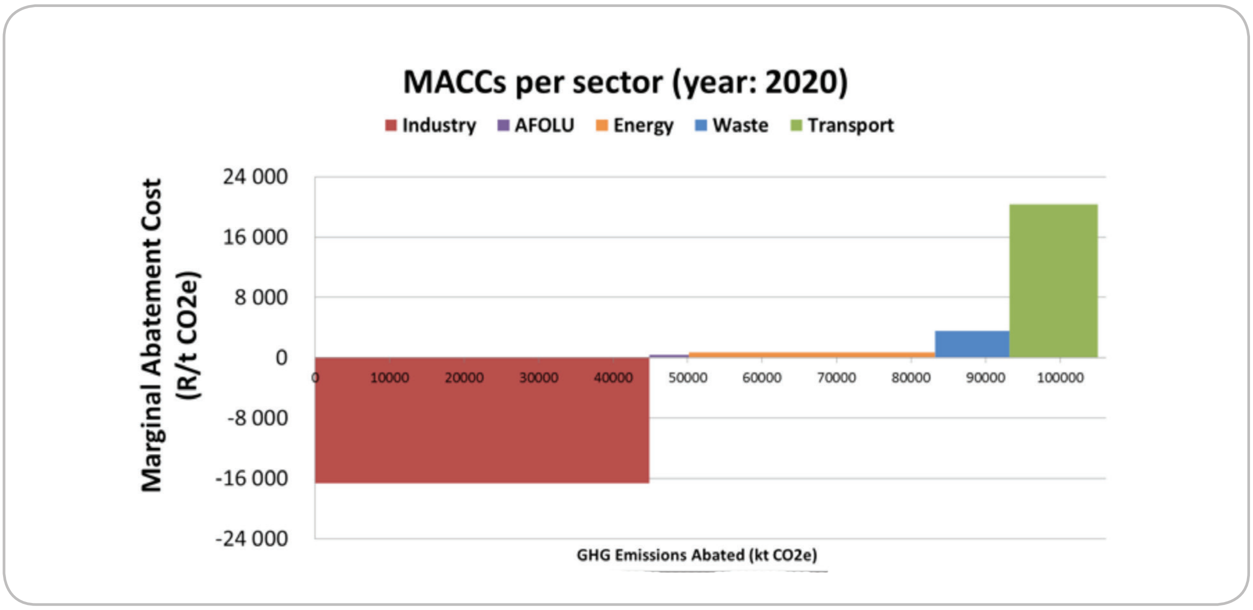


Figure 4.13: National MACCs per sector for the year 2020 (DEA, 2014b, p. 105)

Considering the MACCs for the key industry sector on a grouped basis may lead readers to believe that there are no costs associated with the implementation of mitigation. This is not the case however: it is important to remember that the overall negative value is a result of grouping the total estimated benefits from all assessed mitigation measures within all industry subsectors. A more detailed assessment of the implementation costs for the Industry sector is undertaken in Section 4.4.3.4.

The positive MACCs in Figure 4.13 are in the AFOLU, energy, waste and transport sectors. While the transport sector contains the highest costs associated with abatement (illustrated in the y-axis), the energy sector represents the highest potential for emission abatement activities (represented along the x-axis of the graph) with far less associated costs.

The MACCs for 2030, per sector, are illustrated in Figure 4.14.

The highest positive MACCs in 2030 occur in the energy and transport sectors. The abatement costs under the transport sector remain the highest and the energy sector remains the sector with the largest abatement potential in the 2030 period. The MACCs in the industry sector remain negative but are less negative than the MACCs presented in year 2020. The analyses indicate that measures undertaken in the energy sector in year 2030 will be more costly than measures undertaken in the year 2020.

The MACCs for 2050, per sector, are illustrated in Figure 4.15.

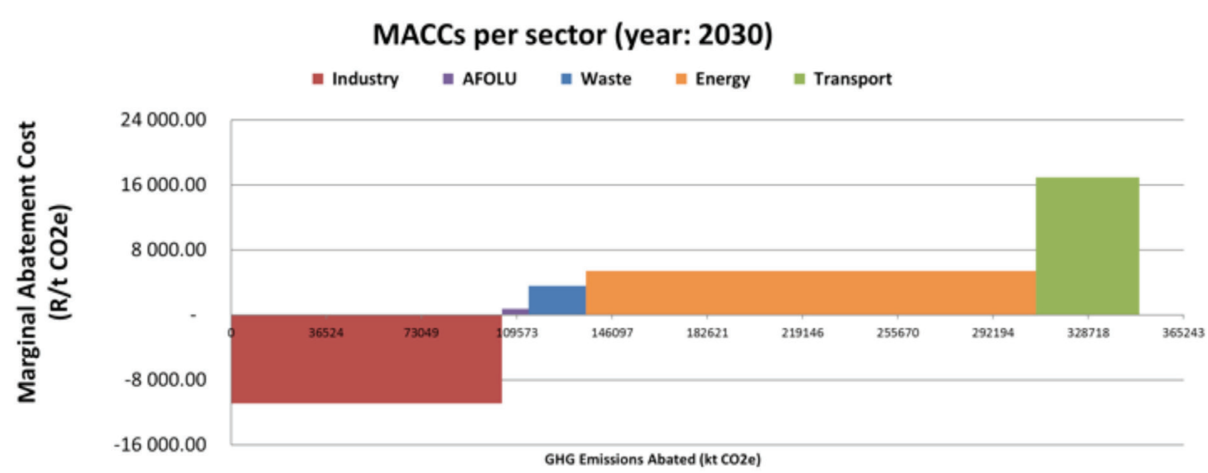


Figure 4.14: National MACCs per sector for the year 2030 (DEA, 2014b, p. 105)

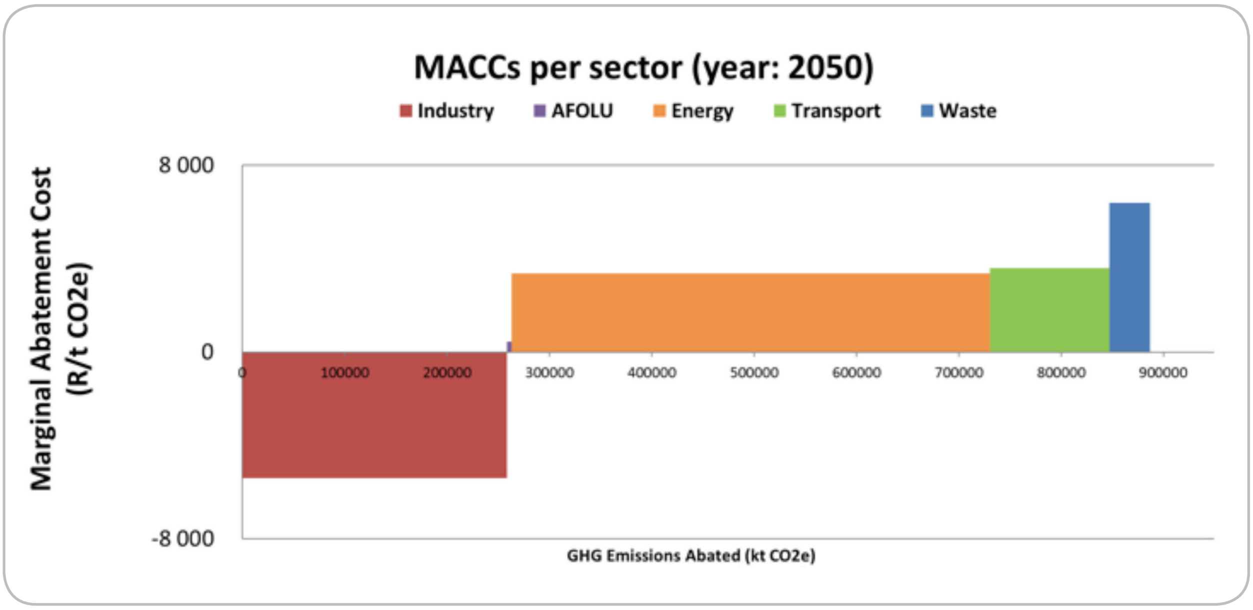
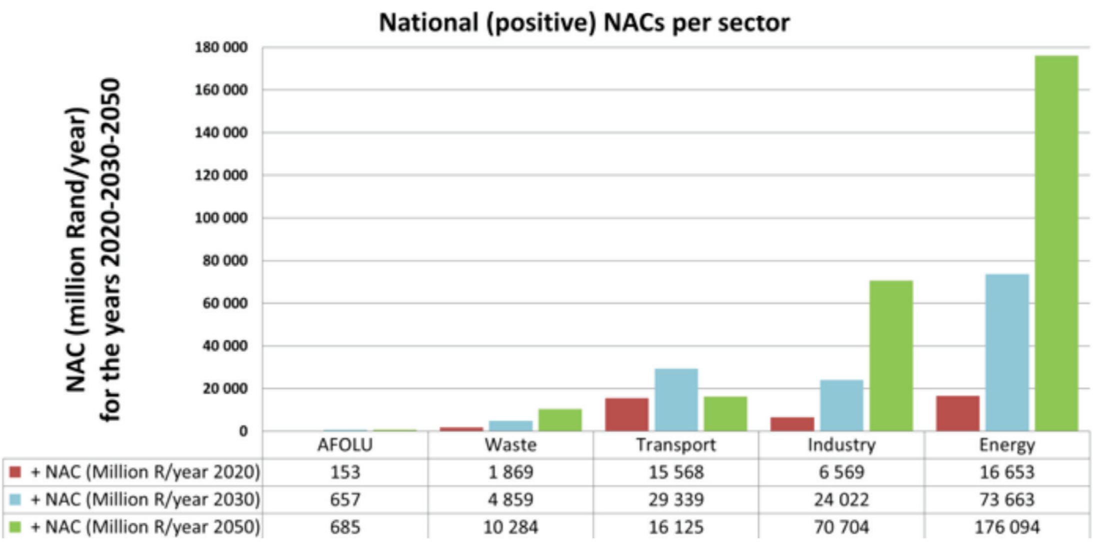


Figure 4.15: National MACCs per sector for the year 2050 (DEA, 2014b, p. 105)

The highest costs associated with emission reduction activities in the year 2050 will lie in the waste sector, and are estimated to outprice the cost of interventions in both the energy and transport sectors. The energy sector represents the sector with the highest opportunities for emission abatements. The costs associated with abatement activities in the energy sector remain on par with 2030 levels. The cost of technology measures in the transport sector are estimated to drop dramatically in the 2050 period, compared to levels in the previous years.

The country's national MACCs have also been annualised in the *Mitigation Potential Analysis*. The national positive NACs for 2020, 2030 and 2050 are presented in Figure 4.16. Considering the positive abatement cost curves, the national NAC for the country is estimated at R40.8 billion/year[22] for the year 2020, if all measures are implemented. The greatest investments could take place in the energy and transport sectors, followed in smaller proportion by investments in the industry sector. The national NAC for 2030 is estimated at 132.5 billion/year, and almost 273.8 billion/year for the year 2050.

22. 1 000 million being the equivlanet of 1 billion



	AFOLU	Waste	Transport	Industry	Energy
+ NAC (Million R/year 2020)	153	1 869	15 568	6 569	16 653
+ NAC (Million R/year 2030)	657	4 859	29 339	24 022	73 663
+ NAC (Million R/year 2050)	685	10 284	16 125	70 704	176 094

Figure 4.16: National (Positive) NACs per sector for the years 2020, 2030 and 2050 (DEA, 2014b, p. 105)

A detailed description of the subsectors within each of these sectors is presented in the following section.

4.4.3.2 Energy sector

The energy sector comprises exploration and exploitation of primary energy sources, conversion of primary energy sources into more useable energy forms in refineries and the transmission and distribution of fuels. The most material subsector in this category is power generation (also called "electricity and heat production[23]").

The MACC for the energy sector (per subsector) for the year 2020 is presented in Figure 4.17. The subsector with the greatest potential for abatement is electricity and heat production (28 585 kt CO_2e), where onshore wind and solar photovoltaic technologies would be the most significant contributors.

23. Measures in electricity and heating include generation of nuclear energy, gas CCGT, onshore wind, solar CSP, solar PV, coal carbon capture and storage, biomass, LFG, energy from waste

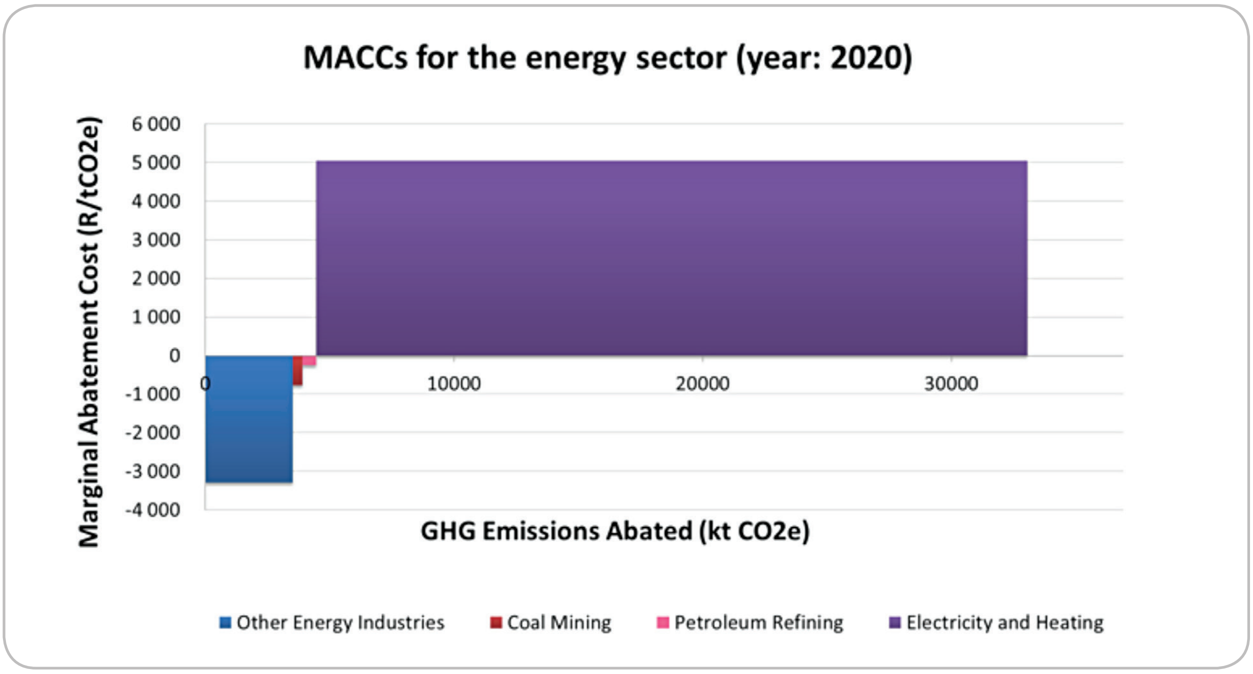
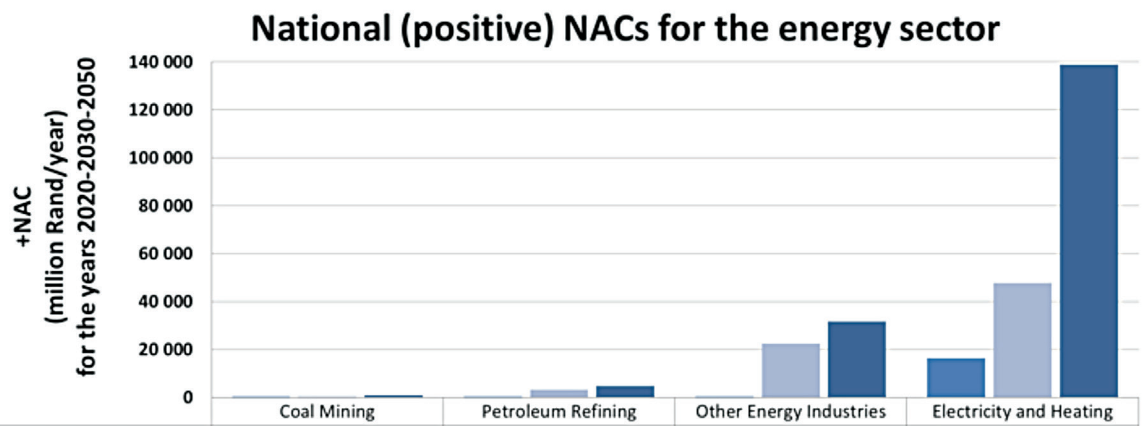


Figure 4.17: MACCs per subsector for the energy sector for the year 2020 (DEA, 2014b, p. 105)

The positive NACs for the energy sector, per subsector, for the years 2020, 2030 and 2050, are presented in Figure 4.18 below. The greatest costs for delivering an emission reduction in this sector arise from the electricity and heating subsectors. However, these are also the areas where more emissions savings can be achieved. For the year 2020, wind and solar energy generation are the considered measures with high potential for emission abatement in the electricty and heating susbsector. For the 2030 and 2050 periods, the measures with high abatement potential also include wind and solar energy generation, other mitigation technogolies as well as carbon capture and storage (the latter assumed in 2050).

For the years 2030 and 2050 investment in subsector 'other energy industries' will also be required, as this is the second highest subsector for investment, after the 'electricity and heating' subsector. The estimated positive NAC for the year 2020 is almost R17 billion, for 2030 it is close to R74 billion, and R176 billion for the year 2050.



	Coal Mining	Petroleum Refining	Other Energy Industries	Electricity and Heating
+ NAC (Million R/year 2020)	173	57	95	16 328
+ NAC (Million R/year 2030)	362	3 242	22 450	47 609
+ NAC (Million R/year 2050)	709	4 849	31 540	138 997

Figure 4.18: National (Positive) NACs in million rand per year, per subsector in the energy sector for the year 2020, 2030 and 2050 (DEA, 2014b, p. 105)

4.4.3.3 Transport sector

The transport key sector includes civil aviation, road transport and railway. The measures related to road transportation account for the some of the largest components of the MACCs.

Figure 4.19 indicates that the MACCs with high potential emission reductions are possible in the road subsector in 2020, although these would occur at significant costs. More efficient engines, biofuels and shifting of freight road to rail are some of the measures with large abatement potential[24].

24. Note that Figure 41 from the Mitigation Potential Analysis (DEA, 2014b, p. 70): Marginal abatement cost curve for the road sector in 2020 does not correspond to the values in Table 32 of the same document. Values from Table 32 have been used for the aggregation in this document, which are aligned with the values presented in Appendix E of the Mitigation Potential Analysis.

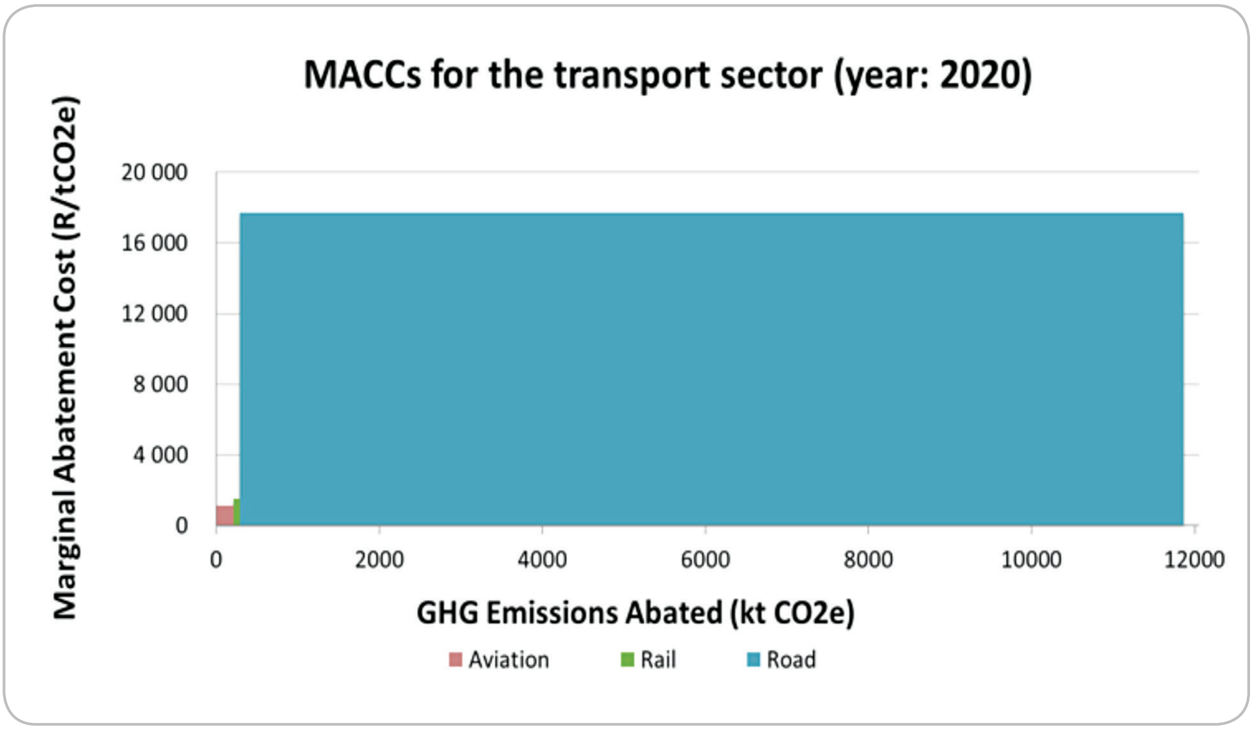
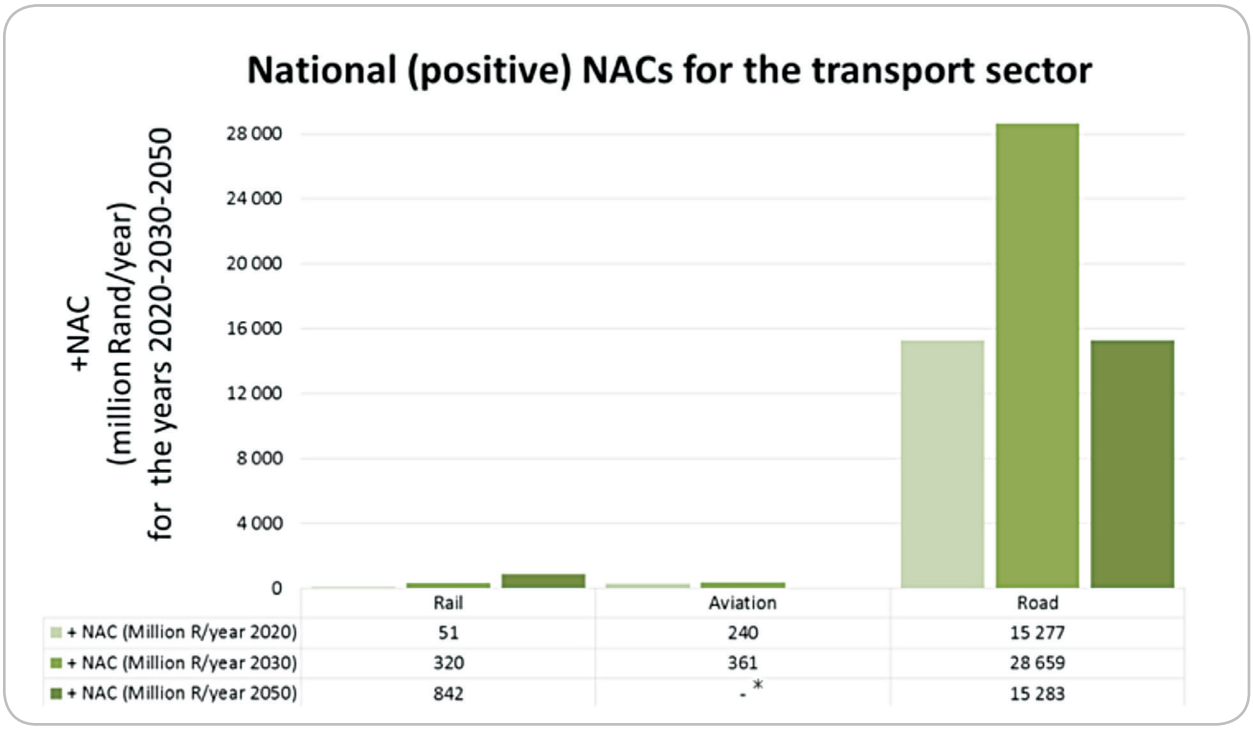


Figure 4.19: MACCs per Transport related subsectors for the year 2020 (DEA, 2014b, p. 105)

As per the Figure 4.19, the road transport sector has high potential for mitigation opportunities (which are also associated with high costs of implementation). The measures investigated are related to the use of alternative fuels, the shifting of passengers from private cars to public transport, shifting freight from road to train and improved efficiency. Other measures include biofuels in the aviation subsector, as well as in the rail sub sector.

Positive transport NACs for the rail, aviation and road subsectors in the years 2020, 2030 and 2050 respectively are shown in figure 4.20. The highest costs are expected to be in the road subsector, especially during the 2030 period.

The estimated positive NAC for the year 2020 is more than R15.5 billion, and it includes measures such as improvement of the efficiency of internal combustion engines (petrol and diesel), the introduction of biofuels and the shifting of freight from road to rail. For the year 2030 the positive NAC is R29 billion; the inclusion of biofuels, the shifting of freight from road to rail and improving the efficiency of diesel engines accounts for most of this. During the year 2050 the positive NAC goes over R16 billion, with notable investments in the shifting of freight mode of transport, biofuels inclusion and electric vehicles.



	Rail	Aviation	Road
+ NAC (Million R/year 2020)	51	240	15 277
+ NAC (Million R/year 2030)	320	361	28 659
+ NAC (Million R/year 2050)	842	- *	15 283

Figure 4.20: National (Positive) NACs in million rand per year, per transport subsector for the year 2020, 2030 and 2050 (DEA, 2014b, p. 105)

* *The measures considered have a negative marginal abatement cost in this year and therefore result in a negative NAC value which is not plotted in this graph.*

4.4.3.4 Industry sector

The following types of mitigation opportunities that could be implemented to reduce GHG emissions produced by industrial processes were considered in the *Mitigation Potential Analysis*:

- Energy efficiency;
- Improved efficiency of onsite heat and power generation techniques;
- Improved production processes;
- Fuel switches; and
- GHG abatement technologies.

The use of fuel in stationary combustion for the provision of heat or mechanical work, and indirect the emissions from the consumption of electricity for industries are included under the industry sector.

The abatement potential for the industry sector has been estimated at just under 45 million tCO_2e for the year 2020 (see Figure 4.21). This sector has a predominantly negative marginal cost. 83% of these emission savings may be possible from interventions in the metal subsector, which includes iron and steel, ferroalloys and primary aluminium production. Further significant abatement is possible from the commercial/institutional and the residential subsectors (22 million tCO_2e), where efficient lighting and improved thermal design of new buildings may have a major impact.

It is important to mention that the difference between the WOM and WEM scenario is mostly due to interventions which were already undertaken by private companies in the industrial sector of the economy. Furthermore, the difference between the WEM and WAM scenarios lies in the uptake of the measures identified as potential mitigation opportunities.

The MACCs for the industry sector in 2020 are presented in Figure 4.21.

The positive NACs for the industry sector, per subsector, for the years 2020, 2030 and 2050 are presented in Figure 4.22.

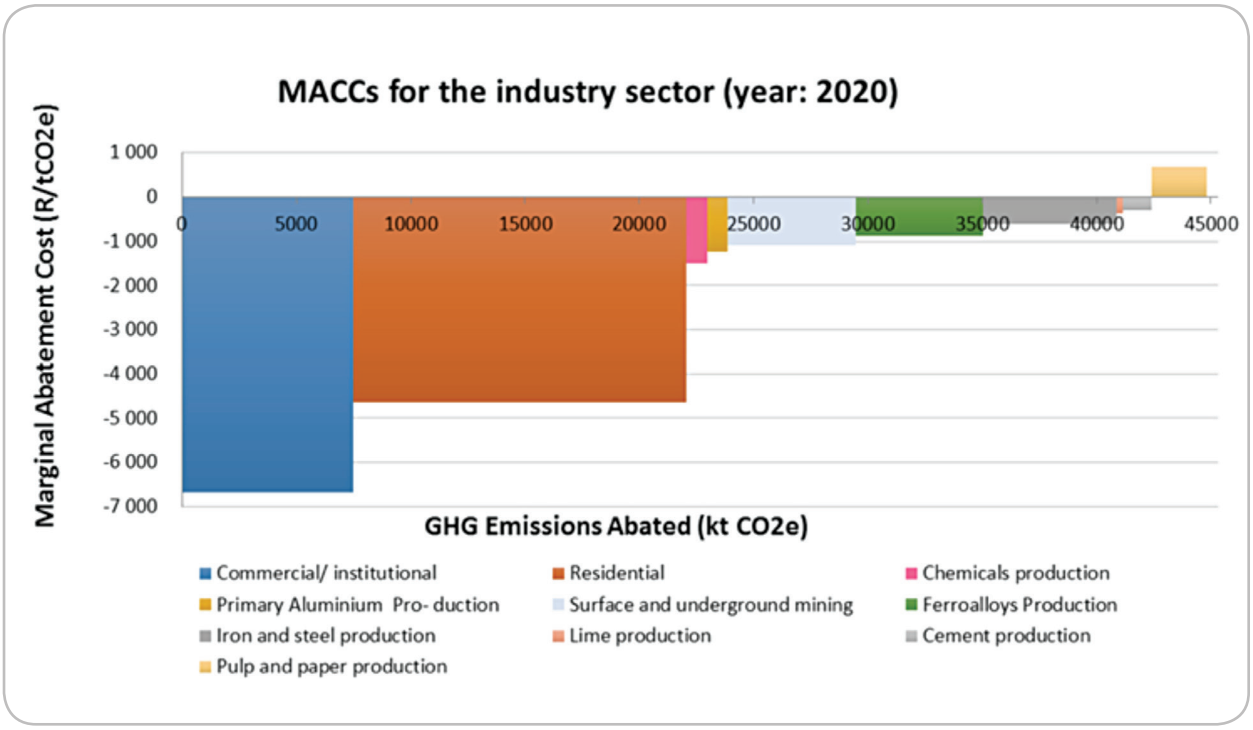
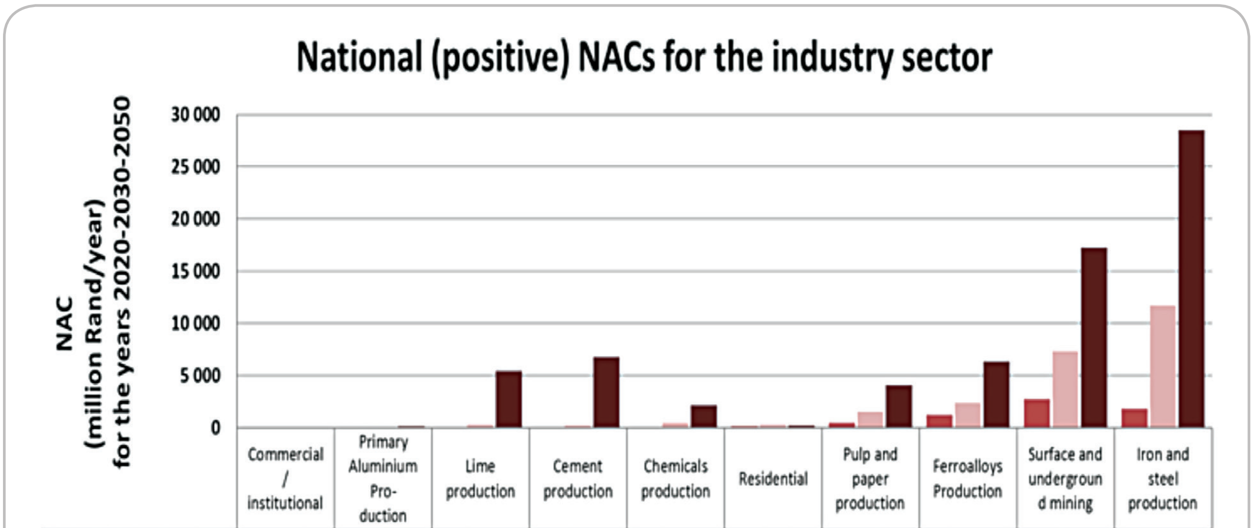


Figure 4.21: MACCs per subsector for the industry sector for the year 2020 (DEA, 2014b, p. 105)



	Commercial / institutional	Primary Aluminium Pro-duction	Lime production	Cement production	Chemicals production	Residential	Pulp and paper production	Ferroalloys Production	Surface and undergroun d mining	Iron and steel production
+ NAC (Million R/year 2020)	- *	14	43	43	68	138	495	1 251	2 706	1 810
+ NAC (Million R/year 2030)	- *	28	228	166	453	221	1 528	2 359	7 335	11 704
+ NAC (Million R/year 2050)	- *	103	5 436	6 761	2 173	178	4 072	6 310	17 206	28 464

Figure 4.22: National (Positive) NACs in million rand per year, per subsector in the industry sector for the year 2020, 2030 and 2050 (DEA, 2014b, p. 105)

* *The measures considered have a negative marginal abatement cost in this year and therefore result in a negative NAC value which is not plotted in this graph.*

For the year 2020 this value is estimated at R6.5 billion, where the surface and underground mining and iron and steel production subsectors require the most investments.

The subsectors with the highest positive NACs in 2020 remain the same for 2030 and 2050; however the cost for the implementation of technologies increases significantly with time. The estimated total positive NAC in 2030 is R24 billion, and for the year 2050 it is expected to reach above R70 billion. In 2050, investments in the cement production subsector are estimated to displace the ferroalloys production subsector from its position in the top three highest NACs in both 2020 and 2030.

4.4.3.5 Waste sector

The estimates of mitigation potential for the waste sector exclude industrial waste and focus only on municipal waste, mainly from managed waste disposal sites and wastewater treatment and discharge. If all technically available mitigation potential activities in the waste sector were implemented, then almost 10 000 kt CO_2e could be reduced in 2020 with a marginal cost of about R3 500 per tonne CO_2e abated. The main contributing measures for abatement are those related to landfill gas recovery (see Figure 4.23).

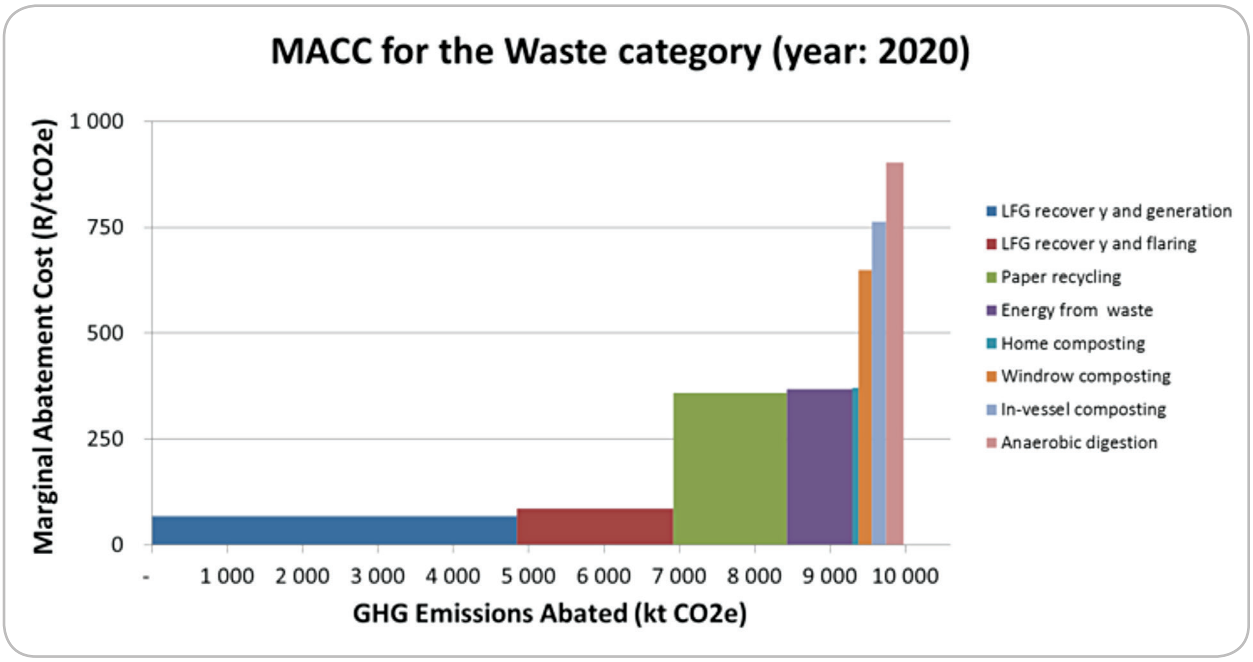
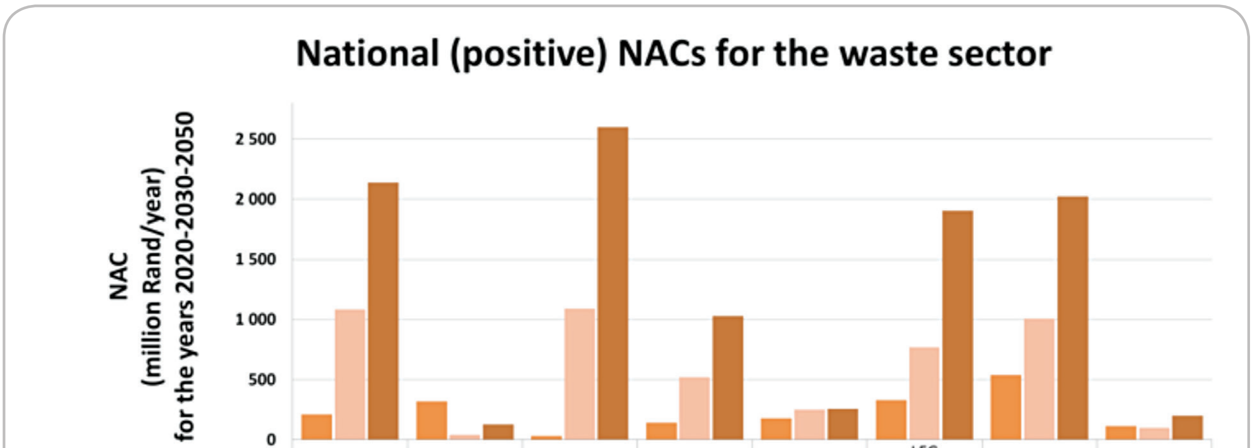


Figure 4.23: MACCs for the mitigation measures investigated under the waste sector for the year 2020 (DEA, 2014b, p. 105)



	Anaerobic digestion	Energy from waste	Home compostin g	In-vessel compostin g	LFG recover y and flaring	LFG recover y and generation	Paper recycling	Windrow compostin g
+ NAC (Million R/year 2020)	211	320	31	144	179	329	541	114
+ NAC (Million R/year 2030)	1 082	41	1 089	520	250	770	1 006	101
+ NAC (Million R/year 2050)	2 139	129	2 598	1 029	258	1 905	2 024	200

Figure 4.24: National (Positive) NACs in million rand per year, for contemplated measures in the waste key sector for the years 2020, 2030 and 2050 (DEA, 2014b, p. 105)

The positive NAC for the waste sector in the year 2020 is estimated at close to R2 billion, almost R5 billion in 2030 and more than R10 billion in 2050. Higher marginal costs are associated with measures such as anaerobic digestion and composting.

4.4.3.6 Agriculture, forestry and other land use sector

The mitigation opportunities for the Agriculture Forestry and Other Land Use sector include options such as expanding plantations, urban tree planting, rural tree planting (thickets), and restoration of mesic grasslands and biochar addition to cropland. The MACCs for the mitigation measures for the Agriculture Forestry and Other Land Use sector is presented in Figure 4.25, which presents a potential for abatement of more than 5 000 kt CO_2e in 2020. The expanding of plantations may contribute to 45% of these reductions.

The combined marginal cost for the agriculture, forestry and other land use measures is close to R441/t CO_2e abated. Most of the measures have negative marginal cost. However compared to the other options, restoration of mesic lands has a significantly high marginal cost, which makes the combined MACC higher.

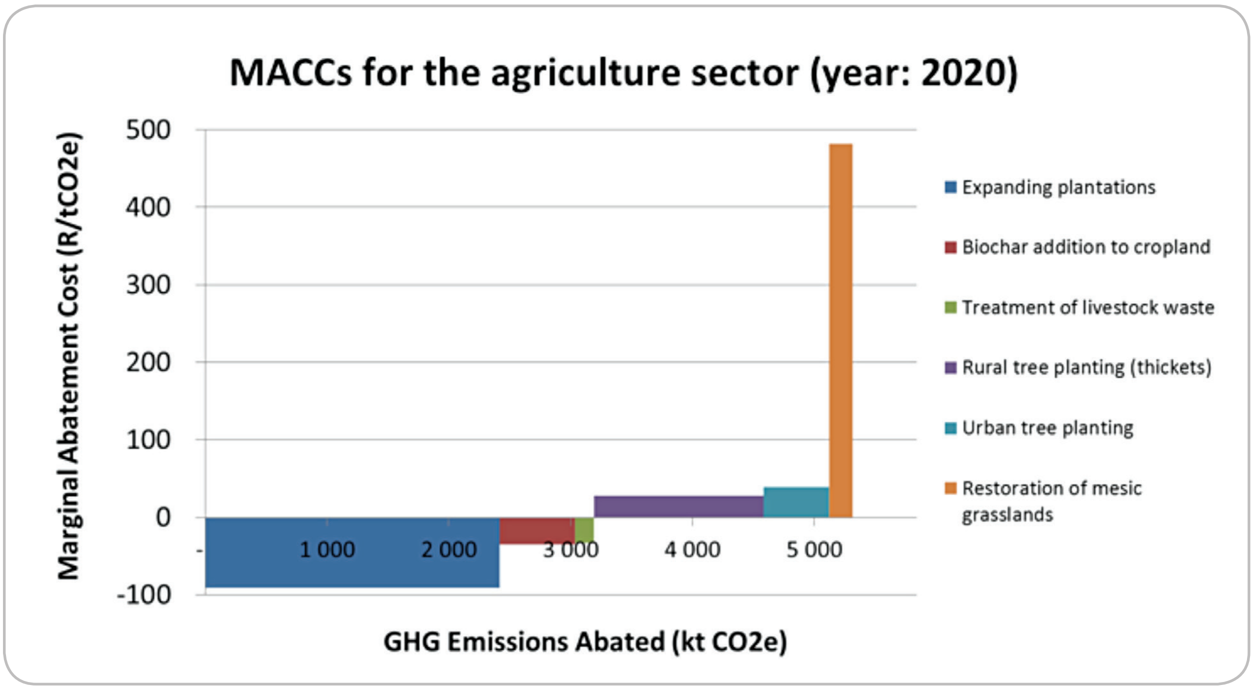
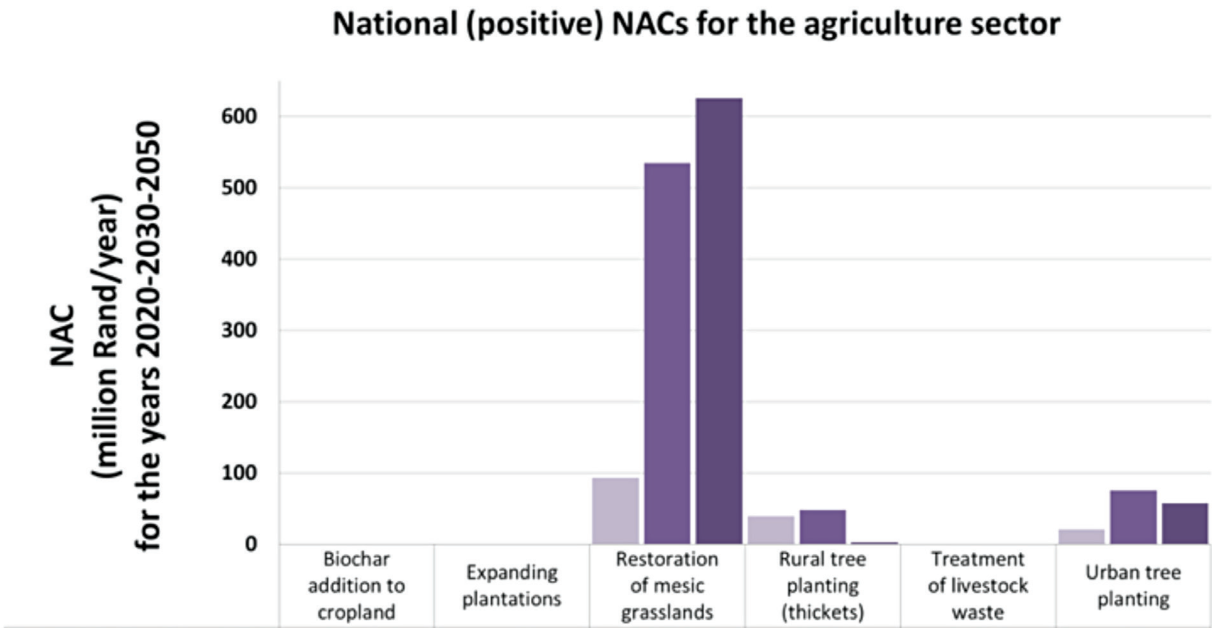


Figure 4.25: MACCs for the mitigation measures investigated under the agriculture, forestry and other land use sector for the year 2020 (DEA, 2014b, p. 105)



	Biochar addition to cropland	Expanding plantations	Restoration of mesic grasslands	Rural tree planting (thickets)	Treatment of livestock waste	Urban tree planting
+ NAC (Million R/year 2020)	- *	- *	93	39	- *	21
+ NAC (Million R/year 2030)	- *	- *	534	47	- *	75
+ NAC (Million R/year 2050)	- *	- *	626	2	- *	57

Figure 4.26: National (Positive) NACs in million rand per year, per agriculture, forestry and land use contemplated measures for the year 2020, 2030 and 2050 (DEA, 2014b, p. 105)

* *The measures considered have a negative marginal abatement cost in this year and therefore result in a negative NAC value which is not plotted in this graph.*

The positive NAC for the Agriculture Forestry and Other Land Use sector in the year 2020 is R153 million, R657 million in 2030 and R685 million in 2050. If all the suggested measures were implemented, almost 90% of this NAC would be allocated to the restoration of mesic grasslands, as depicted in Figure 4.26.

4.4.3.7 National NACs for 2020, 2030 and 2050, per sector

The total net annual cost estimated for the country is presented in Figure 4.27 below. These figures can be interpreted as additional costs on the economy for that particular year, if all the proposed mitigation measures with positive marginal cost were implemented. These numbers are R40.8 billion, R132.5 billion and R273.8 billion, in present value, for the years 2020, 2030 and 2050 respectively.

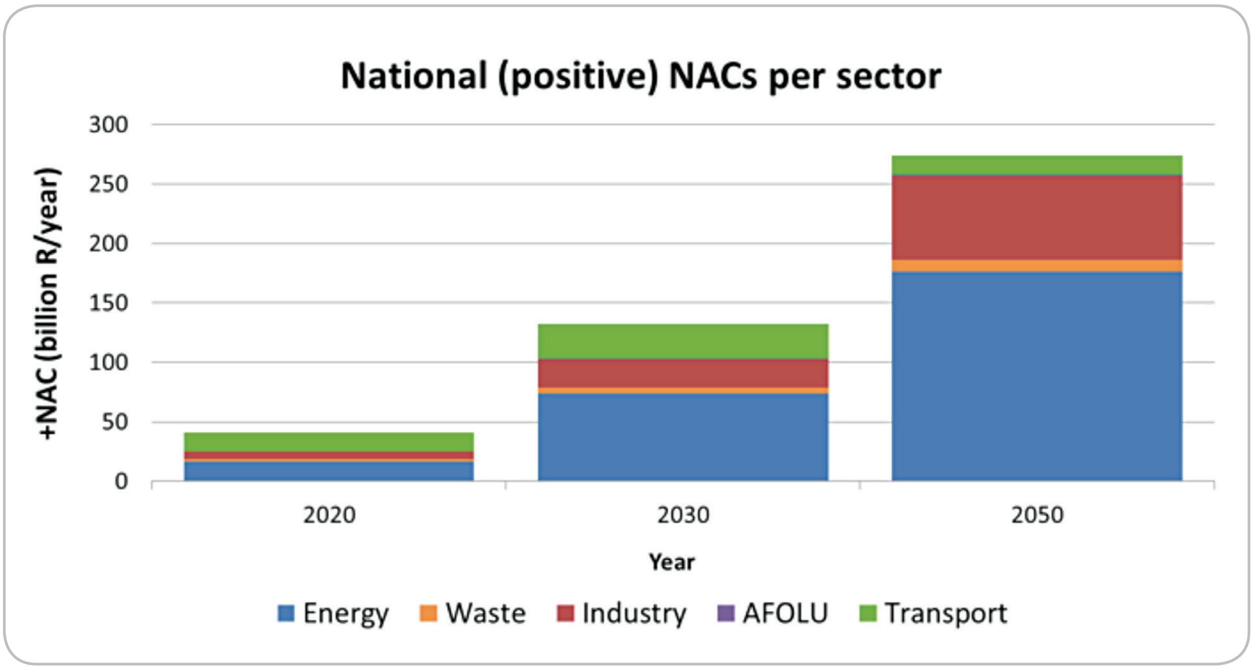


Figure 4.27: National (Positive) NACs in Billion Rand per Year, per Sector, for the years 2020, 2030 and 2050 (DEA, 2014b, p. 105)

4.5 South Africa's Sequestration Potential

South Africa's commitment to emissions reductions entails applying a portfolio of different measures, including those that have the potential to sequester carbon. These opportunities include measures in the Agriculture, Forestry and Other Land Use categories as well as piloting carbon capture and storage in the country.

4.5.1 National carbon sinks

Since reporting in the SNC, much work has been undertaken to establish the extent and potential of the South Africa's national sinks. One of the landmark studies in this regard is the *National Sinks Assessment*. Two biomes have been identified as important, according to various developing land-use based, GHG emission reduction activities. They are the grassland and savanna biomes which together contain approximately three-quarters of South Africa's terrestrial carbon stock (see Table 4.8). They account for over 90% of Gross Primary Production[25] occurring within the country (see Table 4.9). Land-use based climate change mitigation activities should, therefore, be focussed within these biomes, to ensure material contributions are made to the national GHG budget (DEA, 2015c, p. 17).

Table 4.8: Terrestrial total ecosystem organic carbon, soil organic carbon and biomass carbon by land cover class (DEA, 2015c, pp. 9-10)

Land cover class	Area (km^2)	Ecosystem organic carbon	Soil organic carbon	Biomass carbon: woody, herbaceous and litter
		Tera grams of carbon		
Savanna	358 473	2 091	1 943	150
Grassland	224 377	2 392	2 277	119
Nama and succulent Karoo	334 812	593	569	24
Fynbos	61 490	416	348	69
Thicket	27 402	277	212	65
Indigenous forest	857	16	9	6
Desert	7 017	6	6	0
Cultivated[26]	143 948	860	835	26
Plantation forestry	16 952	298	220	78
Settlements, mines, industry[27]	23 119	157	148	12
Other, waterbodies etc.	19 967	64	57	N/A
Total South Africa	1 218 414	7170	6624	548

25. Gross Primary Production refers to the carbon which is taken out of the atmosphere and converted into plant biomass through the process of photosynthesis (DEA, 2015c, p. 12).

26. The area of cultivated land under the biomass carbon category is 138 269 km^2.

27. The area of settlements, mines and industry land under the biomass carbon category is 28 798 km^2.

Table 4.9: gross primary production of terrestrial ecosystems in South Africa (DEA, 2015c, p. 12)

Land cover class	Area (km²)	Gross Primary Production of terrestrial ecosystems (Tera grams carbon/year)
Savanna	358 473	149
Grassland	224 377	145
Karoo	334 812	15
Fynbos	61 490	9
Thicket	27 402	10
Desert	857	1
Forests	7017	0
Total natural ecosystems	1 014 428	329

Climate change is likely to impact terrestrial ecosystems through changes in primary productivity, litter accumulation, decay rates, fire occurrence and intensity, and several other mechanisms that influence terrestrial carbon stocks and associated fluxes (DEA, 2015c, p. 19). It is therefore important to model the effects of predicted climate change and elevated atmospheric CO_2 on terrestrial carbon stocks in South African biomes. The modelling exercise focusses on vegetation types that are important in terms of their contribution to the national carbon stock as well as opportunities for mitigation activities. These vegetation types include: grassland, savanna, woodland, sub-tropical thicket and closed canopy forest ecosystems (DEA, 2015c, p. 20).

The results of the modelling indicate that the impact of projected climate change and elevated CO_2 levels vary between vegetation types and locations. While carbon stocks and sequestration rates are likely to increase for woodland, savanna and grassland ecosystems, they are expected to remain neutral for coastal lowland and scarp forest (DEA, 2015c, p. 23). The modelling exercise was also important in determining the climate change risk to mitigation activities in South Africa. The results indicate that climate change is likely to have a negligible effect on the outcome of mitigation activities across the majority of vegetation types in the country (DEA, 2015c, p. 26).

In addition to mapping carbon sinks it is important to investigate mitigation activities which contribute to terrestrial carbon sequestration, these include:

- Restoration of sub-tropical thickets, forests and woodlands;
- Restoration and management of grasslands;
- Commercial small-grower afforestation;
- Biomass energy;
- Anaerobic biogas digesters;
- Biochar;
- Reduced tillage; and
- Reducing deforestation and degradation (DEA, 2015c, p. 52).

For each of the mitigation activities, potential implementing models, monitoring and reporting aspects, financing, employment implications and institutional support were investigated (DEA, 2015c, p. 5). The assessment on mitigation activities includes the identification of important inhibitory factors that need to be addressed if implementation is to be realised on a national scale (DEA, 2015a, p. 5). These inhibitory factors relate to the applicability of the current international standards and methodologies for carbon offsetting on both forest and non-forest (grassland) systems in South Africa. The process of verifying activities through international carbon standards is complex and can be regarded as an inhibitory factor (DEA, 2015a, p. i).

4.5.1.1 Sequestration potential in agriculture category

The Agricultural Geo-referenced Information System was developed to facilitate access to structured, integrated, relevant, reliable and timely data and information for the agricultural sector of South Africa (Lindemann & Weir-Smith, 2005, p. 43). This system could assist in determining the agricultural carbon sequestration potential within South Africa.

4.5.1.2 Sequestration potential in forestry category

The Institute for Commercial Forestry Research was commissioned by the Department of Environmental Affairs to conduct a scoping study in 2014. The aim of the study was to assess data availability for the development of local carbon estimation equations for all commercial plantation sites and species grown within the three major genera (Pine, Eucalypt and Wattle), as well as the availability and access to grower activity data (Dovey, 2014, p. 3).

The scoping report reviewed the existing data and available information on tree, forest floor litter and soil carbon in South African commercial forest plantations. Most of the data sets were made available by the Institute for Commercial Forestry Research and the CSIR (Dovey, 2014, pp. 3-4). The report included consultations with forestry companies to identify existing commercial forest plantation tree growth information. Carbon stock estimation equations were subsequently developed, using existing commercial forest management information. This report marks an important progression from work reported onin the SNC, as it allowed for industry level estimation of carbon stocks in commercial forest plantations (Dovey, 2014, p. 6).

The scoping report recommends that further research in carbon stocks be undertaken in order to improve the level of carbon stocks estimations suitable for monitoring change over time. The study also noted that a robust methodology to account for carbon stocks in commercial forest plantations does not exist in South Africa, and this is hampering developments in the sector. Data and information from commercial forest plantations were noted to be of high quality, and their use in determining carbon stock estimations was endorsed (Dovey, 2014, p. 8).

4.5.1.3 Sequestration potential in other land use category

The *Spatial Planning and Land Use Management Act* is enabling legislation that could identify and support carbon sequestration projects within the other land use sector. This legislation implies a centralisation of land data, which would cover land use and land use change. The National Land Cover Data Set would also be useful for determining carbon sequestration projects, specifically within the Other Land Use category.

4.5.2 Carbon capture and storage

Carbon Capture and Storage is an integrated technological process which involves off taking a concentrated stream of CO_2 from a source. It is then compressed and transported to a storage location. Storage locations are typically geological formations into which the CO_2 can be pumped and trapped (often deep beneath the sea bed).

The South African government has mandated the development of Carbon Capture and Storage technology through various official channels. One of these being the *National Climate Change Response White Paper*, which lists Carbon Capture and Storage as one of the eight Near-term Priority Flagship Programmes. Carbon Capture and Storage is also included in both the *National Development Plan* 2012-2030 and the LTMS.

The South African Centre for Carbon Capture and Storage was therefore established in 2009, in partnership with national and international stakeholders. It acts as a ring-fenced division within SANEDI, which in turn reports to the Department of Energy. Some of the public, private and international partner organisation include; Eskom, Norway, SANEDI, Sasol, Alstom, AFD, AngloAmerican, Exxaro, PetroSA, Total and Xstrata (SANEDI, 2015, p. 7). The centre is supported by the South African Bureau of Standards Technical Committee 265 which mirrors the work of the ISO Technical Committee 265.

The South African Centre for Carbon Capture and Storage is currently implementing the South African Carbon Capture and Storage Road Map in order conclusively prove the technology. The Road Map entails a five phase process, which aims to attain a commercial rollout of the technology by 2025 (SANEDI, 2015, p. 4).

Phase 1 of the Road Map is complete, and entailed a preliminary investigation into the theoretical potential for CO_2 capture and storage in South Africa. Phase 2, which has also been completed, quantified and mapped the geological storage potential for the country. It was determined that South Africa has a theoretical storage capacity of 150 Gt which more than caters for the 4 Gt capacity required annually to store 40 Mt (~10% of national emissions) for the next 100 years.

Currently, Phase 3 is being implemented where pilot projects are planned for both a CO_2 capture plant and CO_2 storage operation. Under the CO_2 storage pilot, the first injection of 10 000 tonnes of CO_2 into a geological formation is scheduled for 2017. This will be a first for South Africa and will serve as a test for leakages and other structural challenges.

Conditional on the success of the prior phases, Phase 4 plans to implement an integrated demonstration involving capture, transport, injection, storage and monitoring. Following this, the final phase is intended to be a commercial roll out of Carbon Capture and Storage in South Africa.

Completion of the Road Map is contingent on various financial and regulatory conditions. While the World Bank has indicated that it will contribute funds towards some planning aspects of the CO_2 capture plant, additional funds are required.

4.6 Potential GHG Mitigation Project Briefs

South Africa is developing various climate change mitigation projects to meet the country's GHG reduction targets. The following potential GHG mitigation project briefs are therefore presented with the aim of facilitating their advancement into full project proposals, which could be presented to potential funders for further development.

4.6.1 Nationally appropriate mitigation actions

The UNFCCC defines Nationally Appropriate Mitigation Actions (NAMAs) as:

any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative. They can be policies directed at transformational change within an economic sector, or actions across sectors for a broader national focus. NAMAs are supported and enabled by technology, financing, and capacity-building and are aimed at achieving a reduction in emissions relative to 'business as usual' emissions in 2020 (UNFCCC, 2014).

NAMAs in South Africa are embedded within the Near-term Priority Flagship Programmes. The Flagship Programmes comprise scaled-up climate change measures which have completed demonstration phases. In this way, they represent South Africa's top-crop of leading climate change response measures. Flagship Programmes are intended to be catalysts for additional action in key sectors, at a sufficiently ambitious level, so as to achieve critical mass and economic transformation. This makes them the ideal platform to develop NAMAs. The Flagship Programme's steering committee oversees, develops and approves NAMAs for submission to the UNFCCC.

The two NAMAs described below are under development in South Africa. They require implementation support for their advancement and related mitigation project briefs could be prepared and presented to funders for further development.

4.6.1.1 Energy efficiency in public buildings

This vertically-integrated NAMA entails energy efficient lighting, water heating and building refurbishments, specifically in government owned (Including provincial and local) buildings. This NAMA was recently preselected by the NAMA Facility Board as one of the projects that will be funded, subject to the fulfilment of the conditions outlined by the NAMA Facility Technical Support Unit.

Administrators: Department of Energy, Department of Public Works and Department of Environmental Affairs have established an Interdepartmental Task Team on Energy Efficiency which steers, guides and oversees the implementation of the vertically-integrated NAMA.

Purpose: The objective of Energy Efficiency in Public Buildings Programme NAMA is to mobilise public and private sector investments in public (government-owned) buildings. The two primary tools with which it aims to meet its objectives are:

- The provision of a Project Preparation Grant Facility to enable provinces and municipalities to develop bankable energy efficiency investment plans for their public buildings. A supporting Guarantee Fund will assist private Energy Service Companies obtain loans for implementing these plans; and
- A Service Desk will advise provinces and municipalities in the selection of suitable energy efficiency interventions in public buildings and access to the required financial support mechanisms.

Co-benefits: The vertically-integrated NAMA has the potential to stimulate private sector involvement in profitable, energy efficient retrofits in public buildings. This will be facilitated by creating an increased demand for the related services, which could, in turn, lead to increased competition and technical competence countrywide.

Estimated emission reductions: 0.38 $MtCO_2e$ annually.

Diversion of solid waste from landfills in selected municipalities

As a measure under Government's Waste Management Flagship Programme, the main objective of this NAMA is the promotion of diversion of waste (especially organic waste) from landfills in local municipalities to mitigate environmental impacts such as the greenhouse gas effect. Such measures will contribute to the country's efforts to transition to a lower-carbon economy and society (DEA, 2015b). The measure initially will be rolled out in six local municipalities, followed by rollouts in 10-20 municipalities thereafter.

Administrators: Department of Environmental Affairs and the South African Local Government Association.

Purpose: Develop scaled-up waste hierarchy programmes that utilise appropriate waste treatment technologies, suitable for each of the identified municipal areas. These include:

- Waste-to-energy, especially landfill gas utilisation: this is the lowest hanging mitigation programmes in existing landfills;
- Diversion of organic waste away from landfills: this is the long-term approach to mitigating climate change in the waste sector;
- Proper implementation of the waste hierarchy: supports climate change response, waste management and sustainable development simultaneously

There is need to scale up existing response programmes but also to systematically combine various mixtures (combination mechanical, biological, thermal technologies)

Co-benefits: Promote proper waste management practices while contributing to the green economy by creating green jobs and energy products and services.

Estimated emission reductions: not available but can be estimated.

4.6.2 Carbon offsetting: forest and grassland systems

Land-based mitigation opportunities include the restoration and management of grasslands, rehabilitation of the thicket and reducing emissions from deforestation and forest degradation through planning and regulation, among others. The Department of Environmental Affairs undertook a research study in 2015 to assess the applicability of the current international standards and methodologies for carbon offsetting on both forest and non-forest (grassland) systems in South Africa. The opportunities for carbon offsetting projects in these subsectors are yet to be explored and could result in meaningful mitigation projects.

South Africa's above and below-ground woody-plant and herbaceous biomass pools are demonstrated in Figure 4.28, which provides an indication of the areas in which such projects could be situated.

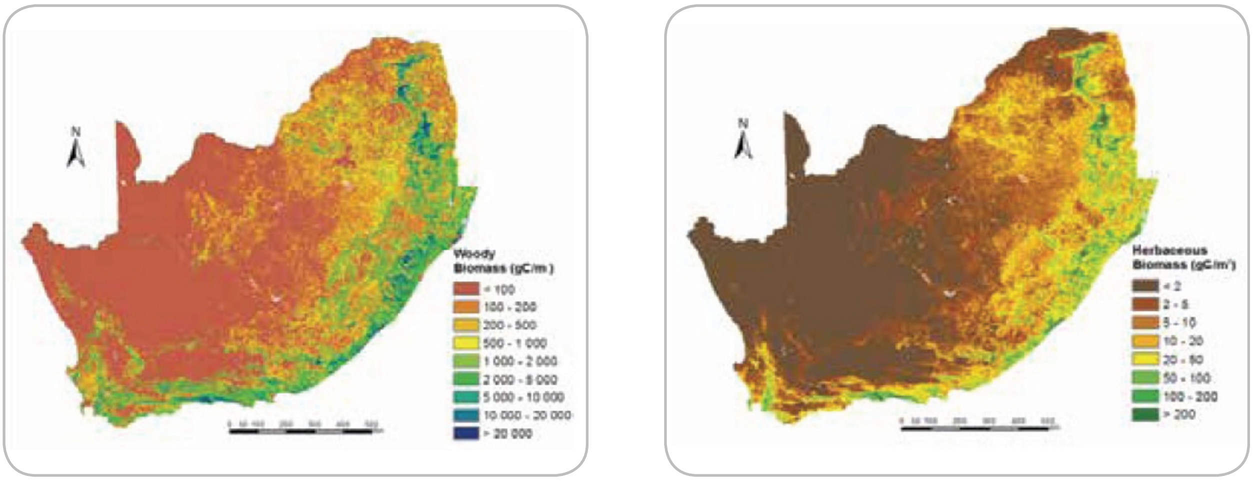


Figure 4.28: The map on the left depicts South Africa's above and below-ground woody-plant pools and the map on the right depicts South Africa's above and below-ground herbaceous biomass pools (DEA, 2015c)

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5 Other information relevant to the convention

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5.1 Technology Needs Assessment (TNA)

5.1.1 Institutional arrangements for the TNA

South Africa has an advanced National System of Innovation (NSI), which provides the necessary framework for the implementation of the TNA. The NSI consists of six sectors that intersect at the national level as demonstrated in Figure 5.1.

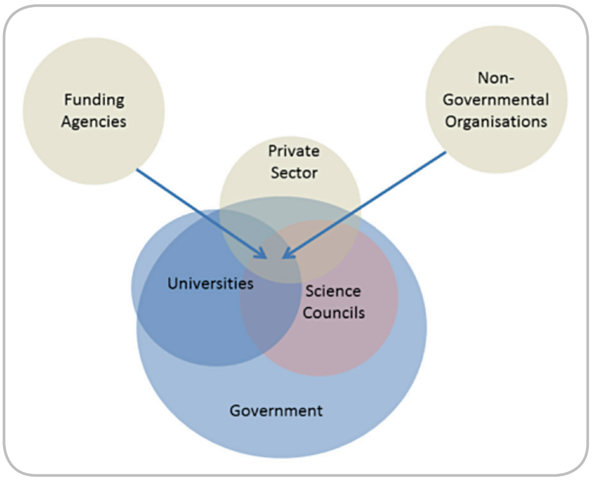


Figure 5.1: Institutional arrangements of the NSI (Adapted from Baatjies, 2013)

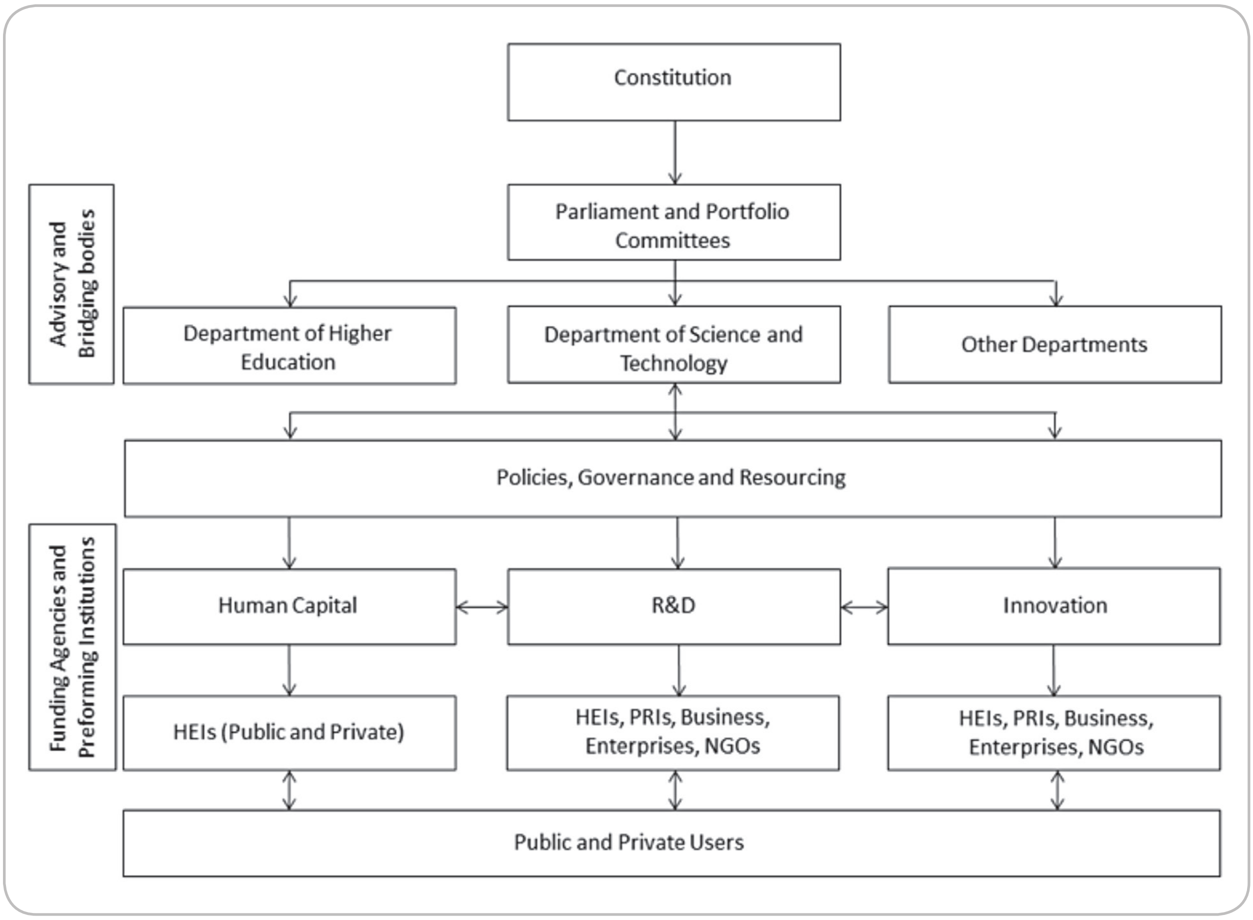
The various national sectors and their functions are as follows (NACI, 2006, Baatjie, 2013). Note that all government departments, in addition to the functions discussed in the following bullets, have the responsibility of formulating policy and providing advice on it, and aspects of which are relevant to the TNA are discussed in the Section 5.1.2

- The Department of Science and Technology (DST) is responsible for overseeing the resourcing and management of public NSI institutions and has direct line management responsibility of science and technology. The DST is involved in several new initiatives to increase the coordination of the NSI. There are several advisory bodies with functions ranging from extensive and statutory to additional and self-initiated. However, only the Council on Higher Education (CEHE) and the National Advisory Council on Innovation (NACI) have statutory Ministerial advisory functions;
- The Department of Higher Education has the role of supporting and producing a pool of high level human resources;
- The Departments of Agriculture, Forestry and Fisheries; Health; Energy; Environmental Affairs; Mineral Resources; Trade and Industry; Water and Sanitation and other government departments fund and perform research and development and focus on a number of core functions such as agriculture health, weather and climate services, the promotion of innovation within industry, energy research and environmental management;
- Higher Education Institutions (HEIs) are the main institutions that contribute to human capital development, followed by science councils. HEIs also conduct basic research and account for about a quarter of the national research expenditure and about a third of full-time equivalent human resources are engaged in research;
- Science councils contribute to human capital development (in collaboration with HEIs because the science councils do not themselves offer degrees but may provide co-supervision of students engaged in research degrees), perform strategic basic research, directed applied research and develop technologies. There are currently 12 major public research institutions some of which are the Agricultural Research Council (ARC), Council for Scientific and Industrial Research (CSIR), Human Sciences Research Council (HSRC), Mintek, Medical Research Council (MRC), the South African Bureau of Standards (SABS), the South African Weather Service (SAWS), the Council for Geoscience, the South African National Energy Development Institute (SANEDI), the South African Biodiversity Institute

(SANBI), the Marine and Coastal Management division (a division of the Department of Environmental Affairs) and the Africa Institute of South Africa (AISA);

- The private sector, including industry and state enterprises such as Eskom (the national energy utility company), where knowledge is transformed into innovation;
- The non-governmental organisation (NGO) sector conducts research in areas of high public interest (such as social or environmental research) or in the event of market failure; and
- Funding agencies, which include NGOs, many private companies, institutions and international agencies.

Figure 5.2: Political context and institutional arrangements within the NSI.



To facilitate and support innovation initiatives in all sectors of the South African economy in particular, as relevant to the TNA, in climate sensitive sectors or those sectors that might impact the climate, the NSI institutions are arranged in the national political context as shown in Figure 5.2. At the time of producing this communication to the UNFCCC, South Africa was in the process of updating its TNA, as elaborated further below. Unlike previously, the current update will allocate considerable resources to a detailed and in depth characterisation of the NSI, as an existing environment, to identify barriers to technology transfer and deployment. Figure 5.2 shows the institutional arrangements in the context of which the TNA outcomes will be implemented, with the ultimate aim of contributing to South Africa's transition from a resource-driven economy to one that is characterised by innovation and knowledge (DST, 2008a). More specifically, the TNA will contribute the various grand challenges as identified in the country's innovation plan. The Technology Action Plan (TAP) that will result from the new TNA process will then form the basis of a more specific mapping of each technology, identified those stakeholders who are for the relevant policy level decision making, those who will participate in the market chain from development to final use, and investors that currently finance these kinds of technologies (UDP, 2015).

The institutional arrangements, as presented by the NSI framework, operate in the global context of the Climate Technology Centre and Network (CTCN); in as far as climate technology transfer issues are concerned. The CTCN is the implementing arm of the Technology Mechanism, which was established during the sixteenth Conference of the Parties (COP 16), that was held in Cancun in 2010. The CTCN was established the following year and it officially opened for business in 2013 at COP 19 in Warsaw. It exercises its global footprint via three mechanisms namely its National Designated Entities (NDE) which each and every country in the world must nominate, its fourteen consortium partners (CPs) spread out evenly around the globe, as well as its network of organisations such as universities, NGO, public or private entities. The NDEs are officially network members, whereas the CPs are not. CSIR, which is largest PRI in the NSI is one of the CTCN CPs and it is one of three CPs located on African soil. The Department of Environmental Affairs (DEA) nominated the Department of Science and Technology (DST) as South Africa's NDE. In order for the NDE to perform its duties and functions optimally, one of the required pieces of information in an up to date TNA.

South Africa's NDE will set out to accelerate climate technology transfer in the country and has established its operational processes, including an advisory committee comprising representations from all relevant government departments, operational organisation structure and tools, such as periodic technical assistance project calls and project assessment procedures.

5.1.2 Policies supporting the TNA

The National Development Plan (NDP) provides the platform for South Africa to tackle the issues of poverty and inequality that face the country. Specifically the NDP provides a long-term perspective to guide the country's development trajectory such that poverty is reduced by 2030. The overarching mechanisms to achieving this is envisaged through measures aimed at reducing unemployment and building the country's economy. Other core objectives of the plan are to ensure the provision of services to improve the lives of South African people and the economy. These objectives focus on individuals, households and industry, and include access to improved public transport which is both safe and affordable; increased access to electricity for more households, as well as ensuring nutritional security and food security at a household level. Ensuring a secure energy supply to support industry and obtaining a food surplus are also among the important objectives of the NDP.

Government sectoral plans are structured to ensure long-term alignment with the NDP, with sectors typically developing short-term plans (up to 5 years) that are implemented and updated at regular intervals in line with the 2030 vision of the NDP. The Agriculture, Industrial and Energy sectors are among the key sectors identified in the NDP as being critical to achieving the economic developmental goals. The industrial and agricultural sectors are recognised as important sectors for employment, with the latter also being key to food security since it is often the primary economic activity in rural areas. The 5-year South Africa Agricultural Policy Action plan and the periodical Industrial Policy and Action Plans aim to address the challenges facing these sectors. The National Energy Act No 34 of 2008 (RSA, 2008) makes provision for the adoption of measures that provide for the universal access to appropriate forms of energy or energy services for all the people at affordable prices. In addition to promoting economic growth, the NDP also aims to promote the health and well-being of all South Africans and to provide affordable access to quality health care by 2030. The National Department of Health Strategic Plan (NDHSP, 2014) sets out the strategic goals for the period of 2014-2019 in light of supporting these NDP priorities. The water sector has impacts on the agricultural, industrial, and energy sectors, as well as human health and constraints on the water sector will have cross-cutting implications on the other sectors. The Strategic Framework for Water Services Framework therefore aims to ensure all South Africans have access to an adequate and affordable supply of clean water and sanitation services.

While the emphasis of the NDP is on economic growth and development, it does acknowledge the need to protect the country's natural environment. The NDP further recognises that climate change is already having an impact on South Africa with marked temperature and rainfall variations and rising sea levels, and this is likely to affect the ability of the country to meet its developmental goals.

The National Climate Change Response Policy (NCCRP) White Paper (DEA, 2011a) provides a policy framework for country's response to both climate change mitigation and adaptation. Interventions proposed in the NCCRP aim to ensure that the country is able to manage impending climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity (DEA, 2011a). To mainstream climate-resilient development, all government sectors have to ensure that all policies, strategies, legislation, regulations and plans are in alignment with the NCCRP (DEA 2011a). All national departments are thus further mandated to develop sector specific climate change adaptation plans, as outlined in Chapter 3. In addition to the development of climate change adaptation sectoral plans the country also recognises the need to prepare for climate related disasters and mitigation of greenhouse gas (GHG) emission. Furthermore the need to focus on activities and technologies that have the most potential to mitigating GHG and supporting efforts to reducing vulnerability to climate change to enable the country to meet its development priorities outlined in the NDP is also recognised.

5.1.3 Evolution of the TNA process in South Africa

As reported in the SNC, the very first TNA was commission by the DST in 2007 and was conducted by the Council of Scientific and Industrial Research (CSIR). This process followed the UNDP (2003) and Gross *et al.* (2004) guidelines for conducting TNAs globally. The second phase of the development of South Africa's TNA included extensive stakeholder consultation to prioritize technologies that the country needs for climate change mitigation and adaptation (DST, 2007) and this was later updated due to other mitigation priorities that were identified by the Long Term Mitigation Scenarios (LTMS, Winkler and Boyd 2009).

The TNA (DST, 2007, 2010) identified five responses to climate change from a technology needs assessment perspective and these are discussed in turn as follows:

- **Adaptation:** The most important climate change adaptation sectors in South Africa in the 2007 TNA were human health, agriculture, forestry and other land use (AFOLU), water resources, and the built environment and infrastructure. The relevant technologies for each sector are given in Table 5.1.

Table 5.1: Prioritised adaptation technologies for the 2007 South African TNA

Human Health	AFOLU	Water resources	Built environment and infrastructure
• Provision of water supply and sanitation; and • Control of the spread of vector-borne diseases.	• New crop species and cultivars; • Information technology; • Macro-economic • Pest management; and • Vulnerability research. diversification and livelihood in rural areas;	• Technologies that promote water efficiency.	• Climate- sensitive building design.

- **Mitigation:** The mitigation sectors identified by the 2007 TNA were energy, AFOLU and transport; with energy further divided into three subsectors, namely, electrical energy generation. Industry and mining, and waste management. The mitigation technologies considered are presented in Table 5.2

Table 5.2: Prioritised mitigation technologies in the 2007 South African TNA

Energy	AFOLU	Transport
• Solar power. • Clean coal technologies • Wind power • Boiler improvements • Promotion of source reduction, recycling and reuse	• Conservation agriculture; • Control of biomass burning in wildfires (including fires).	• Fuel – efficiency improvements

As noted above, results from the LTMS showed that there was a need to update the above mentioned technologies for climate change mitigation in the country.

- Other issues related to climate technology needs: The South African TNA process also identified financial mechanisms and other cross cutting issues as important topics to be considered in the determination of the country's climate technology needs. Financial mechanisms included incentives for energy efficiency, incentives for renewable energy and disincentives for high fuel consumption vehicles. The advent of the LTMS result rendered these more relevant and important as the LTMS raised the awareness of the role that energy efficiency technologies may play in climate change mitigation in the country, as noted in the SNC (DEA, 2011b). Other cross cutting issues considered in the 2010 TNA were improved data management, processing and integration; improved communication and response in disaster management; and networks for information sharing and data integration.

5.1.4 Barriers to technology transfer and envisaged barrier analysis

The aim of the CTCN is to accelerate the transfer of environmentally sound technologies through technical assistance, capacity building through knowledge sharing and enhancing global corporation and networking. These services of the CTCN largely address the barriers to technology transfer. However, domestic measures as identified by a detailed barrier analysis (to be discussed further below) should be conducted to optimise domestic systems as much as possible. The current update of the TNA will build on barrier analysis findings of the 2007 TNA as listed below. The barriers may be categorised (UNDP, 2015) and listed in Table 5.3 below, together with suggested initiatives for creating an enabling environment for technology transfer (DST, 2007). These were listed in the SNC as informed by the TNA (DST, 2007), but not categorised. These are relevant to the South African state of affairs.

Table 5.3: Typical categories of barriers to climate technology transfer and examples

Category of	Example of barrier
Economic and financial	• High cost of capital; • Low expected rate on return; • Technology investment considered risky (e.g. due to few prior local reference examples).
Market conditions	• Few local suppliers of auxiliary goods and services; • Market control by industry; • Uneven playing field (e.g. due to subsidies on competing technologies);
Legal and regulatory	• Bureaucracy; • Conflict if interests; • Highly controlled sector; • Insufficient legal framework; • Political instability; • Rent-seeking behaviour; • Technology opposing incumbent actors (such as utilities).
Network	• Incumbent networks being favoured; • Limited distribution networks; • Weak connectivity between actors.

Category of	Example of barrier
Institutional and organisational capacity	• Few professional institutions; • Limited institutional capacity; • Limited management and organisational skills
Human skills	• Unskilled technical personnel and inadequate training
Social, cultural and behavioural	• Consumer preferences and social biases; • Dispersed settlements; • Traditions.
Information and awareness	• Inadequate information; • Lack of awareness; • Missing feedback.
Technical	• Few local reference examples; • Poor technology quality/performance.
Other	• Environmental impacts; • Physical infrastructure conditions

5.1.5 Process to update the current TNA

5.1.5.1 Development priorities and sector prioritization

At the time of writing, the DEA and DST had recently commissioned a study to update the TNA for South Africa. This was the responsibility of the CSIR. The implementation of the update began in May 2016 and will be completed at the end of October 2017. Since 2007, several critical studies have been that have a direct bearing on the contents of the new TNA. These studies are a direct response to the National Climate Change Response White Paper and National Climate Change Response Strategy. These include the LTAS, LTMS, the latest GHI, MPA, Climate Change Mitigation Technology Implementation Plan (DEA and DST, 2015), Global Change Research Plan and departmental plans. Analysis of these documents has revealed that the sectors and subsectors that must be characterised in terms of existing technologies and potential impact on sustainable development priorities for mitigation and adaptation. The TNA presents an opportunity to link climate technology transfer needs for South Africa to development in an integrated manner. The sectors considered in the update in their entirety are:

- **Adaptation:** Agriculture; Biodiversity; Commercial Forestry; Human Settlements; and Water;
- **Mitigation:** AFOLU; Energy; Industry; Transport; and Waste.

These are clearly broader than those considered in the previous TNA and therefore will be more inclusive. On the basis of this sector characterization (Table 5.4), which is the first value added to the update of TNA, a broader technology prioritization process that will attempt to minimise biases will be conducted. While sector prioritisation was conducted on a sector by sector basis, it is important to note that key linkages among sectors were also considered in terms of interactions among adaptation and mitigation priorities, as well as in terms of cross-cutting issues among sectors.

Table 5.4: Results from the sector prioritization

Sector/Priority	Adaptation	Mitigation
1	Water	Energy
2	Agriculture	IPPU
3	Biodiversity	Waste
4	Human Settlements	AFOLU
6	Forestry	
7	Fisheries	

Climate change adaptation and mitigation efforts, including the technology transfer that informs them, should be linked to developmental priorities. The update of the TNA will therefore take this into consideration.

5.1.5.2 Proposed Technology Prioritization

The second value added to the current update of the TNA is a better informed and broader technology prioritization process, particularly as a result of the numerous recent studies pertaining to mitigation. Depending on the outcome of the prioritization of the sectors, the technology prioritization will be conducted on a sector by sector basis, and will be informed by the expertise of the sector working groups that will be formed during the extensive consultation process. Mitigation technology prioritization has been conducted by the Climate Change Mitigation Technology Implementation Plan, which, based on the MPA outcomes, resulted in shortlisted short, medium and long term technologies as shown in Table 5.5.

Table 5.5: Climate Mitigation Technologies time frames

Timeframe	Technology
Short term (< 5 years)	• Energy efficiency lighting • Variable speed drives and energy efficient motors • Energy efficient appliances • Solar water heaters
Medium term (5 to 10 years)	• Hybrid electric vehicles • Solar photovoltaics (PV – centralised and decentralised) • Wind (onshore) • Advanced biofuels
Long term (10 years and beyond)	• Carbon Capture and Storage (CCS) • Nuclear Pressurised Water Reactor (PWR) • Smart grids • Energy storage technologies

The update of the TNA will build on the outcomes of the Climate Change Mitigation Technology Implementation Plan. The technology prioritisation process will involve ranking climate change mitigation and adaptation technologies which are most important to transfer in the context of these technologies playing a key role in supporting the effective implementation of climate change project initiatives in the country. A technology prioritisation process will be conducted on a sector by sector basis using technologies selected based on the country's priorities and ranked within each sector through a series of technology prioritisation workshops using the Multi-Criteria Analysis (MCA) approach (described by Dodgson *et al.* (2009)) which was outlined in a guideline for countries conducting a technology needs assessment (Haselip *et al.*, 2015). The technologies selected are viewed through a climate change lens, with cross-cutting considerations also included to illustrate key linkages among sectors.

5.1.5.3 Barrier analysis

The previous phase of the South African TNA went as far as identifying the barriers to technology transfer and making suggestions of how to address them as noted in Section 5.1.3. In the current update a proper barrier analysis will be conducted. It is absolutely critical for the barrier analysis to categorise and characterise the prioritized technologies. For such an analysis the technologies need to be categorised as (UDP, 2015) market (consumer and capital) and non-market (publicly provided and other non-market) goods. Consumer goods are those that are specifically intended for the mass market. The mass market includes households, businesses and institution, whereas capital goods are machinery that is used in the production of goods such as consumer goods and electricity. Technologies in the publicly provided goods category are often (although not always) publicly owned and production of goods and services are available (free or paid) to the public or to a large group of persons. Finally other non-market goods are non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs.

As noted in Section 5.1.1, South Africa already has a sophisticated system of innovation, which provides the general institutional arrangements for the operationalization of the TNA. More specifically, the NSI also provides an environment for the development and transfer of the prioritized technologies. In the update of the TNA, the NSI will be characterised for the purpose of understanding the barriers to the acceleration of technology implementation. Different categories of technologies require different types of analysis that build on the characterization of the NSI. These include market mappings, which is followed by the identification of barriers to technology transfer, the identification of measures to remove these barriers by putting policy improvements in place, strengthening relevant organisations and institutions in the NSI, and facilitating technology development. To address aspects of this last issue South Africa has developed a Framework for Engagement in National Technology Localisation Actions (DST, 2008b). Technology localisation is the increase in local content of technology inputs in imported systems. This implies the expansion and development of the local supplier base to enter the supply chains of the foreign Original Equipment Manufacturers (OEMs), and hence requires the supply of globally competitive components, subsystems and services. The CSIR was nominated as the custodian of the Technology Localisation Implementation Unit (TLIU). Since the DST introduced this technology localisation framework, various climate technology localisation studies have been commissioned by other government departments, name the localisation of photovoltaic technologies (DTI, 2013) and wind energy technologies (DTI, 2015).

5.1.5.4 Technology Action Plan

In as far as the development of the mitigation components of the envisaged Technology Action Plan (TAP) is concerned; the latter will build on the efforts outlined below (Table 5.6). The Climate Mitigation Implementation Plan (DEA and DST, 2015) presented a high-level implementation plan for a small selection of greenhouse gas mitigation technologies in South Africa (see Table 5.5 for their timeframes). The implementation plan highlights that for almost all of the technologies considered there is already substantial activity underway including research and development and in many cases roll out. Furthermore, for many of the technologies one or more plans, industry strategies and critiques of previous attempts at roll outs have already been developed. In some cases, there is not necessarily agreement on the proposed findings and approaches. One of the recommendations of the DEA and DST (2015) was that rather than DEA and DST develop additional programmes to support roll out of such technologies, they rather explore ways in which information about existing mitigation technology initiatives can be disseminated beyond the departments (and sometimes even units within departments) and entities that are directly involved in the initiatives.

It was also noticeable that the majority of implementation plans reviewed did not explicitly consider greenhouse gas mitigation, and in particular how the roll-out of technologies can be influenced to ensure maximum mitigation impact. A mechanism or initiative to facilitate collaboration among existing activities related to specific technologies, and to provide a strategic overview on the role the technologies can play in the larger portfolio of mitigation measures and approaches that needs to be deployed to meet South Africa's mitigation ambitions, is therefore also worthy of consideration. Policymaking by its nature is complex and requires a trade-off between multiple societal objectives. Without a mechanism to place the roll-out of specific technologies within the larger South African mitigation policy context, it is likely that even technologies that are inherently low carbon will not be deployed in a way that maximises mitigation outcomes (subject to other policy constraints). In fact, this risk is particularly acute for inherently low carbon technologies, since it is taken as a given that their deployment will lead to positive mitigation outcomes and the emphasis can prematurely move to reaping secondary benefits.

Table 5.6: A summary of the key actions to support roll out of the technologies considered in DEA and DST (2015)

Technology	Actions required to support large scale roll-out
Energy Efficient Lighting (LEDs)	• Competitiveness of expanding the local industry needs to be assessed. A full study of the LED value chain is required to identify additional areas where South Africa could have a competitive advantage (clearly outlining the sources of any competitive advantages) and where job creation could be maximised • Availability of less energy efficiency alternatives could be restricted or the use of taxes to make them more expensive could be expanded • Distribution schemes where LEDs are distributed at no or low cost would increase uptake and change purchasing behaviour • Public awareness campaigns to promote the life cycle benefits of LEDs would increase the uptake thereof • Activities undertaken to support this technology need to align with current activities of IESSA, SANEDI, SABS, the BRICS solid state lighting group and local universities, among others • DST, DoE or other relevant institutions should monitor developments in the use of LEDs in data transmission applications, and identify opportunities in the global markets
Variable Speed Drives and Energy Efficiency Motors	• The focus in South Africa should be on promoting uptake of the technologies, rather than on local manufacture • Awareness programmes are critical to promoting technology uptake. This includes emphasising the importance of technologies being fit for purpose, and being selected in the context of broader system optimisation • Subsidies, tax credits, rebates or differential import tariffs could help overcome cost differentials between more and less efficient motors

Technology	Actions required to support large scale roll-out
Variable Speed Drives and Energy Efficiency Motors	• Training programmes are required to ensure that technicians are able to select appropriate motors, and for servicing particularly of VSDs (although recognising that training is specific to individual manufacturers' products)
Energy Efficient Appliances	• Focus needs to be on consolidating and growing the local refrigerator industry as there is potential for value add and increasing penetration in local and African markets • The viability of a refrigerator recycling plant needs to be explored as this is central to removing older less efficient models from the market • Establish broader incentivesfor disposal of older refrigerators. Incentives aimed at lower end of market/first time buyers could be considered • Mandatory energy efficient standards and labelling requirements need to be implemented efficiently and enforced
Solar Water Heaters	• Quality issues need to be addressed. Developing a self-regulating body to monitor and enforce quality of installations and follow-up services would help in this regard • Skills shortages also need to be addressed through expanding technical training initiatives • Solar water heater standards need to be developed and implemented to go beyond current short-term performance standards and address issues with system quality (long-term performance) and quality of installations • Design and implementation of local content requirements need to be reviewed to ensure they are supportive of the development of quality local manufacturing • A review of the National Solar Water Heater Programme is urgently required, and the long-term future of the programme needs to be outlined, to provide certainty to the industry • Public awareness campaigns are required to promote the uptake of SWHs • Roadmaps under development may help to provide strategic direction for the industry
Hybrid Electric Vehicles (HEV)	• Consumer awareness programmes are required to support the transition through HEVs and ultimately into PHEVs and EVs • HEVs could be included in incentives aimed to increase uptake of PHEVs and EVs in the EVIRM • Non-financial incentives like access to public transport lanes and preferential parking, amongst others, could be used to support uptake of HEVs, PHEVs and EVs. • HEVs could be temporarily exempted from vehicle import duties
Solar PV	• Certainty for the local utility scale industry needs to be provided through the REIPPP procurement targets and timelines • Electricity sector planning models should be updated to accommodate bundles of renewables (e.g. solar and wind energy together) to potentially address intermittency concerns • The issues of whether local content requirements will lead to a net benefit to the industry need to be explored in detail • Concerns regarding availability of grid connections must be addressed

Technology	Actions required to support large scale roll-out
Solar PV	• For distributed solar PV, funding models (for both PV installations and network operator models that decouple link between electricity supply and revenues), local content requirements, incentives, market rules and regulations, certification, training, and ways to encourage PV connections to the grid (i.e. prevent a large-scale move to off-grid applications) are all aspects that need to be addressed
Wind (onshore)	• Certainty needs to be offered to the local utility scale industry by providing certainty on the future of the REIPPP procurement targets and timelines • Updating of electricity sector planning models to accommodate bundles of renewables (e.g. solar and wind energy together) to potentially address intermittency concerns needs to be considered • The potential competitiveness of the local wind manufacturing industry needs to be established, which will help to inform local content requirements specifications in new wind procurement rounds • Concerns relating to the availability of grid connections need to be addressed • For small and medium wind turbines, a scheme that links export performance to local content requirements should be developed • An overarching strategy providing direction to the wind energy market in South Africa should be developed, similar to the way that, for instance, the Solar Energy Technology Road Map is expected to provide guidance for solar technologies
Advanced Biofuels	• Public-private partnerships and government support are required to commercialise technology – including support for on-going research and development and the establishment of pilot plants • Regulations and policies are required – including alignment with the development of first generation biofuels and biomass more broadly in applications such as co-firing • Ensuring availability and optimal recovery of bioenergy requires regional planning beyond the borders of South Africa
Carbon Capture and Storage (CCS)	• Planning is required to address expected skills shortages in the sector. • A suitable regulatory regime is required to address potential liability issues associated with CCS • Clear and substantial funding commitments are required for the successful implementation of the CCS programme
Nuclear PWR	• The current approach to implementing nuclear in South Africa is not in the public domain, so no comment can be offered as to approaches being pursued
Smart Grids	• Expected costs and benefits of individual technologies needs to be quantified • Roll out of smart grids should be supported by alternative revenue models for municipalities who lose income as a result of reduced energy supply • Regulations are required to incentivise the roll out of smart grid technologies • Customer awareness programmes highlighting the benefits of smart grids will help to drive customer acceptance
Energy Storage Technologies	• A detailed repository of all the local energy storage-related research is required in order to maximise synergies.

5.2 Research and Systematic Observation

5.2.1 Introduction

South Africa recognises that climate change is occurring and that it poses a significant threat to the water resources, food security, health, infrastructure, ecosystems and biodiversity of the country. Furthermore, South Africa's vulnerability to climate change impacts is increased due to its socio-economic conditions. It is critical that the country is able to provide accurate climate forecast and is able to understand the impacts so as to develop appropriate adaptation and mitigation responses to build resilience and lead the country towards a lower carbon economy.

Due to the high degree of climate variability it is becoming increasingly difficult to forecast from past climatic conditions and we are becoming more reliant on researchers and modellers to provide accurate predictions for the future. Research and observations play a critical role in providing accurate data to inform and support the developing climate change policies and adaptation and mitigation plans of the country. Furthermore, South Africa is uniquely positioned given its proximity to the Antarctic, the Southern Ocean, and the Agulhas and Benguela currents, to make a major contribution to understanding climate change impacts on the oceans surrounding it and to contribute to global change research in the southern hemisphere.

South Africa has one of the most advanced research, observation and climate modelling programs on the African continent. The expertise is situated across a number of universities and science councils and covers most aspects of earth system science (including atmosphere, oceans, land, biogeochemistry and water). Through government and international investment South Africa continues to support climate change research and systematic observations to assist in developing a robust and functional climate change science and technology platform and to fulfil its obligations under Article 4 and 5 of the United Nations Framework Convention on Climate Change (UNFCCC). This platform will also enable the country to lead climate change research on the continent and become a significant global player in the green economy.

5.2.1.1 Research and the National Climate Change Response White Paper

The National Climate Change Response Policy (NCCRP) (DEA, 2011a) mentions education and research in several sections of its agenda. The government aims to mainstream climate change knowledge into education and training curricula so as to '..equip South African citizens to re-orient society towards social, economic and ecological sustainability.' It aims to do this by, amongst other actions, including climate change issues into formal education curricula, including climate change elements into the National Skills Development Strategy, establishing incentives for research and training, and encouraging tertiary and research institutions to develop national monitoring, reporting and verification guidelines for a climate-resilient South Africa.

In terms of developing climate change science research and technology platforms the NCCRP indicates that South Africa will need to develop:

- a highly informed decision-making process which will involve instituting a new government arrangement with a Chief Scientific Advisor to the Minister of Science and Technology and the establishment of a Scientific Advisory Council;
- medium- and long-term planning by developing a science and technology plan for climate change in partnership with the Department of Science and Technology (DST) and developing a climate change technology roadmap. For this it is indicated that DST will conduct a feasibility study into the development of a special-

ized funding agency named the Climate Change Science Council; and that Department of Environmental Affairs (DEA) will engage relevant partners (DST, National Research Foundation (NRF), Technology Innovation Agency (TIA), Department of Trade and Industry (DTI)) to develop R&D funding instruments. These will include:

- Climate Change Research Chairs in the family of the DST/NRF South African Research Chairs Initiative (SARChI).
- a Climate Change component within the current NRF-administered Technology and Human Resources and Innovation Programme sponsored by the DTI;
- Climate Change Centres of Excellence; and
- Research and innovation partnerships in the area of climate change resilience.

The NCCRP also recognises the importance of monitoring for providing the accurate, current and complete information required to ensure that climate change interventions are effective. The NCCRP therefore indicates that South Africa will, amongst other things:

- Ensure that nation-wide climate change and atmosphere monitoring systems are maintained and enhanced where necessary, including through monitoring networks at appropriate spatial density and frequency. Data analysis, synthesis, archiving, interpretation and dissemination will be a key component of this effort;
- Ensure that climate change impacts are monitored at appropriate spatial density and frequency; and
- Establish a monitoring system for gathering information (with bottom-up inputs where possible) and reporting progress on the implementation of adaptation actions.

Lastly the NCCRP discusses medium- and long-term climate modelling in support of impact studies and adaptation planning. Here it indicates that South Africa will:

- publish and implement the 10-year Global Change Research Plan (GCRP) for South Africa, especially those elements of the plan that increases South Africa's modelling capacity for climate and impacts projections and vulnerability assessments;
- compile and publish a strategy to continuously update and maintain the South African Risk and Vulnerability Atlas (SARVA), using the full range of medium- and long-term climate modelling results and the full range of possible risks;
- develop and pilot a methodology to downscale climate information and comprehensive impact assessments to specific geographical areas, including provinces and municipalities;
- Roll out the downscaling work within two years of the publication of the NCCR policy onwards, with appropriate monitoring and evaluation safeguards;

Ensure that all National Communications (NC) submitted as part of South Africa's UNFCCC commitments contain the most up to date medium- and long-term modelling results and appropriately downscaled risk and impact assessments.

5.2.1.2 Responding to the NCCR Policy

5.2.1.2.1 Department of Science and Technology

The DST is responsible for implementing the National Research and Development Strategy (DST, 2002) and the 10-Year Innovation Plan for South Africa (DST, 2008a). The South African Medium Term Strategic Framework 2009-2014 identifies technology innovation as one of the critical policy areas required to speed up growth and transformation.

The 10-Year Innovation Plan identifies five grand challenges for the National System of Innovation for the period 2008-2018. One of the grand challenges relates directly to climate change (Global change science with a focus on climate change). The plan states that by 2018 South Africa anticipates that it will have:

- an internationally recognised science centre of excellence with climate change research and modelling capability, benefiting the entire continent;
- robust regional scenarios for the rate and impact of climate change and extreme weather conditions for South Africa and the continent;
- initiated climate change adaptation and mitigation actions;
- an internationally recognised centre of excellence focussed on the Southern Ocean and its contribution to global change processes; and
- strengthened research and global monitoring capabilities on Marion Island, Antarctica and the Southern Ocean in partnership with other nations.

While the Global Change Grand Challenge has a focus on climate change adaptation and monitoring, research and development in support of the countries climate change mitigation activities reside mostly within the Energy Security Grand Challenge. The Energy Security Grand Challenge states that by 2018 South Africa will have:

- expanded the energy supply infrastructure, with more than 50% of new capacity coming from clean coal technologies and nuclear plants;
- 5% of energy coming from renewable sources, 20% from nuclear and 75% from coal;
- expanded the knowledge base for building nuclear reactor and coal parts;
- source more than 50% of all new capacity locally;
- successfully integrated uranium enrichment into the fuel cycle and feeding into the commercial reactors;
- a well-articulated energy efficiency programme and per capita energy demand reduced by 30%;
- a 25% share of the global hydrogen infrastructure and fuel cell market with novel PGM catalysts; and
- demonstrated, at pilot scale, the production of hydrogen by water splitting, using either nuclear or solar power as the primary heat source.

In addition to the Global Change Science and the Energy Security Grand Challenges the Space Science and Technology Challenge will also contribute, through the satellite and Earth Observation data.

The National Research and Development Strategy (DST, 2002) and the 10-Year Innovation Plan for South Africa (DST, 2008a) provides the basis of national research policy in South Africa.

5.2.1.2.2 Departmental strategies and plans

Climate change has started to be integrated into all the department strategic plans. Research and observations are required to develop, monitor and update these policies and thus many of the strategies (example Department of Agriculture, Forestry and Fisheries (DAFF) Climate Change Sector Plan (DAFF, 2012), Draft Adaptation and Mitigation Plan for Agriculture and Forestry (DAFF, 2015), National Water Resource Strategy Implementation Plan (DWS, 2013), Department of Energy (DoE) Strategic Plan (DoE, 2015a), South African National Space Agency (SANSA) Strategic Plan (DST, 2013) highlight the need to support research and advance technology innovation. These plans and strategies provide focus for climate change research.

5.2.1.2.3 National framework for climate services

A National Framework for Climate Services (NFCS) in South Africa is in the process of being developed, in collaboration between the SAWS and the Department of Environmental Affairs (DEA), to map South Africa's climate services landscape. The NFCS is based on the Global Framework for Climate Services (GFCS) which is endorsed by the World Meteorological Organization (WMO). The framework is designed to mainstream climate science into decision-making at all levels and help ensure that the country and every climate-sensitive sector of society is well equipped to access and apply the relevant climate information. In a proposition note to the National Committee on Climate Change (NCCC) (DEA, 2015a) it is stated that the overarching goal of the Framework is to enable better management of the risks of climate variability and change at all levels, through development and incorporation of science based climate information and prediction services into planning, policy and practice. The framework for Climate Services is user-need driven, and includes five major components: (i) observations; (ii) climate research, modelling and prediction; (iii) a climate services information system (CSIS); (iv) a climate user interface programme (CUIP); and (v) capacity building.

The first step towards the GFCS implementation in South Africa saw SAWS, in partnership with DEA and WMO, hosting a national climate services workshop from 19 to 22 August 2013 in Pretoria. This arose out of a need for the country to consolidate climate change and variability as well as climate mitigation services. Out of the workshop, emerged the Roadmap for Climate Services in South Africa (GFCS SA, 2013). South Africa is now in the process of developing an Implementation Plan, along with an Action Plan for the National Framework for Climate Services.

5.2.2 Major funding initiatives

The DST provides support for research in South Africa. DST has identified 5 grand challenges as part of their 10 year innovation plan for South Africa (2008-2018). The grand challenges aim to address social economic, political, scientific, and technological benefits. They are designed to stimulate multidisciplinary thinking and to challenge our country's researchers to tackle existing questions, create new disciplines and develop new technologies. Thus the grand challenges (outcomes outlined in Section 5.2.1.2.1) are a way of expanding the research agenda while promoting scientific outcomes. DST has also developed a 10-year GCRP for enhancing the scientific understanding of global change. The research plan mainly comprises four knowledge streams (Table 5.7): understanding a changing planet; reducing the human footprint; adapting the way we live and innovation for sustainability.

The NRF is an independent government agency which facilitates the creation of knowledge, innovation and development in all fields of science and technology. They have a Research and Innovation Support and Advancements programme which is the grant-making programme that translates the mandate of the NRF into initiatives that support research, researchers and the provision of research infrastructure. Since global change is high on the government's agenda, the NRF has been mandated to support knowledge generation and technological innovation that will enable South Africa to respond to global environmental change. The NRF also, together with DST, established the SARChI in 2006. Research chairs are held solely by a university or by a university in partnership with a public research institution. It is designed to retain excellence in research and innovation at South African public universities. There is a Climate Change chair and two new chairs that have been created which are relevant to global change, namely Climate Change and Energy Policy, and Global Change Social Learning Systems.

Table 5.7: Four themes from the Global Change Grand Challenge National Research Plan (DST, 2010).

A Understanding a changing plant	B Reducing the human footprint	C Adapting the way we live	D Innovation for sustainability
Observation and monitoring	Waste minimisation methods and technologies	Preparing for rapid change and extreme events	Dynamics of transition at different scales – mechanisms of innovation and learning
Dynamics of the oceans around southern Africa	Conserving biodiversity and ecosystem services	Planning for sustainable urban development in a South African context	Resilience and capability
Dynamics of the complex internal earth systems	Institutional integration to manage ecosystems and ecosystem services	Water security for South Africa	Options for greening the developmental state
Linking the land, air and sea	Doing more with less	Food and fibre security for South Africa	Technology innovation for sustainable social-ecological systems
Improving model predictions at different scales			Social learning for sustainability, adaptation, innovation and resilience

The Green Fund is a national fund that seeks to support green initiatives in South Africa. The fund is managed by the Development Bank of South Africa on behalf of the DEA. The fund is program-focussed and project cycle-focussed, so different financing instruments are available for different types of projects, and it encourages partnerships, co-financing, and programmatic type projects. The focal areas of the Green Fund are:

- Green Cities and Towns:
  - sustainable transport; sustainable waste management and recycling; renewable energy; sustainable water management; energy efficiency and demand side management; sustainable human settlements, the built environment and green buildings; and ecosystem services;
- Low Carbon Economy:
  - energy efficiency; renewable energy; rural energy including off grid and mini grid; biogas and biofuels; sustainable transport; and industrial cleaner production and consumption projects;
- Environmental and Natural Resource Management:
  - payment for ecosystem services (PES) projects; biodiversity benefiting businesses; land use management and models; and rural adaptation projects and plans.

There are also numerous projects that are funded through government departments, industry and international agencies.

5.2.3 Key research organisations and capabilities

Observation, monitoring and research programmes are undertaken by numerous relevant science councils, universities, government departments, agencies of government departments, municipal councils and public corporations through local, regional and international partnerships.

The 23 South African universities all have active researchers and most have some climate change related research expertise (SARUA, 2014). Climate change research ranges from ocean and terrestrial observational studies to emission reduction and adaptation responses. There are numerous climate change focussed centres. The Southern African Regional Universities Association (SARUA) compiled a report of South Africa's universities contribution to climate compatible development (SARUA, 2014) and Table C1 in Appendix C provides a list, although not exhaustive, of the nodes and centres of expertise for climate change research in each of the universities.

Climate change research is mostly scattered throughout university departments, but there is a realization that this research needs to be brought together under one roof. The University of Cape Town (UCT) has a whole system approach to climate change research, and formed the Africa Climate and Development Initiative (ACDI). This group (established in 2011) brings together research from many departments within the university (e.g. Botany, Business, African Centre for Cities, Centre for Film and Media Studies, Public health and family medicine, Criminology, Climate Systems Analysis group, Chemical engineering, Social anthropology, Sociology). It is a research group which aims to answer the problem of achieving sustainable development in a changing climate. ACDI is involved in identifying, facilitating and coordinating of innovative multi-disciplinary research programmes that are responding to policy needs. The various research themes cover climate-smart development; low carbon energy and poverty alleviation; African earth system responses to global warming; climate scenarios and information systems; impacts of and resilience to climate variations and change; institutions, governance and economics of development and climate change; and global to local scale issues and linkages. Some of their current projects, along with the collaborating partners, are shown in Table 5.8. ACDI has grown over the last five years, starting with five people but now employing 27 staff members who engage in research, teaching, support and management (ACDI Five Year Reflection 2011-2015, www.acdi.uct.ac.za). The ACDI offers a one year Masters in Climate Change and Development. The ACDI is planning to establish an African Climate & Development Academy to contribute towards meeting the climate change and development challenges of the African continent through training courses, action-research dialogues, briefing sessions and an exchange fellow programme.

Table 5.8: Current projects in ACDI and their collaborating partners

Project	Timing	Focus Area	Partners
ASSR: Adaptation at Scale in Semi-Arid Regions	2014-2018	Semi-arid areas across Africa & Asia, including Botswana, India, Ethiopia, Ghana, Kenya, Mali, Namibia, Uganda	Oxfam, START, UEA, IIHS
Benchmarks for the future	Ongoing	Namaqualand	UCT
Berg River Climate Knowledge Network	Ongoing	Berg River Municipality; West Coast District Municipality	Multiple academic departments and partners from the region
CCAFS Nera-term Climate Project	2012-2015	South Africa, Zimbabwe, Malawi, Tanzania	
China and South-South coping Assessment for Learning and Development	2012-2013	Africa (Angola, Ethiopia, Kenya, South Africa, Rwanda); Asia (Bangladesh, Nepal, Indonesia) and the Caribbean (Grenada, Jamaica)	INTASAVE
The Climate Impact Research Capacity and Leadership Enhancement in Sub-Saharan Africa (CIRCLE) programme	2015-2018	Sub-Saharan Africa	Association of Commonwealth Universities (ACU); African Academy of Sciences (AAS).
Food, Energy, Water, Land-use and Biodiversity Nexus	2013-2014	Berg River Catchment	DEA&DP; Berg River stakeholders
FLOW: Fostering Local Wellbeing	2014-2015	Berg River municipality, Western Cape and Kokstad, KZN	Meshfield
Global Islands' Vulnerability Research, Adaptation, Policy and Development Project	2012-2014	Global Islands	CARIBSAVE (Lead); University of Waterloo; University of Oxford Global Climate Adaptation Partnership; University of Mauritius; CaribRM; Munich Climate Insurance Initiative; St Mary's University; Governments of St Lucia, Jamaica, Mauritius, Seychelles and Trinidad & Tobago
Green Skills: Building capacity for a sustainable future	2015-2018	South Africa	Rhodes University (Lead); UCT; UWC; Wits; DEA; WESSA; WWF; GreenMatter; SANBI

Project	Timing	Focus Area	Partners
IDRC Indigenous Health and Climate Change	2012-2015	Peru	McGill University/IHACC
Monitoring and Tracking Climate Resilience	2014	South Africa	DEA&DP
Regionally-extensive droughts and climate change in southern Africa	2014-2017	Southern Africa	South African Weather Service , CSIR
Southern African Regional Universities Association (SARUA)	2015-2016	Southern Africa	Sekoine University of Agriculture of Tanzania Open University of Tanzania University of Namibia University of Mauritius University of Eduardo Mondlane of Mozambique
Scientific Capacity Development Study	2014-2015	Africa	START, INTASAVE, CSAG, Rhodes University's Environmental Learning & Research Centre
Smart Agriculture for Climate Resilience	2014-2016	Western Cape	
Sustainable Economic Development in Water Constrained Catchments	2015-2018	Saldanha Bay and Berg River Catchment	Green Cape

In addition to research conducted at universities there are several other research councils, government departments and institutes in South Africa which play a role in climate change research and the main focus areas for each of these organisations is highlighted below.

The Council for Scientific and Industrial Research (CSIR) is one of the leading scientific and technology research, development and implementation organisations in Africa. Its mandate under the Scientific Research Council Act (Act 46 of 1988, as amended by Act 71 in 1990) includes fostering industrial and scientific development through directed and multi-disciplinary research and technology innovation. The division of Natural Resources and the Environment recognises South Africa's vulnerability to climate change and its research builds on the existing capacity in the fields of Ocean Systems and Climate, Climate Studies Modelling and Environmental Health, and Global Change and Ecosystem Dynamics. Research is undertaken on the global carbon cycle in the marine, terrestrial and atmospheric domains in the aim of understanding the land ocean- atmosphere continuum, through improved observation capacity of these three earth systems. The CSIR has invested heavily in developing the skills for high precision measurements of CO_2, CH_4 and H_2O using Cavity Ring-Down Spectroscopy (CRDS) analysers (Picarro) and CO_2 and H_2O fluxes using eddy covariance analysers. The successful deployment of ocean gliders (in early February 2012) to undertake measurements in the Southern oceans has provided a platform to advance modelling capabilities, and to make inputs into the coupling processes within the atmosphere ocean domain. It also enabled the development of an array of infrastructure for long-term observations. In terms of policy, CSIR develops models and tools for evidence-based policy making and also support policy implementation in respect of the potential for greenhouse gas mitigation. Research into understanding the impacts of climate change and monitor and evaluate actions to deal with climate change are also investigated. Furthermore, the CSIR recently assisted in establishing the South African Carbon Observatory Network (SA-ICON) to integrate and synthesise carbon data and knowledge from various institutions across the country (see Section 5.2.4.4 of this chapter). Currently the network includes the South African Weather Service (SAWS), DEA, South African National Biodiversity Institute (SANBI) and the City of Cape Town, but the aim is to grow the network to include other institutions in the future.

Other divisions conducting global change research at CSIR include the Built Environment and the Meraka Institute. Research within Built Environment includes GHG emissions from transport and building materials as well as the measurement and analysis of atmospheric aerosols (through the Air and dust laboratory and the Laser Centre's mobile LIDAR system). Some of the projects include modelling the dynamics of passenger transport in SA; development of a cross-border transport model; development of infrastructure management systems; innovative housing design and technologies; and an improved Köppen-Geiger map for improved climatic design of buildings. The Laser Centre's LIDAR is also used for studying the structure of the troposphere layer and planetary boundary layer (PBL), with the aerosols as passive tracers of the atmospheric dynamical processes. The Meraka Institute is an operating unit of the CSIR focussed on Information and communication technology (ICT). The earth observation science and information technology competence area uses ICT to derive societal benefits from earth observation (EO) data and technology in line with the DST's grand challenges of Global Change and Space Science and Technology. Recent projects in this group includes: Time-series analysis of Hyper-temporal satellite data; satellite derived vegetation phenology; advanced fire information system (AFIS); automated feature extraction in urban areas; African monitoring of the environment for sustainable development (AMESD); automated land-cover change detection; and LiDAR and hyperspectral work in the Kruger National Park.

SAWS is the national provider of weather and climate related information. It provides regular forecasts, warnings, monitoring and advice for the entire country. It is an entity of the DEA and conducts research on the meteorological fundamentals of climate change and is the custodian of the National Climatological Database. SAWS has several research priority areas, namely, early warning services, numerical weather prediction, climate change, air quality, atmospheric monitoring and research, science/social impact research and technology development. The research conducted by SAWS has assisted the DEA in the implementation of the National Climate Change Response Policy. SAWS also hosts the South African Air Quality Information System (SAAQIS) and works towards the expansion and enhancement of the National Ambient Air Quality Monitoring Network (NAAQMN). The development of SAAQIS started in 2007 and phase 1 (ambient air quality module) has been completed, with phase 2 (development of the National Atmospheric Emissions Inventory System) under development and phase 3 to start by 2017/18.

SANBI collects, generates, processes, co-ordinates and disseminates information about biodiversity and the sustainable use of indigenous biological resources, and establish and maintain databases in this regard. The Climate Change and Bio-Adaptation Division (began in early 1990s) co-ordinates the research and communication regarding South Africa's response to the biodiversity impacts of climate change. Their activities include monitoring and understanding ecosystem and population processes as they respond to climate change; carbon dynamics; climate change impacts and vulnerability; and providing support for policy makers on adaptation to climate change impacts. SANBI was accredited by the Adaptation Fund as South Africa's National Implementing Entity (NIE) to the UNFCCC Adaptation Fund in 2011. Since 2011, the NIE has invested in governance and stakeholder engagement processes that have resulted in the development of an Investment Framework for the NIE, and the development of two detailed project proposals that were submitted to the Adaptation Fund and approved in October 2014. These projects will be implemented over the next 5 years.

The South African Institute of Aquatic Biodiversity (SAIAB) is a National Facility of the NRF and serves as a major scientific resource for knowledge and understanding the biodiversity and functioning of globally significant aquatic ecosystems. Research includes investigating the influence of global change and the impact of reduced freshwater supplies on aquatic biodiversity in estuaries and inshore marine environments. SAIAB runs the African Coelocanth Ecosystem Programme (ACEP) and hosts the Elwandle Node (coastal and inshore areas) of the South African Environmental Observation Network (SAEON) (see Section 5.2.8.1.3 of this chapter). ACEP is a research platform which provides access to research infrastructure (e.g. ship time, coastal craft, remote operated vehicles, etc.) and associated funding to the research community to undertake research along the east coast of South Africa. It is a flagship programme of the Department of Science and Technology (DST) and the National Research Foundation (NRF) and has several key partners (DEA, DAFF, SAEON, and SANParks). It puts out an open research call every three years and it is now in the third phase (2015-2018). Since 2007 ACEP has supported 17 large multi-disciplinary projects. Between 2007 and 2013 ACEP formed the key South African contribution to the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) project.

The Agricultural Research Council (ARC) is the principal agricultural research institute in South Africa as mandated through the Agricultural Research Act 86 of 1990 (as amended by Act 27 of 2001). The ARCs Institute of Soil Climate and Water (ARC-ISCW) has an Agro-Climatology programme which provides information about the climate system at micro, meso and macro scales and maintains an operational national Agro-climate Network of weather stations (approximately 500) and Climate Databank as a national asset. Applications of this data include operational products such as disease outbreak warnings, rainfall and drought monitoring advisories and potential fire danger ratings. ARC-ISWC also has an Earth Observation Programme which facilitates a synoptic understanding and study of various spatial systems including land cover/use, soil systems, ecology and rangeland systems, cropping systems and climate systems. It has applications in risk and disaster assessment and management. The Soil and Water Science Programme and Soil Health and Remediation Programme provide research on soil maps, conservation agriculture, carbon management and degradation. In the Crop Science division there is an extensive breeding programme to develop new cultivars that are drought tolerant, tolerant of higher temperature, resistant to a wider variety of pests and diseases, or cultivars that have shorter growing periods. The Livestock division investigates more efficient beef production with a lower carbon footprint. The Research and Innovation Systems division conducts research around renewable energy, biodigesters on farms, conservation agriculture and drought monitoring.

The South African National Space Agency (SANSA) is South Africa's government agency responsible for the promotion and development of aeronautics and aerospace space research. It provides a comprehensive sensor portfolio involved in the archiving, processing and delivery of earth observation data to all national stakeholders. SANSA's Earth Observation directorate focusses on streamlining the conversion of raw imagery into accessible formats to end users. The products have far reaching applications and the observation directorate has five focus areas: human settlements, water, vegetation, disaster management and agriculture. The Earth Observation directorate of SANSA is actively involved in a number of research projects and has identified two flagship research projects which will spearhead the unit's research directions in the upcoming years. The first of these is a project focussing on Housing, primarily targeted at understanding the national dynamics of low-cost and informal settlement developments. The second research area is an environmental flagship which is tailored to investigate national vegetation dynamics. The Space Science Directorate of SANSA is host to the only Space Weather Centre in Africa providing early warnings and forecasts on space weather activity, playing an important role in protecting satellite technology, communication and navigation systems. This division is responsible for research, infrastructure and data for monitoring the near-Earth space environment, including fundamental and applied space physics research, post-graduate student training, science advancement, and space weather monitoring.

The Council for GeoScience (CGS) is mandated under the GeoScience Act (Act 100 of 1993) to provide for the promotion of research and the extension of knowledge in the field of geoscience as well as the provision of specialised geoscientific services. It has regional aeromagnetic, radiometric and gravity coverage of the country and is involved in a number of collaborative research projects. Carbon capture and storage (CCS), one of the approaches to mitigate global change, is one of the areas of research. CGS was involved in producing an atlas on the geological storage of CO_2 in SA.

The Water Research Commission (WRC) runs a flagship programme on climate change which entails collaborative research on priority climate related issues. The aim of this programme is to empower the poor and reduce their vulnerability to climate change impacts and improve their livelihoods, to provide policy makers with a toolbox of appropriate decision support systems, and to support adaptation action by various sectors and enhance their adaptive capacity to climate impacts. The aim in the long term is to ensure access to good data; enable improved uptake of available scientific information and assess current adaptive capacity of systems. WRC has five key strategic areas for research: water resource management; water-linked ecosystems; water use and waste management; water utilization in agriculture; and business systems, marketing and communication.

The South African National Parks (SANParks) Scientific Services conducts research in the following areas: Species Research, Systems research (aims to understand a broader ecosystem functioning and interaction) and Environmental Impact Research. The Kruger National Park hosts the Ndlovu Node for SAEON which focusses on understanding change occurring in the savanna biomes. There are two flux towers, one at Skukuza (began collecting data in 2000, and is still active) and the other at Malopeni (began collecting data in 2008 and is still active) which form part of SAEON and also CarboAfrica and FLUXNET (Section 5.2.8.1.3).

The South African National Energy Development Institute (SANEDI) is involved in energy and technology development as well as energy efficiency measures implementation. Research focus is largely on renewable energies through the South African Renewable Energy Resource Database. The current portfolios include: advanced fossil fuels; clean energy solutions; energy efficiency; green transport programme; smart grids energy data and knowledge management; and the working for energy programme. Current collaborative projects include the Solar Roadmap; Solar measuring station project; Renewable energy testing, training and demo facility; and the Waste to energy pilot plant.

The Medical Research Council (MRC) has an Environment and Health Research Unit which has created a portfolio for Climate and Health research projects. It is currently focussing on heat related risks to health in small and medium sized towns and investigates coping mechanisms. It will also be investigating the use of weather based early warning systems to reduce levels of malaria, diarrhoeal disease and pneumonia following adverse weather events.

5.2.4 Climate system, variability and interactions within the earth system

South Africa's growing climate change research community has been productive over the last decade and the researchers are well respected in the international arena. The Second National Communication (DEA, 2011b) reported that the number of peer-reviewed publications produced in South Africa remained static between 1999 and 2009. A recent study by ASSAf (2017), however, shows that the number of peer-reviewed journal articles and book chapters related to climate change and its impacts in the country has been rising at an average rate of 16% per year over the past decade (from 131 per year in 2005 to 596 in 2015). This rate is higher than the rate of increase of publications on all research topics (around 5% per year). The report also indicates that the mean number of times these papers are cited by other authors is 24.7 times which is high by global standards.

The ASSAf (2017) report also roughly classified the outputs (between 2006 and 2015) in terms of the research areas and found that:

- 93% was in the natural and engineering sciences including
  - 19% environmental sciences and ecology
  - 11% general earth systems
  - 10% climatology and meteorology
  - 10% biodiversity (including conservation, zoology, freshwater and marine biology)
  - 6% agriculture and food security
  - 4% oceanography and fisheries
  - 4% water resources
  - 3% health
  - 2% engineering topics
  - 1% urban and transport
- 7% in humanities and law

There is a large amount of global change related research being conducted across South Africa so this section just highlights some of the major projects and scientific outputs.

5.2.4.1 Overarching research programmes

The Applied Centre on Climate and Earth Systems Science (ACCESS) is an overarching programme which covers all aspects of climate change. The *Weather and Climate Variability: Fundamentals, Predictability and Application* theme focusses research on the controls of the characteristics of high impact weather events, climate variability and predictability. *Climate Change Impacts and Adaptation* theme investigates the vulnerability of southern Africa to regional changes in climate. Research outputs have been incorporated into the SADC climate change strategy as an ongoing process. Understanding the impact of global change on water resources as well as the capacity of society to respond to these changes is the focus area of the *Water Resource Dynamics* theme. The continual monitoring is contributing to a database of real observation that can be used for model development and process understanding and overall early detection. The *Ecosystems and Livelihoods* theme gathers data on socioeconomic, demographic, health, livelihoods and the environment in rural and urban areas of South Africa to provide information on the well-being of communities threatened by global change. Understanding the drivers of land cover change in response to intrinsic (e.g. carbon fertility) and extrinsic (e.g. bush encroachment) pressures as well as producing decision making tools for land use planning and management is the research focus of the *Land Cover and Change* theme. Marine and Coastal research investigates the influence of the marine environment on climate, weather and rainfall patterns on land and how these in turn impact the marine environment. It aims to understand the links between the ocean component of the earth system and the terrestrial and atmospheric components. The *Biogeochemistry and Earth Systems Modelling* theme aims to assist in integrating the existing work done on ocean, terrestrial, atmospheric, and aquatic environments into an Africa-based Earth System Model. This is an essential contribution to the national endeavour of a global change research program that will support national policy and planning.

ACCESS is involved in a number of international collaborations and partnerships and has links to the Science and Technology Research Partnership for Sustainable Development Program (SATREPS) and the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL). ACCESS is currently in the process of being decommissioned as a Centre of Excellence under the NRF and will soon become a programme of global change.

5.2.4.2 Atmospheric research

The Environmental Sciences and Management Unit at North-West University (NWU) has a Climate change, Air Quality and Impacts sub-program that is aimed at providing key information to support the development of sustainable air quality policies and practices in Southern Africa. The influence of activities associated with human and industrial development as well as natural biogeochemical processes typical of the region (e.g. biomass burning) are the main focus points. A multidisciplinary approach is followed including scientists from chemistry and botany. The Atmospheric Chemistry Research Group (ACRG) at the university monitor temporal and spatial variations in atmospheric gaseous and particulate pollutant concentrations; measure chemical and physical properties of atmospheric aerosols; and monitor deposition of atmospheric pollutants and their impacts on crops and natural vegetation. The university also has a monitoring supersite at Welgegund (active since 2010) which will be discussed in Section 5.2.8.1.1 of this chapter.

The Atmospheric Research in Southern Africa and Indian Ocean (ARSAIO) project is a research consortium funded through a bi-lateral research programme between South Africa and France. The first phase was completed in December 2013 and the second phase will be completed by the end of 2017. The primary objective of the project is to investigate the structure and dynamics of the atmosphere by using ground-based, in-situ, space-borne and model simulation techniques. The ARSAIO research activities focus on obtaining a better understanding of southern tropics/sub-tropical areas, including: atmospheric pollution and climate change in southern Africa; troposphere ozone and aerosol studies over the Indian Ocean Region; greenhouse gas and solar ultraviolet radiation measurements; middle atmosphere dynamics and thermal structure; water vapour variability in the Upper Troposphere-Lower Stratosphere (UT-LS) region; and stratospheric ozone variability, transport and mixing processes in the southern tropics.

The quantitative characterisation of anthropogenic aerosols and their relative climatic impact is still uncertain. Compared to developed regions of the northern hemisphere, the tropical and austral regions of the southern hemisphere are poorly documented in terms of climate change, even though they are important components of the global atmosphere. The CSIR designed and developed a mobile LIDAR system (Sharma *et al.*, 2009) which is

one of the most powerful techniques for active remote sensing of the earth's atmosphere. It can provide aerosol/cloud backscatter measurements for the height region from ground to 30 km with a 10 m vertical height resolution. The measurements elucidate the aerosol concentration, optical depth, cloud position, thickness and other general properties of the cloud that are important for a better understanding of the earth-radiation budget, global climate change and turbulence. First data comparison results were presented at the International Laser Radar Conference (ILRC) in USA in 2008 (Sivakumar *et al.*, 2009). Since then it has been used in a study with two other LiDAR systems at a site in Durban to investigate cloud structure and properties (Shikwambana and Sivakumar, 2016).

At the Global Atmospheric Watch (GAW) site at Cape Point (details provided in Section 5.2.8.1.1) the long-term trends, seasonal cycles, depletion events and continental emission estimates for atmospheric mercury have been investigated (Brunke *et al.*, 2015; Gichuki & Mason, 2013). The studies also investigated how inter-annual variability is influenced by weather phenomena.

5.2.4.3 Marine research

South Africa has a long track record in Southern Ocean and Antarctic research and has recently invested considerable funds in acquiring new infrastructure (new base at Marion Island (opened March 2011) and the research vessel Agulhas II (April 2012)) for ongoing support of this research. These platforms will be discussed in further detail under Systematic Observations (Section 5.2.8.1 of this chapter). CSIR, through funding from DST, obtained a state-of-the-art autonomous long-range ocean glider which was first deployed in 2012 during the Southern Ocean Seasonal Cycle Experiment (SOSCEx) (which forms part of the SOCCO programme). SOSCEx started in 2012 and the first two phases have been completed (Swart *et al.*, 2012; Swart *et al.*, 2014) with the third phase underway (due to be completed in 2018). The multi-platform element of the project will obtain data covering numerous disciplines (oceanography, meteorology, carbon-climate, bio-optics, bio-geochemistry) and will extend over new temporal scales. One of the aims of SOSCEx is to investigate the scale sensitivity of the Carbon-Climate and Ecosystem-Climate links in the southern Ocean.

ASCLME was completed in March 2014. It gathered new information about ocean currents and how they interact with and influence the climate, biodiversity and economies of the western Indian Ocean region; documented the environmental threats that are faced by the countries of the region in a Transboundary Diagnostic Analysis; developed a Strategic Action Plan which sets out a strategy for the countries to collectively deal with transboundary threats; and strengthened scientific and management expertise. Countries involved include the Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa and Tanzania. In all 24 oceanographic cruises were undertaken and a wide range of oceanographic instrumentation was deployed and serviced between 2008 and 2012. The South African research vessel, FRV Algoa, played a significant role in the deployment and ongoing maintenance of this instrumentation. Data gathered during the oceanographic cruises have contributed to the compilation of the Transboundary Diagnostic Analysis of the Large Marine Ecosystems of the West Indian Ocean (WIO) and significantly improved knowledge and understanding of the marine and coastal processes and resources of the region. It is hoped that the data generated by the oceanographic instruments deployed during the lifetime of the ASCLME Project will eventually provide the basis for long-term oceanographic studies.

Marine Research on Southern Oceans, Other Islands and Antarctica, known as South African National Antarctic Programme (SANAP), is a programme that facilitates the development of individual strategies for marine and southern ocean research in Antarctica. It is a collaborative effort between the Department of Water Affairs (DWA), DAFF, the DST and NRF. In the past SANAP's research had four major components: biological sciences, earth sciences, oceanography and physical sciences. However, a new Marine and Antarctic Research Strategy for South Africa is being developed (DST, 2015) which focusses on five distinctive themes (Table 5.9). Each theme is concerned with understanding environmental variability which has major impacts on human quality of life. These impacts range from the effects of "space weather" on long distance communications and power supply, to the impacts of climate change on natural resources.

Table 5.9: Five focus research themes for marine and antarctic research

Theme	• Description
Oceans and marine ecosystems under global change	• Understanding modes of ocean variability across temporal and spatial scales • Developing a regional observations network. • Developing end-to-end modelling and operational prediction capabilities • Establishing global, regional and coastal system indicators • Delivering robust & useful information to society • Reconstructing past climate changes
Earth system observation	• Usage of South African space science in Antarctica, as a window into geospace • Understanding the links between ocean-atmospheric physics, ocean iron availability, trace element biogeochemistry and ocean productivity • Understanding large scale ocean circulation and global climate
Ecosystems, biodiversity and biodiscovery	• Understanding modes of ocean variability across temporal and spatial scales • Developing a regional observations network. • Developing end-to-end modelling and operational prediction capabilities • Establishing global, regional and coastal system indicators • Delivering robust & useful information to society • Reconstructing past climate changes
Innovation and development	• Sustainable coastal and ocean development • Oil & Gas, Fisheries, Mining and Mariculture • Energy management • Development of technology and vessel design • Development of energy exploration capacity • Development of links to ecotourism • Antarctic Waste management
Human enterprise	• Geopolitics, international and national law and policy • Usage of the resource and to develop and refine human History and Palaeosciences • Antarctic arts, architecture and literature • Social Adaptation and Human Impact

5.2.4.4 Land research

One of the focus areas of terrestrial research has been carbon stocks and fluxes in the various biomes, particularly in forests and plantations (e.g. Mills *et al.*, 2012; Alembong, 2014; Lawal, 2014; Dovey, 2014). One of the larger projects was the National Terrestrial Carbon Sinks Assessment (NTCSA) commissioned by DEA (DEA, 2015b). This provides an understanding of the distribution of the carbon stocks and fluxes across South Africa and identifies the land based mitigation opportunities. The outputs are shown in a 1km resolution map. The results enhance South Africa's understanding of how the stocks vary across the country and which biomes are most important in terms of developing land-use based GHG emission reduction activities. It also provides a policy review to understand the impacts of policy on sustainable land management. The project has since been extended to develop the South Africa Carbon Sinks Atlas. The first phase of this project provided data at a national, provincial and municipal level and the second phase is underway to develop an online atlas. The online National Carbon Sinks Atlas aims to make the NTCSA easily accessible via the web, for viewing and for downloading the data.

Carbon and water flux studies have continued at the various SAEON sites, but this will be discussed further in Section 5.2.8 of this chapter.

The SA-ICON Project is a project recently initiated by CSIR and involves many stakeholders and collaborators. It aims to develop processes and systems that consolidate the measurements of the concentrations and fluxes of CO_2 between the marine and terrestrial surfaces and the atmosphere. It aims to provide policy management with an independent assessment capability of the effectiveness of emissions mitigation measures at local and regional scales and contribute to the global effort to reduce the CO_2 emissions. SA-ICON has nine main objectives (Feig *et al.*, 2016) and included in these are:

- establishing an operational CO_2 flux observation network across ocean, terrestrial and atmospheric platforms in Southern Africa;
- enabling improved carbon accounting approaches to link observations and modelling (such as land and sea-surface models, and emissions reports at the national and metropolitan scale) to establish in a CO_2 inventory for Southern Africa;
- developing empirical approaches to determine local and regional CO_2 flux estimates; and
- developing monthly and annual indicators of the state of the terrestrial, atmospheric and ocean carbon systems.

SA-ICON will be completed using a phased approach over the next five years. Phase 1 (2 years) will be to assemble and establish the data quality from ocean and terrestrial observations. Preliminary results were presented at the National Association for Clean Air Conference in 2016 (Feig *et al.*, 2016). The second phase (year 3) will focus on establishing empirical approaches relating *in situ* CO_2 concentrations and fluxes to more readily available remotely sensed observations using inverse models; while the final phase (year 4-5) will produce operational outputs of annual CO_2 flux estimates for the southern African region.

Research has also focussed around agriculture and food security. The Global Change and Sustainability Research Institute (GCSRI) was established at the University of the Witwatersrand and has conducted research around vulnerability, adaptation and mitigation; coupling ecosystem and human health; people, practice and policies; and resilient cities. It has collaborative partnerships with recognised centres of expertise including the Council for Scientific and Industrial Research (CSIR), the Carnegie Institute of Science (USA), SANParks, the Rochester Institute of Technology (USA) and the University of Bonn (Germany). One of its projects is Delivering Food Security on Limited

Land (DEVIL). This 4-year international project started in June 2015 and is funded by the Belmont Forum, a consortium of funding agencies that includes the South African National Research Foundation. The project aims to tackle the challenge of feeding a growing population now and in the future on limited land resources. The project will explore feedbacks and interactions between land use change and food security dynamics using high resolution, spatially disaggregated global models, databases of soils, land-use, crops and livestock and a range of scenarios related to food production and demand side measures. The research team consists of scientists from 11 institutions worldwide.

As a product of the Department of Science and Technology's 10 year Global Change Grand Challenge the Risk and Vulnerability Science Centres (RVSCs) were established under the Human and Social Dynamics Grand Challenge. These were set up in recognition of the unique challenges faced by the most vulnerable people in rural areas and the centres are strategically located at rural based universities such as University of Limpopo, University of Venda, Walter Sisulu University, University of Fort Hare and the University of Zululand (Howard *et al*., 2014). The RVSCs are designed to empower rural-based universities to contribute to effective production and application of Global Change knowledge, to develop the capacity for Global Change research, and to provide risk and vulnerability assessment services to local communities and other potential users of such information. The centres at UL and UFH have been more active and are engaged in a wide range of research activities and issues relating to mitigation and adaptation to climate change. Research topics include climate variability, soil conservation, food and fibre security, water security, impacts and adaptation on livestock farming and crop production, biodiversity and environmental law.

5.2.4.5 Water research

The Water Research Commission of South Africa (WRC) commissions and manages water related research on behalf of the water sector and the Department of Water and Sanitation. This work entails the socio-economic, policy as well as biophysical aspects or the science of climate change. The research is undertaken collaboratively with other partners such as UCT, UKZN, CSIR, UNW or various research institutions. The WRC has several funding thrusts and one of these is Water Resources and Climate. These studies cover research around three programmes, namely predictive tools (e.g. regional climate change projections for adaptation and policy); climate change risk, vulnerability and adaptation (e.g. developing water-related climate change adaptation options to support implementation of policy and strategies for Water for Growth and Development); and integrated floods and drought management (e.g. extreme events). The DWS utilizes the research outcomes and applies the results in response to required needs. For example model projection scenarios may be used for water planning purposes or for reconciliation studies.

The Framework Programme for Research, Education and Training in the Water Sector (FETWater) was started by Department of Water Affairs in 2002. The first phase completed an assessment of education and training needs and capacities of the then Department of Water Affairs and Forestry and linked it with the needs of other government departments, non-governmental organisations and the private sector dealing with water. This then stimulated a process of establishing a framework programme for effective cooperation for the provision of education, training and capacity building in the water sector as the project moved into its second phase (2007-2010). This resulted in the formation and support of seven thematic areas. In 2011 the project was reviewed and was proven to be effective in addressing its capacity needs for effective implementation of the National Water Act (Act 36 of 1998).

In this regard, FETWater Phase III (2014 – 2017) currently focusses on six new thematic areas, with the objective of achieving sustainability beyond 2017:

- Water Infrastructure;
- Water Monitoring and Assessment;
- Water Planning and Implementation;
- Water Regulation Requirements;
- Water Use, Services and Sanitation; and
- Institutional Management and Governance.

The Centre for Water Resources Research (CWRR) at the University of KwaZulu-Natal was established in October 2012. The research in this group over the last few years has included: impacts of climate change on water resources, freshwater systems and crops (maize and wheat); water harvesting; adaptation and what it means for the water resource sector; managing water in a changing environment and hydrological impacts of land use change.

5.2.4.6 Climate modelling and prediction

South Africa has continued its research into developing improved climate models that are more specific for southern Africa. The Climate System Analysis Group (CSAG) based at the University of Cape Town has developed a statistical downscaling method (SOMD) to produce downscaled climate projections for southern Africa and Africa. This is part of the Co-ordinated Regional Downscaling Experiment (CORDEX). The CORDEX empirical statistical downscaling project (2015) aims to undertake a series of carefully designed downscaling experiments across various regions of the world in order to contribute substantively to the broader CORDEX objective of describing and understanding regional downscaling methodologies. CORDEX Africa (Hewitson *et al*., 2012) was initiated in 2011 and phase 1 was completed in 2013, while phase 2 stretches over the period 2015-2017. The downscaled climate projections for Southern Africa have been used in numerous other collaborative projects. A critical component of this initiative is the Climate Information Portal (CIP) that has been developed to deliver CMIP3 and CMIP5 statistically downscaled projections to end users through a web based, guidance text rich, interface.

Over the recent years CSIR's climate modellers have been developing the first African-based Earth system model, called the Variable-resolution Earth System Model (Engelbrecht *et al*., 2016). Key focus areas of the development of the new model are the simulation of convective rainfall over Africa, aerosol-climate feedbacks over Africa, dynamic land-surface modelling of the African savanna and regional ocean-atmosphere feedbacks over the Atlantic and Indian Oceans. It is also important to understand and better model the role of the Southern Ocean in regulating African and global climate. The model's development is taking place with the immediate objective of generating the first African-based projections of future global climate change as a contribution to the Intergovernmental Panel on Climate Change's Assessment Report Six.

Other climate initiatives by CSG, SAWS and ARC include a Wind Atlas for South Africa (WASA) (Phase 1: 2010 – 2014; Phase 2: 2014 – 2018); the South African Flash Flood Guidance System (SAFFG) (Poolman, 2014); the South African Regional Flood Guidance System (SARFFG); the Severe Weather Warning System (SWWS) and a Drought Monitoring System software package.

5.2.5 Research in support of the GHG inventory

The DEA, under the Chief Directorate: Climate Change Monitoring and Evaluation, is running a GHG Improvement Programme (GHGIP) which supports projects aimed at improving the quality and accuracy of the National Greenhouse Gas Inventory. These are DEA driven projects, but a significant portion of the projects are donor funded. More than 15 partners are involved in this programme. All the results of the improvement projects are incorporated into the following years inventory.

In the Energy sector the research has been focussed around developing country specific emission factors (EFs). GHG emission calculations from the electricity sector have been improved through the development of country specific EFs for stationary combustion of fuels in the electricity generation sector (DEA, 2016a). This study conducted direct measurements on some boilers at Sasolburg and Secunda coal and gas power plants and applied the Tier 2 and 3 IPCC methodology to determine EF for these power plants. The outputs of the two methods were compared so as to provide verification of the calculated EFs. The study also applied Tier 2 IPCC methodology to estimate the country specific EF for Eskom. It recommended that further measurements and calculations be carried out at other plants and that more professionals be trained in EF measurement to provide continuity. Other projects in this sector that have been completed include the development of country specific EFs for coal mining, including emissions from abandoned mines and spontaneous combustion; development of higher tier methodologies to estimate fugitive emissions from processing of fuels through a detailed life-cycle emissions analysis coupled with a material balance approach; and an economy wide fuel consumption survey to determine the split in consumption between the energy carrier and the demand-side sector.

There is also currently a project which is seeking a service provider to determine country specific emission factors for the transport sector.

In the IPPU sector there has also been a focus to move to higher tier methodologies with a study being completed on the implementation of a Tier 3 IPPC method for estimating process emissions from aluminium production. Sector-specific CO_2 EFs for ferroalloy production are also currently being determined. A survey on HFC consumption has been commissioned and this aims to assess all baseline data on the current use of HFC's in South Africa.

The AFOLU sector projects have been focussed around improving activity data for the sector. In order to determine the impacts of land use change on the GHG inventory good land change maps at the national level are required. This was found to be lacking in SA as many maps are only at provincial level and these are often at different scales, years and make use of different classifications as their development is often on demand and project specific. Recently land cover maps, and subsequent change maps, were developed for 2001, 2005 and 2010. These were based on the lower resolution MODIS data. Improvements in this sector therefore included the development of a higher resolution national land cover change map (based on Landsat data) for the period 1990 and 2013. The other focus has been the collection of more detailed data on cropland management.

Projects in the Waste sector focus on the development of source specific activity data. In addition to the GHGIP, the Tshwane University of Technology (TUT) together with the University of Pretoria (UP) conducted research and measurements to develop country specific EF's in the livestock sub-sector. Country specific EFs for enteric fermentation and manure management for all livestock have been developed (Du Toit *et al.*, 2013a-d) and incorporated into the 2010 and 2012 national GHG inventory. A full uncertainty analysis still needs to be completed to determine the impacts of these country specific EFs on the inventory outputs. In addition, UP is currently measuring direct CH_4 and N_2O emissions from manure management on cattle feedlots, dairy and pig farms.

There is also a collaborative project between the Paper Manufacturers Association of South Africa (PAMSA), University of Stellenbosch and the Institute of Commercial Forestry Research (ICFR) on carbon sequestration in plantation forests. This research investigates techniques used to estimate carbon sequestration at the Tier 2 level and provides detailed activity and EF data for plantations.

A research project at the University of the Witwatersrand has provided country specific EF's for the Waste sector (Bhailall, 2015). The research (a) predicted LFG generation from landfills in South Africa using theoretical models and compared these results to actual measured LFG yields; (b) measured CH_4 and CO_2 fluxes from the landfill surface to assess the impact of LFG emissions on the air quality of the surrounding environment; (c) assessed the feasibility and functionality of gas extraction and utilisation at landfill sites in South Africa to mitigate greenhouse gas emissions. The measured EF's provided in this study have been incorporated into the 2015 inventory.

5.2.6 Climate change impacts and adaptation research

5.2.6.1 Ecosystems and biodiversity

Since the last national communication there has been further research on the impacts of climate change on biome distribution and the impacts of CO_2 fertilisation. The latest findings suggest that the biome that is most threatened by increased temperatures and rising carbon dioxide levels is the grassland biome, which could be taken over by woody plants. The other four biomes that are particularly vulnerable to climate change are the Nama Karoo biome, the Indian Ocean coastal belt, the Fynbos biome and the Forest biome. Research shows there is an increase in woody plant biomass, which is attributed to the CO_2 fertilisation effect. A recent dynamic vegetation modelling study suggests there is a rapid shift in extensive African grassland and savanna to more densely vegetated woody states (Higgins & Scheiter, 2012). This can increase carbon storage in woody vegetation but can have a negative effect on wildlife populations, water supplies, and global warming.

SANBI has a Climate Change and Bio-Adaptation Division which has two sub-divisions: Monitoring Climate Change Impacts and Climate Change Adaptation and Policy. The former has pioneered the use of several integrated models of how biodiversity may respond to climate change. SANBI therefore works together with universities, conservation agencies and land owners to build a network of reference sites and species for which data can be gathered to support these models and the decision making process. An example project is the Southern African Bird Atlas Project (SABAP). The first phase of the project took place between 1987 and 1991, and the second project was launched in 2012 and will run indefinitely. At the moment the database contains over 153 000 checklists. The Climate Change Adaptation and Policy group provides data and policy guidance to inform and support government's goals of striving towards a low carbon economy. The SANBI Adaptation group will also be playing a role as South Africa's NIE for the Adaptation Fund. It will facilitate limited funding for approved projects. Two projects are currently under implementation, namely (a) Building resilience in the greater uMngeni catchment, SA; and (b) Taking adaptation to the ground: A small grants facility for enabling local level responses to climate change in South Africa. The group was also involved in the second phase of the Long Term Adaptation Scenarios flagship project which was completed in 2014.

The University of Venda hosts the South African Research Chair in Biodiversity and Change in the Vhembe Biosphere Reserve. The Research Chair, co-hosted by the Centre for Invasion Biology at the University of Stellenbosch, is funded by the Department of Science and Technology and administered by the National Research Foundation. Research projects are grouped under four themes:

- Global change where drivers of current biodiversity and projected future changes are analysed through zoological and botanical North-South and East-West transects;
- Ecosystems services and livelihoods which has a focus on the development of models to determine the economic value of ecosystem services in provincial nature reserves as well as in agricultural landscapes;
- Invasion biology which investigates eco-friendly and sustainable solutions to reduce crop damage due to invasive rodents and spread of invasive plants; and
- Biodiversity conservation.

The Limpopo Living Landscapes (LLL) project was launched in 2013 under the auspices of the SPACES (Science Partnerships for the Assessment of Complex Earth Systems) and ACCESS (Applied Centre for Climate and Earth Systems Science) programmes. It is expected to be completed in 2016. This is a broad inter-disciplinary consortium involving agronomists and ecologists from seven partner institutions from South Africa (University of Venda, Limpopo and Witwatersrand) and Germany (University of Bonn, Frankfurt, Gottingen and Cologne). Within the agricultural landscapes of Limpopo Province, the Limpopo Living Landscapes project aims to understand and predict the combined effects of land use and climate change processes on (a) rangeland vegetation; (b) unique biodiversity; and (c) rural livelihoods and to identify farm and policy level intervention strategies that support sustainable rural livelihoods and the natural resource base on which these people depend.

5.2.6.2 Agriculture

In terms of agriculture research is focussed around climate change impacts and adaptation (Maponya & Mpandeli, 2012) and how to build resilience. Impact assessments have focussed on staple crops and key commodities, such as maize, wheat and plantation forestry. Other studies have also investigated the economics of climate change impacts on crops, yield and soil nitrogen interactions and the impact of climate on the livestock sector (Ziervogel *et al.*, 2014). The WRC commissioned a project to investigate adaptive interventions in agriculture to reduce vulnerability of different farming systems to climate change in South Africa. This project focussed on maize, wheat, soya, grapes, mangoes, citrus and avocado (Araujo and Johnston, 2014). It investigated summer and winter rainfall areas and looked at rain fed and irrigated farming systems. It also integrated climate, hydrological and economic models. Models suggest that key cereal crops such as maize in the winter rainfall region and wheat in the summer rainfall region will be negatively affected by climate change. One of the research concerns in agriculture is a projected increase in the need for irrigation, particularly since most parts of the country are predicted to become drier.

The ARC is involved in a global network called AgMIP (Agricultural Model Inter Comparison and Improvement Project) which aims to evaluate the impacts of climate change on food production and economic status of farmers. A project under this network is the Southern Africa Agricultural Model Intercomparison and Improvement Project (SAAMIIPP) (Beletse, 2014). This project involves 10 institutions, namely universities of Cape Town and Free State, South African Sugar Research Institute, Human Sciences Research Council, Polytechnic of Namibia, National University of Lesotho, Botswana College of Agriculture, and Swaziland Meteorological Services. The ultimate objective is to estimate regional-scale food production for different future periods and development scenarios, identify field-level adaptation strategies and evaluate economic impacts of climate change on commercial and small-scale farming systems.

Data also shows that certain pest and pathogen species will benefit from the changing climate and become more of a problem for agriculture. Thus breeding programmes to develop drought and pest resistant plants are high on the agenda for the ARC.

5.2.6.3 Coastal regions

In the coastal zones a recent manuscript (Potts *et al.*, 2015) was completed which reviews the global understanding of climate related stressors on coastal fish communities and makes qualitative predictions on the likely impacts of climate change on migratory, resident, estuarine-dependent and catadromous fishes in the various biogeographical zones. It provides some of the first information for the Southern Hemisphere, outside of Australasia. It reviews information on the response of coastal fish to changes in temperature, increased CO_2 and ocean acidification, sea level rise, changes in current speed, upwelling, and the effect of changing rainfall patterns. This review reveals our lack of fundamental knowledge in this field, in particular in southern Africa and highlights research priorities, including the need for process-based fundamental research programs.

5.2.6.4 Health

Health related research in South Africa has been focussed around health outcomes that are sensitive to climate, such as diarrhoeal diseases, respiratory diseases, cardiovascular health and vector-borne infectious diseases such as malaria. Research investigates the impacts of water scarcity and water quality; the geographical spread of vector and waterborne diseases such as malaria, rift valley fever and schistosomiasis; reduced air quality; and heat stress (Ziervogel *et al.*, 2014; Wright *et al.*, 2014). Research has also investigated the impacts of climate change on children's health (Thompson *et al.*, 2012). Other health related issues that may be influenced by climate change are food insecurity (Wright *et al.*, 2014), hunger and malnutrition, natural disasters, infectious diseases, mental and occupational health. The links between these issues and climate change need further investigation in the future.

The University of KwaZulu-Natal and the CSIR participated in an international project (14 partners) called Earth Observation and Environmental Modelling for the Mitigation of Health Risks (EO2HEAVEN). This was a research project co-funded by the European Commission as part of the 7th Framework Programme (FP7) Environmental theme which started in 2010 and ran for three and a half years. This project contributed to a better understanding of the complex relationships between environmental changes and their impact on human health. Under the project, public health stakeholders worked closely with technology and service providers in both satellite and in situ monitoring to develop models and visualization tools relating environmental data with exposure and health data. Ground-breaking studies were conducted in Dresden, Germany (environmental effects on allergies and cardiovascular diseases); South Durban industrial basin, South Africa (pollution and respiratory diseases); and Uganda (impact of climatic variables on the outbreak of cholera). Results of these studies will help scientists and policy makers better understand the complex relationship between climate change and the emergence of health effects and infectious diseases. The partners included Technische Universitat Dresden (Germany), ATOS SPAIN S.A. (Spain), Bureau de Recherches Geologiques et Minieres (France), European Commission – Directorate General Joint Research Centre (Belgium), University of Twente (The Netherlands), Open Geospatial Consortium (UK), and Makerers University (Uganda).

A useful source of research information in the field of health is the National Health Reseach Database (NHRD). This is an online database which serves as a repository of health-related research currently being conducted in South Africa. It is a tool for monitoring and managing health research at the national and provincial level. The database is also used to identify research gaps and facilitates policy makers, donors and research institutions allocate resources to relevant research priorities. This type of database is something which could be investigated in other areas of research.

5.2.6.5 Adaptation research

There has been a fair amount of research focussed around adaptation with some of the research projects already mentioned in the previous as impacts and adaptation are often studied together. Only a few projects are mentioned below as Sections 3.6 and 3.7 of Chapter 3 of this report provides detailed discussions on the various adaptation research outputs.

A flagship project was the Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) lead by DEA in collaboration with SANBI. The first phase of this project was completed in 2013 and developed a consensus view of climate change trends and projections for South Africa. It summarised key climate change impacts and identified potential response options for primary sectors, namely water, agriculture and forestry, human health, marine fisheries, and biodiversity. The second phase (completed in 2014) used an integrated assessment approach and model to develop adaptation scenarios for future climate conditions using the information, data and models from Phase I and inputs from a range of stakeholder consultations and task-team workshops.

Research has also been conducted under the ACCESS theme of Climate Change Impacts and Adaptation.

South Africa is also a partner in the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) which is a Regional Science Service Centre (RSSC) for the Southern African region. The German government, through the Ministry of Education and Research (BMBF), initiated discussions in 2009 with five southern African countries - Angola, Botswana, Namibia, South Africa, and Zambia. Its mission is to conduct problem-oriented research in the area of adaptation to climate and change and sustainable land management and provide evidence-based advice for all decision-makers and stakeholders to improve the livelihoods of people in the region and to contribute to the creation of an African knowledge-based society. The SASSCAL initiative focusses on three thematic areas – climate change, water and land management – and has three thrusts: research, capacity development and regional advisory and information outputs (products and services). In South Africa SASSCAL is implemented under the auspices of the DST through the NRF and ACCESS.

The semi-arid regions of southern Africa are particularly vulnerable to climate-related impacts and risks. These areas are highly dynamic systems that already experience harsh climates and adverse environmental change, and the people living in these regions are marginalised by high levels of poverty, inequality and rapidly changing socio-economic governance. The CSAG, through the ACDI at UCT, participates and contributes to the Adaptation at Scale in Semi-Arid Regions (ASSAR) project. This project aims to develop a base of knowledge that will guide and inform climate change adaptation in semi-arid areas in Africa and India. ASSAR is an international and interdisciplinary project and its partners are a mix of research and practitioner organisations which include groups with global reach as well as local organisations involved in community work. The consortium is a partnership between five lead institutions (UCT, Oxfam, University of East Anglia, Indian Institute for Human Settlements, and System for Analysis, Research and Training (START)) and 12 partner institutes.

5.2.7 Energy and mitigation research

This section highlights some of the mitigation research activities in South Africa, particularly in the Energy sector, but further details of mitigation research and outputs are provided in the Mitigation Chapter of this report.

5.2.7.1 Energy research

Under the Energy Security Grand Challenge a number of flagships (technology innovation enabling initiatives) have been implemented in order to speed up the uptake of clean energy technologies in support of South Africa's

transition to a low carbon economy. Most notable are the Hydrogen South Africa (HySA) Programme, Renewable Energy Hub and Spokes Initiative, Bio-fuels Demonstration Programme and the Energy Storage Research Development and Innovation Platform.

The HySA Strategy was developed in 2007 to create knowledge and enable the development of high-value commercial products in the hydrogen and fuel cell technology sector through beneficiation of the country's platinum group metal (PGM) resources. The HySA Programme has three phases, namely:

- Technology Catch-up phase (2008 – 2014) which involved the establishment of research and development (R&D) capability
  - This phase succeeded in producing students and knowledge products, with the biggest impact being through technology demonstrations. The most notable being a hybrid hydrogen-electric fuel cell tricycle and golf cart which improves the reliability of electric transport.
  - In addition, a private public partnership between DST, HySA and Impala Platinum led to the first African hydrogen fuel cell powered forklift and refuelling infrastructure.
- South African Extension phase (2014 – 2019) focussing on technology demonstration, testing and validation as well as delivering niche products to targeted markets; and
- South African Innovation phase which involves contributing to international innovation while capturing 25% of the hydrogen fuel cell market.

DST is driving a number of initiatives in the renewable energy space: supporting research and development work at various universities through different instruments including Renewable Energy Hub and Spokes programme, Research Chairs and Bio-fuels Demonstration Programme.

The Renewable Energy Hub and Spokes have a specific focus in developing national technical capabilities in wind, solar photovoltaic and solar thermal. The Centre for Renewable and Sustainable Energy Studies is located at Stellenbosch University and acts as the hub for DST's Renewable Energy Hub and Spoke Programme.

The Solar Photovoltaic (PV) Spoke (Fort Hare University and the Nelson Mandela Metropolitan University (NMMU)) focusses on cell characterisation, concentrator photovoltaic, module design, systems evaluation and building integrated photovoltaic. The Solar Thermal Spoke (Stellenbosch University and University of Pretoria) focusses on system analysis (design), cooling, hybrid power systems, heat exchangers, energy storage using locally available materials. The Wind Energy Spoke (Stellenbosch University and University of Cape Town) focusses on new generation electrical generators for wind turbines, energy storage using flywheels, integrating wind energy into local/rural grids, fault detection and condition monitoring of wind turbines. The focus is to develop turbine blades for small-scale systems that have high aerodynamic efficiencies at low wind speeds by focussing on cost reduction and the use of permanent magnet/alternative materials.

The bio-fuels research work is through various instruments that span the whole value chain from basic research to facilitating the establishment of the bio-fuels industry. These investments include the two research chairs on bio-fuels, support to the Eucalyptus genome project in order to use the outcomes in unlocking un-fermentable sugars, and previously supported the development of national bio-fuels standards and bio-fuels by product beneficiation. The DST has since exited the last two initiatives and shifted its focus to further development and demonstration of late generation technologies which is coordinated through the National Research Foundation Research Chairs and the Technology Innovation Agency-Bio-fuels Demonstration Programme.

The DST supports research around the development of late generation technologies to delink the bio-fuels sector from the food industry, exploiting the rich South African biodiversity by using alternative feed-stocks (including waste materials) and using the technological heritage that the country has on related sectors. The current work that the DST is pursuing includes the use of coal fines together with algae to produce a 10% blended feedstock, Coalgae. This work provides the opportunity to use low quality discard coal which accrues at 60 million tonnes per annum.

In South Africa, the Department of Energy (DoE) projects 40GW of new energy generation capacity by 2030, of which 42% will be renewable. Recent technological advances show that the constraint to technology deployment is no longer production, but energy storage. On the power grid, advanced battery storage systems can help with the integration of solar and wind power, improve power quality by controlling frequency variations, handle peak loads and reduce costs by enabling utilities to postpone infrastructure expansion. DST therefore established the Lithium Ion Battery Programme to initiate the development of advanced energy storage technologies, with a focus on manganese beneficiation as well as the power to gas for renewable energy storage using hydrogen gas under the HySA Programme. The activities will be centred on the development of competence and infrastructure for the SA energy storage industry. The main elements are electrode materials for Lithium Ion cells, development of futuristic superior performing materials that contribute to weight reduction, and the development of low-cost, long cycle life and safe electrode materials based on local minerals. The objective is to develop the skills and know-how to manufacture various cells at large scale to commercialisation while reducing cell manufacturing cost. The expected outcomes from the Research, Development and Innovation programme will be substantial mineral beneficiation of manganese, lithium, nickel, zinc and other high value minerals leading to a South African up-stream industry producing precursor and active materials for energy storage applications. A South African downstream industry, focussing on manufacture of large format battery cells and packs for on-grid and off-grid storage, as well as for selected industrial and vehicle applications. There are numerous role players that are expected to contribute to these Research, Development and Innovation activities, for example CSIR, the South African Nuclear Energy Corporation (NECSA) partners, University of the Western Cape (UWC), Mintek, Nelson Mandela Metropolitan University (NMMU) and University of Limpopo (UL).

There has been a significant amount of research into alternative energy sources and renewable energy. Solar and wind energy have been the main focus, with much of the research being conducted under SANEDI. The DoE recently compiled a report on the state of renewable energy in South Africa (DoE, 2015b). A number of tertiary institutions from the Southern African Development Community (SADC) member states are collaborating on a new Solar Data and Resource Mapping study. The primary aim of this work is to promote the use of solar energy in SADC Member States and to improve the quality of satellite-derived solar data available for the area. The Solar Data and Resource Mapping study is conducted by the Southern African Universities Radiometric Network (SAURAN) (Brooks *et al.*, 2015). SAURAN is an initiative of the Centre for Renewable and Sustainable Energy Studies at Stellenbosch University and the Group for Solar Energy Thermodynamics at the University of KwaZulu-Natal. It aims to make high-resolution, ground-based solar radiometric data available from stations across southern Africa. Stellenbosch University released new solar maps in 2016.

The DoE in collaboration with CSG, CSIR, SAWS and DTU Wind, developed the first numerically verified wind Atlas for South Africa (WASA I). This project was supported by the Global Environmental Facility (GEF), United

Nations Development Programme (UNDP) through the South African Wind Energy Project (SAWEP), and Danish International Development Agency (DANIDA). The WASA has confirmed results from the previous Wind Atlases developed in 1995 and 2001, which showed greater potential for wind energy in the coastal areas. In addition, the WASA has also demonstrated significant wind energy potential inland. The WASA dataset has been used for verification of the International Renewable Energy Agency (IRENA) Global Wind Atlas. The second phase of WASA, involving the same partners, started in 2015 and will expand to other provinces, i.e. KwaZulu-Natal and the Free State. A previous study showed that the biomass resource potential was previously estimated to be significant. With technical support from the Netherlands government, work has begun to develop a Biomass Action Plan for South Africa. The results from this 18-month project, which includes biomass resource assessment, were expected by June 2016.

The Energy Research Centre at UCT researches the intersection between energy, local environment and global climate change. It aims to contribute to minimising impacts of energy use and production, from social, economic and environmental perspectives. Research themes relating to global climate change include mitigation, greenhouse gas inventories, and impact of potential future allocation schemes on South Africa, Clean Development Mechanism (CDM), capacity building and adaptation to the impacts of climate change.

In 2012 DST commissioned the development of a Bioenergy Atlas for South Africa which was completed in 2015. Its development was led by the South African Environmental Observation Network (SAEON) and National Research Fund (NRF), with the assistance of a number of collaborators in academia, research institutions, and Government. With the bioenergy resource map was also a feasibility study of the country's bioenergy resource (Hugo, 2015). In developing the atlas, the potential, availability and application of biomass from household waste, wastewater and agriculture were considered. Various process technologies were also evaluated with consideration of appropriate and optimal sizes, location and type. Building on the work of the Bioenergy Atlas, the development of a Biomass Action Plan for Electricity Production (BAPEPSA) was initiated in November 2014 (DoE, 2015b). BAPEPSA's primary objective is to identify and address the requirements for creating an environment that would enable and promote the utilisation of biomass resources in South Africa. It will also look at formulating appropriate medium- and long-term national targets for electricity and heat production as well as opportunities for stimulating local economic and socio-economic development linked to this industry.

5.2.7.2 Carbon capture and carbon storage (CCS)

The capture of CO_2 at the point of release and the deep underground storage of this CO_2 is one of the mitigation options to reduce CO_2. CCS technology is a way of bridging the gap from today until the existing energy infrastructure is replaced with non-fossil fuel based power generation. Research in this field has been around CCS technology and techniques for CO_2 capture; power plant designs to optimize CO_2 capture; the identification of possible sites for CCS; and CO_2 transport (Osman *et al.*, 2013). An atlas on geological storage for South Africa was developed by the Council of GeoScience. The Strategic Roadmap of the South African Centre for Carbon Capture and Storage (SACCCS) (established in 2009), a division of SANEDI, indicates that there are plans to identify a pilot study site and set up a pilot CO_2 storage project experiment (Vincent *et al.*, 2013). Research on the dispersion and transformation reactions of the CO_2 in the storage medium and its effects on the surroundings of the storage medium will then be conducted at this site. The timelines, provided in the Strategic Roadmap, for this research are:

- 2004 – Assessment of the potential for CCS in South Africa (Completed);
- 2010 – Development of the Atlas on geological storage of CO_2 in SA (Completed);
- 2017 – Commencement of a pilot CO_2 storage project;
- 2020 – Facilitate the commencement of a CCS demonstration plant;
- 2025 – Inform the implementation of commercial CCS deployment.

The University of Pretoria (UP) Department of Geology Carbon Storage (UP-CS) Working Group also conducts research on various geological approaches to store anthropogenic CO_2 and investigates two main streams of CO_2 storage: Mineral Carbonation in mine tailings and Geosequestration in deep formations.

5.2.8 Monitoring and data management

5.2.8.1 Systematic observations

5.2.8.1.1 Atmosphere and climate observations

The SAWS is mandated under the South African Weather Service Act (Act 8 of 2001) to '*be the foremost provider of relevant services in respect of weather, climate and related products, which contribute to sustainable development in South Africa and the African continent*'. It aims, amongst other actions, to provide useful and innovative weather, climate and related products and services, to effectively disseminating weather services products to the users, and to convert data into meaningful products and services for risk mitigation. SAWS has weather offices in all nine provinces and weather stations throughout the country. SAWS also operates weather stations on Gough Island and Marion Island, as well as at the Antarctic base of the South African National Antarctic Expedition (SANAE). In addition to these weather stations, it also operates and maintains the Global Atmospheric Watch (GAW) Station at Cape Point, two ozone observation stations, a baseline surface radiation network and 23 sea surface observation sites. The products and services of SAWS enable various sectors and communities to develop weather and climate risk mitigation strategies. It also maintains the South African Lightning Detection Network (SALDN) which covers the whole country. In 2005 19 sensors were installed, and by 2015 this had increased to 25.

The ARC-ISCW maintains an operational national Agroclimate Network of weather stations (approximately 500) and Climate Databank. Hourly, daily, monthly, yearly or long-term average data is available for temperature, rainfall, humidity, radiation, wind speed and wind direction. In addition certain value-added information, such as evapotranspiration, is also available.

The GAW Station at Cape Point started measuring just two parameters in 1978 when it was opened and this has increased to over 10 parameters in 2015. It is still in operation and continues to measure the following:

- Primary GHG - CO, CO_2, CH_4 ,N_2O
- Surface O_3;
- Halocarbons: $CFCl_3$, CCl_4, CH_3CCl_3, CCl_2F-$CClF_2$ and CCl_2F_2;
- SO_2, 7Be and 210Pb;
- 222Rn (tracer for identifying air masses);
- Solar Radiation: UV-A, UV-B, global (total & diffuse);
- Aerosols – optical properties, carbon and ion species, CPC;
- AOD (PFR) since 2008;
- TGM (total gaseous mercury);
- Wet precipitation chemistry –DEBITS;
- Passive sampling for NO_2, NH_3, SO_2 and O_3; and
- Meteorological parameters.

GAW is co-ordinated by the Environment Division of WMO/AREP (Atmospheric Research and Environment Programme) under the WMO Commission for Atmospheric Science (CAS). Currently it co-ordinates activities and data from 33 global stations, 413 regional stations and 164 contributing stations.

NWU has set up an atmospheric measurement station at Welgegund supersite. This site contains a measurement trailer that was constructed in Finland during 2005 and 2006 with funding from the Finnish Foreign Ministry. From the beginning the focus was on long term measurement as opposed to short campaign measurements. Initially, in 2008 the trailer was set up at Maikana village in Rustenberg mining area to study air pollution resulting from mining, domestic burning and other industrial emissions. During this period it was upgraded to measure black carbon. In 2010 the trailer was moved to its permanent location in Welgegund on a grazed grassland-savanna approximately 100 km west of Johannesburg. Here monitoring includes meteorological data; solar radiation; aerosol number, size and mass distribution; air ion size distribution; light absorption and scattering by aerosol particles; vertical aerosol profiles; trace gas concentrations (SO_2, NO_x/NO, O_3, CO) and gas flux (CO_2, H_2O, SO_2, NO_2) measurements; wet deposition and soil temperature, moisture and heat flux measurements. The site is operated jointly by the NWU, the University of Helsinki (UH) and the Finnish Meteorological Institute (FMI). The specific research topics include formation and growth of aerosol particles, concentrations of aerosol particles of natural and anthropogenic origin, aerosol optics, atmospheric trace gases, grassland-savanna carbon balance, ecosystem interactions and water balance in a water-limited ecosystem.

Atmospheric deposition (wet and dry) continues to be measured at three sites in South Africa, namely Louis Trichardt, Amersfoort and Cape Point. These sites form part of the global Deposition of Biogeochemically Important Trace Species (DEBITS) programme which aims to provide a fundamental understanding of the processes that control the distributions of chemical species in the atmosphere and their impact on global change and air quality (Vet *et al*., 2014). Phase I was initiated in 1990 and has moved to phase 2 to maintain the operational structure and provide support to a new integrated approach to deposition flux measurements and impact studies. There are three regional initiatives and South Africa forms part of the IGAC DEBITS Africa (IDAF) programme to measure inter annual-to-decadal variability of atmospheric deposition in Africa.

The Marine Research on Southern Oceans, Other Islands and Antarctica (previously known as SANAP) has three base stations which routinely measure meteorological data amongst other things:

- the SANAE base in Antarctica:
    - SANAEs research is focussed in 4 science areas, namely physical, earth, life and oceanographic sciences;
    - Only the physical sciences programme is conducted year-round at SANAE IV. The other programmes are conducted during the short summer period when the temperatures and weather permits field work and the extent of the sea ice is at its minimum.
- Marion Island base:
    - Biological/environmental research is a major function of the Marion Island base (weather data collection being the other). Close to 1000 scientific papers and dozens of post-graduate theses have been produced from research on Marion, and the long-term biological monitoring programmes provide exceptional research potential into the rate and impacts of climate change as a result of global warming.

- Gough Island base:

  is uninhabited except for the 6 to 8 expedition members of the weather station as part of SANAP.

There are several air pollution monitoring networks throughout SA with around 90 monitoring stations (Figure 5.3, SAAQIS, 2016). These are managed by local authorities, mostly metropolitan municipalities (Tshwane, Johannesburg, Ekurhuleni, Cape Town and eThekwini), provincial authorities (Western Cape), two private entities (Sasol and Eskom) and the Richards Bay Clean Air Association. Nelson Mandela Bay municipality only recently started to collect data from its network (Cairncross, 2016). The priority area networks of the Vaal Triangle and the Highveld (and two background stations) are managed at the national level by the South African Weather Service (SAWS). The most common parameters measured are PM, SO2, NOx, CO, O3, and meteorology (DEA, 2016b). The other pollutants measured include lead, carbon monoxide, total suspended particles (TSPs), VOCs, benzene, toluene, ethylbenzene, xylene components (BTEX), hydrogen sulphide, and total reduced sulphur (TRS). Less than half the stations in 2012 collected PM10 data (Cairncross, 2016). Since then the national network has been expanded through the addition of two background stations, with three stations in the Waterberg-Bojana Priority Area and, more recently, two (privately owned) Nelson Mandela Bay municipality stations also adding particulate matter to their measurements. To date 84% of stations are indicated to report their data on the SAAQIS system.

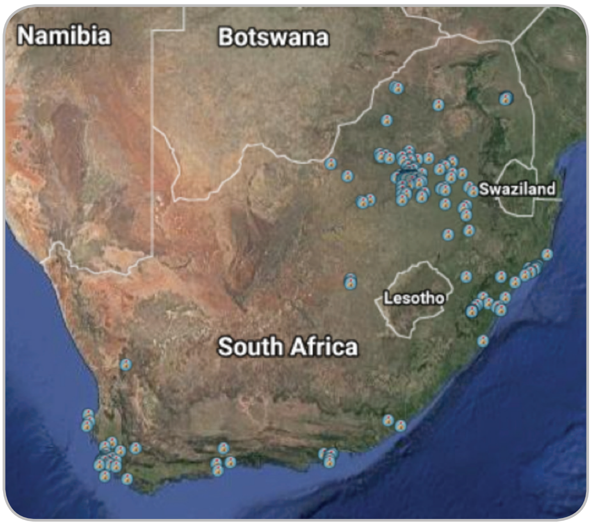


Figure 5.3: Location of air quality monitoring stations across South Africa (Source: SAAQIS website

Source: http://www.saaqis.org.za/Mashup.aspx accessed on 26/09/2016)

5.2.8.1.2 Ocean observations

An important platform for ocean research is the SA Agulhas II. In November 2009 the DEA signed a contract with STX Finland for the construction of a new polar research and supply vessel that would replace the ageing SA Agulhas, which was scheduled to be retired by 2012. It was handed over to DEA on 4 April 2012. This ship is used as a research platform by companies and universities from Finland and South Africa to gain more knowledge about the interaction between ice and the ship. Unlike her predecessor, SA Agulhas II was built from the beginning as both a polar supply ship as well as a research vessel. There are on board laboratories for scientific research as well as cargo holds and tanks for supplies for South African polar research stations. SA Agulhas II has eight permanent and six containerized laboratories for different fields of marine, environmental, biological and climate research. Deep-water probes can be launched either via a large door in the side of the vessel or, if the ship is operating in ice-infested waters, through a moon pool. A drop keel containing transducers for the measurement of plankton density and ocean currents can be lowered 3 metres below the bottom of the ship. A hydraulic A-frame in the stern of the ship can be used to tow sampling nets and dredges.

The Southern Ocean Carbon and Climate Observatory (SOCCO) is a South African born science programme, in support of the Global Change Grand Challenge and the Marine and Antarctic Research Strategy. SOCCO is an interdisciplinary ESS (Earth Systems Science) programme which focusses on the issues of scale sensitivity in the links between physics and biogeochemistry in the ocean and its coupling to the atmosphere. The team engages in joint system scale Carbon – Climate research and publications use a combination of expertise in both ocean observations and modelling. Carbon research in SOCCO includes:

- An established long-term ship–based CO_2 observation system making observations in the southeast Atlantic Ocean and the southwest Indian Ocean. The data are made available to the national (SADCO) and global (CDIAC) databases from where they are then integrated after quality control into the Surface Ocean CO_2 Atlas (SOCAT) and later ocean acidification databases.
- Understand the sensitivity of the carbon cycle in and CO_2 fluxes to the seasonal and intra-seasonal dynamics of upper ocean physics (meso and sub-mesoscale). Robotics (surface wave gliders and ocean interior buoyancy gliders) are used to make observations within these spatial and temporal scale constraints. The SOSCEx is the platform for these experiments, which target the core hypothesis of the programme: fine scale (carbon) – large scale (climate) links.
- CO_2 Modelling: SOCCO investigates the use of different empirical numerical / machine learning methods to address the need for high precision (< $0.1 PgCy^{-1}$) CO_2 air – sea exchange fluxes in a data sparse system. This part of a global effort to reduce the global uncertainty of CO_2 fluxes to ~10% of the mean annual flux necessary to resolve inter-annual variability and long-term trends. SOCCO also makes use of a hierarchy of global and regional, from coarse (200km) to very high resolution (2km), model runs to test both scale sensitivity research questions for CO_2 and the carbon cycle as well as explore the understanding and use of the seasonal cycle as a mode that provides a rigorous test to model outputs.

The 5-year strategy (2014 – 2019) for SOCCO has three main themes, namely, to advance understanding of the scale-sensitivity of Carbon – Climate linkages in the Southern Ocean; to derive low uncertainty annual CO_2 exchange fluxes in the Southern Ocean through sustained observations and empirical modelling and contribute to the assessment of the effectiveness of national and international carbon mitigation goals through SA-ICON (Section 5.2.8.1.3); and to contribute to the optimization and robustness of the South African Variable Resolution Earth Systems Model.

SAEON has the Egagasini node for marine-offshore systems and the Elwandle Coastal node in Port Elizabeth which provides long term monitoring. Egagasini has four main research themes going forward, namely: Climate, currents and creatures; Shelf seas and skies; Biodiversity mapping and monitoring; and Sentinel sites. The focus of the Elwandle Coastal node research activities in 2016 – 2018 will be around four main themes: Algoa Bay Sentinel Site; National Estuaries Network; MPA Network and National Coastal Temperature Network.

5.2.8.1.3 Environmental observations

SAEON was established in 2002 as an institutionalised network of departments, universities, science institutions and industrial partners. SAEON was a business unit of the NRF which has now moved over to CSIR. SAEON's research and infrastructure continues to be supported. SAEON provides long term in situ environmental observations at six nodes which are situated in different biomes or ecosystem types. The nodes are:

- *Arid Lands Node* which conducts observations on the ecological effects of Global Change and Land Use Changes across the hyper-arid to semi-arid western half of South Africa;
- *Egagasini Node* which is hosted by the Oceans and Coasts branch of the DEA and conducts observations to understand the role of the oceans and their ecosystems and biodiversity in climate change. Also to investigate the impact of climate change on the oceans' resources;
- *Elwandle Coastal Node* based in Port Elizabeth which undertakes long-term monitoring and research on South Africa's coastal zone;
- *Fynbos Node* which undertakes long term environmental observations to understand the impacts of global change in the Fynbos;
- *Grasslands, Forests and Wetlands Node* which conducts in situ monitoring to detect human induced global change and understand mechanisms and processes allied to these changes in these biomes and within South Africa; and
- *Ndlovu Node* based at Phalaborwa in the Kruger National Park which focusses on understanding environmental change occurring in the savanna biome of South Africa. It runs a number of long-term research projects in the north-eastern part of the country, in national parks, private conservation areas, mining areas and rural rangelands.

Some of the recent flagship research projects of SAEON are highlighted in Table 5.10. SAEON contributes globally through the Long-Term Ecological Research (LTER) initiative. This seeks to provide greater understanding of the trends in global environmental change and its impacts, and promote the development of strategies for adapting to the change. SAEON also participated or played a role in the following activities:

- International Council for Science (ICSU) data and information management programmes;
- Nairobi Convention data clearing house mechanism;
- World Data Centre for Biodiversity and human Health (WDCBHH); and
- Future Earth and International Platform for Biodiversity and Environmental services (IPBES) discussions in Africa.

Table 5.10: Flagship projects of SAEON.

Projects	Description
Tierberg Karoo Research Centre: 20 years of data	Assembled, organised, analysed and archived 2 gigabytes of various long-term datasets (raw data, photographs, publications, etc.) as a contribution to SAEON's Node for Arid Lands.
Jonkershoek High Altitude Catchment: 60 years of data	Ensured the continuation of long-term monitoring by the CSIR when government funding was withdrawn. The importance of the project for monitoring climate change is demonstrated by the decline in Mean Annual Precipitation and Runoff.
Mapping the potential influence of climate change on the distribution of the mopane tree *(Colophospermum mopane)*	Conducted with volunteers and in collaboration with SANParks to determine baseline information necessary to establish if and how the mopane veld will respond to climate change.
Long-Term Ecological Research (LTER) in Algoa Bay	A multi-disciplinary and multi-institutional project to gather baseline data and to monitor ecosystem changes off Port Elizabeth and Coega.
Giyani Rehabilitation Monitoring	A project funded by DEA to determine the success of a project to rehabilitate degraded rangelands in a communal grazing area.
Seventy Years of Change in Rocky Shores	Biodiversity observation sites from 70 years before are being re-sampled to determine the impact of resource use, coastal development and climate change.
Development of a Geo-portal for online data exchange	Conducted in collaboration with CSIR and the Department of Minerals and Energy. It meets the national requirement for data-sharing among SAEON participants, as well as data provision to users, including government departments and the Global Earth Observation System of Systems (GEOSS).

The CarboAfrica project is a GHG flux monitoring network in Africa which aims to quantify, understand and predict GHG emissions in Sub-Saharan Africa and understands the spatial and temporal variability. Weather stations also collect very valuable meteorological data at these sites. The flux tower at Skukuza (fineleaf/broadleaf savanna) in the Kruger National Park, which is part of SAEON, contributes information to CarboAfrica. CarboAfrica is a sub-dataset of CarboEurope, which has also been combined with the FluxNet datasets. Flux measurements are also being made at sites in Letaba (Mopane savanna), Bushbuckridge (Mopane savanna), Acornhoek (degraded broadleaf), and Gazankulu (degraded Mopane savanna) which also contribute to CarboAfrica. The Malopeni site (Mopane savanna), which is also part of the SAEON Ndlovu Node, forms part of FLUXNET. In addition to these sites, there are also stations which include H_2O and CO_2 measurements at Middleburg, Giyani, Mike's Pass (part of SAEON's grassland node), Elandsfontein, Lephalale and Welgemund. In October 2015 a new site was established at the Ezulu Game Reserve in the Albany Thicket biome (maintained by Rhodes University in collaboration with ARC) and has been collecting continuous data since inception (Feig *et al.*, 2016).

The measurements at Skukuza, Malopeni and Bushbuckridge continue under the Adaptive Resilience of Southern African Ecosystems (ARS AfricaE) project (August 2014 – July 2017). This is a joint research project with four German and six South African partner institutions. The

Thünen Institute of Climate-Smart Agriculture takes the overall coordination of the project. ARS AfricaE combines ecological knowledge with socio-economic factors. One of the research areas is the use of wood for energy and lighting in rural communities. Wood supply-and-demand models have highlighted potentially unsustainable rates of woody biomass extraction from these communal savanna woodlands at various spatial scales (Wessels *et al*., 2013). While the drivers and impacts of human disturbance in these communal landscapes are now relatively well understood, appropriate models for promoting resilience and sustainable resource use and management remain elusive and these issues are trying to be addressed.

As part of the SA-ICON project the CSIR has operated five Picarro Cavity Ring-Down Spectroscopy (CRDS) analysers for measurement of CO_2, CH_4 and H_2O concentrations. The aim is to increase the number of sampling stations in the southern land regions which will in turn improve global estimates of CO_2 fluxes and improve monitoring of CO_2 emissions in South Africa (Feig *et al*., 2016). The high precision analyzers will be set up by CSIR and will include the continued operation of the instruments that have already been deployed at Cape Point (since 2012), Kwadela, Kwazamokuhle, Elandsfontein and Lephalale. CSIR has also be collecting continuous CO_2 flux data from Skukuza since 2000 and Malopeni since 2008 which is essential validation data. Recently a companion flux tower to the Skukuza tower has been installed outside the village of Agincourt, approximately 25km NW of Skukuza to assess the ecosystem flux of CO_2 in an anthropogenically influenced savanna site. Two additional eddy covariance towers were installed in Middelburg, Eastern Cape for monitoring CO_2 fluxes in the Karoo (Feig *et al*., 2016).

A proposal has been put forward to DST for a 15-year research infrastructure grant to support six integrated sites for flux monitoring and some of the sites listed above will form part of this long term project.

5.2.8.1.4 Satellite-based observations

SANSA is South Africa's government agency responsible for the promotion and development of aeronautics and aerospace space research. It provides a comprehensive sensor portfolio involved in the archiving, processing and delivery of earth observation data to all national stakeholders. The sensor data is used in the following applications: agriculture, geology, hydrology, coastal management, environmental management, meteorology and oceanography. SANSA's Earth Observation directorate focusses on the utilisation of space to address day-to-day societal needs including resource and environmental management; disaster management; food security; global change monitoring; health, safety and security; planning, development and service delivery monitoring. One of the key tasks within this directorate is to develop and improve the automated processing chains involved in image processing in order to speed up production and ensure accuracy for the delivered satellite image products. SANSAs observation directorate has a focus on 5 flagship projects described in Table 5.11. Satellite data plays a crucial role in many global change projects as it crosses all disciplines and has many applications.

As of 1 April 2011, the CSIR Satellite Applications Centre forms part of the South African National Space Agency (SANSA).

Table 5.11: Flagship projects for SANSA.

Project	Description
Human settlements	Involved in informal settlement monitoring, infrastructure development, urban growth assessments and service delivery monitoring.
Water	Generates water body maps which are used by catchment management agencies and water use managers.
Vegetation	Creates vegetation maps used in national vegetation monitoring projects.
Disaster management	Develops flood risk, drought risk and fire scar maps used in risk assessments for natural disaster planning and management.
Agriculture	SANSA products are used in agricultural resource monitoring. These allow crop classification and condition assessment and yield estimation, mapping of soil characteristics and management practices, and compliance monitoring.

5.2.8.2 Data management and dissemination

Data management and dissemination is an important aspect of research as there are more datasets and they are also increasing in size due to the increased detail and the use of spatial data. It is important that the data not only be kept and documented somewhere but that it is also accessible to others so as to reduce replication and enhance research efforts by building on existing data. Many projects now have their own dedicated data management system, and there are also some data management systems which are linked to regional or international data systems.

The DEA has several data management systems that it supports and uses to disseminate global change related information to the public:

- The National Climate Change Response Database (NCCRD) is a database that has been developed by DEA to provide easy access to the climate change adaptation and mitigation work being conducted in South Africa. The content and management of the website is provided as a public service by the DEA, however, the department is only the custodian of the system. The information contained in the system is provided and updated by individual participants;
- The National GHG Inventory System (NGHGIS) being developed by DEA will enable the management of the GHG inventory compilation process. The main objectives of this national system are as follows:
    - Strengthening the institutional arrangements around national inventories, including legal matters; and
    - Sharing experiences on methodological matters, including technical guidelines, data collection and archiving, documenting methods (including assumptions, EFs and calculations of results), and working with quality assurance and quality control, uncertainty analysis, reporting (formats and guidelines) and tools for dissemination (including web-based tools);
- SAAQIS provides a common platform for managing air quality information in South Africa. It makes data available to stakeholders including the public and provides a mechanism to ensure uniformity in the way air quality data is managed;
- The South African NAEIS is an online national reporting platform that will hold both air pollutants and greenhouse emissions inventories of the republic. The system offers new innovative ways to report emissions as is required by the National Environmental Management Air Quality Act of 2004. It is also being developed further to hold the GHG information

that will be reported as part of the newly developed GHG regulation. The NAEIS objective is to provide all stakeholders with relevant, up to date and accurate information on South Africa's emissions profile for informed decision making; and

- The National Climate Change Response Monitoring and Evaluation (M&E) system is currently being designed and developed by DEA and will have five sections:
  - Monitoring which will include a data and information network as well as a web-based platform that will host a list of adaptation and mitigation projects;
  - Evaluation which involves defining and assessing the output or impact indicators that respond to the objectives of the M&E system;
  - Guidance to support the M&E system;
  - Outputs where the results of the evaluation process will be published annually to inform decision-making on climate change response; and
  - Feedback, learning and review.

For water related data the DWS operates the National Integrated Water Information System.

The Southern African Data Centre for Oceanography (SADCO) stores, retrieves and manipulates multi-disciplinary marine information from the areas around southern Africa. SADCO is funded by the CSIR, DEA, the Namibian Ministry for Fisheries and Marine Resources, SAEON and the South African Navy.

The Ocean Data and Information Network for Africa (ODINAFRICA) brings together more than 40 marine related institutions from twenty-five countries in Africa to address the challenges faced in accessing data and information for coastal management. With the support of the Intergovernmental Oceanographic Commission (IOC) of United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Government of Flanders (Kingdom of Belgium) the network strives to address the challenges faced in ensuring that ocean and coastal data and information generated in national, regional and global programmes are readily available to a wide range of users in an easily understandable format.

Earth observations data obtained from satellites, aircraft and surface-based systems and innovatively processed, provide the required decision support information. In South Africa these datasets are collected, processed, disseminated and used by a large number of Government departments, state agencies, parastatals, academia, NGOs and private industry. South Africa faces the challenge of making Earth observations discoverable, accessible and usable at local, provincial and national levels of government, as well as to the private sector, academia, science councils, and more recently, to educators and learners. South African Group on Earth Observations (SA-GEO) promotes the use and application of earth observation data; promotes networking in the earth observing community in South Africa; encourages sharing of knowledge on the uses of earth observation; and provides a platform for researchers, academics, public officials, industry, consultants and NGOs to interact. Part of SA-GEO is the South African Earth Observation System of Systems (SAEOSS) portal which offers the South African Earth observations community the opportunity to discover, access and eventually analyse Earth observations datasets. SA-GEO is an initiative funded by the DST, and hosted at the CSIR and is a voluntary community of local Earth observations users and suppliers. It is established around self-organising Communities of Practice (CoPs) which are based on but not limited to the nine GEO societal benefit areas (agriculture, air quality, coastal and marine, earth observation infrastructure, education and awareness, land cover, legal and policy, natural resources, radiometry, synthetic aperture radar and water). It co-ordinates SA's participation and inputs to, amongst others, Group on Earth Observations (GEO), Committee on Earth Observation Satellites (CEOS), ARMC, GMES-Africa, MESA and TIGER. More recently AfriGEOSS (initiated in November 2013) provides the necessary framework for countries and organisations to access and leverage ongoing bilateral and multilateral EO initiatives across Africa, creating synergies and minimizing duplication for the benefit of the entire continent. There are currently 27 member countries with key contributors being Gabon (AGEOS), Nigeria (NASRDA) and South Africa (CSIR, DST). AfriGEOSS will contribute data towards the global GEOSS.

The SARVA (launched in 2010) is one of the flagship projects under the DST's 10 year Global Change Grand Challenge. It aims to improve the flow of information from the research community downstream to society by providing up-to-date information on risks, vulnerability and impact of global change on the key sectors. The themes cover agriculture, biodiversity, emissions and air quality, environmental health, forestry, ground water, oceans and coasts, settlements, socio-economics, surface water and weather and climate. The information on SARVA is regularly updated. The outputs support strategy development and decision-making in the area of risk and vulnerability. The SARVA project is currently implemented by the CSIR and hosted by SAEON, with key inputs from South African research and science institutions. The NCCRP indicates that a strategy will be developed to continuously update and maintain the SARVA, using the full range of medium- and long-term climate modelling results and the full range of possible risks.

The South African Biodiversity Information Facility (SABIF) is the South African node of the Global Biodiversity Information Facility (GBIF) established by the DST in collaboration with the NRF, CSIR, as well as members of the scientific community. The aim of SABIF is to contribute to South Africa's sustainable development through the facilitation of access to biodiversity information through its web portal. SABIF works across South Africa with a network of partners to digitise species and specimen records and make them accessible on the SABIF and GBIF websites. In addition, the Biodiversity GIS (BGIS) website developed by SANBI provides access to land based GIS datasets.

SANSA has a satellite imagery archive dating back to 1972 from the first Landsat satellite. The majority of the SANSA imagery archive is available for purchase or download via the SANSA Earth Observation Online Catalogue.

5.2.9 Research needs going forward

Table 5.12 provides information on the climate change research needs for South Africa going forward. These research needs and focus points were sourced from SARUA (2014), Ziervogel *et al.* (2014), Potts *et al.* (2015), ASSAf (2014), DoE (2013) and NPC (2012).

Table 5.12: Global change related research topics and questions for South Africa going forward

Area of research	Research topics for the future
Observation and monitoring	• Developing critical thresholds that if exceeded will lead to irreversible change; • Consequence of such irreversible change; and • Indicators for the detection of these critical thresholds.
Ocean dynamics	• Strengthening capabilities of the coupled ocean-atmosphere-biosphere to improve climate predictions; • Response of large-scale Southern Ocean ocean-climate systems to global warming; • Change in response of the Southern Ocean's capacity to take up anthropogenic and natural CO_2, and to provide the required energy supply to its ecosystems, to climate change; • Response of the Southern Ocean to climate change through changes in ecosystem function and structure that modify food webs and climate feedbacks such as atmospheric albedo.
Linking land, sea and air	• Priority forms of change on the land that will directly or indirectly affect atmospheric, estuarine, and marine dynamics.
Model predictions	• Relative importance of southern Africa's biomes in terms of their influence on climate and on carbon storage; • Understanding of which global climate changes favoured the evolution of the impressive diversity of flora and fauna of southern Africa; • Relationships between bushfires and greenhouse gases and carbon storage; • Degree to which the land and the oceans around southern Africa act as sources and sinks for carbon and other important elements; and • How changes in sea surface temperature and ocean currents will affect rainfall patterns.
Air quality	• Increased monitoring and research of PM10 and MP2.5.
Water security	• Important secondary effects of a changing climate on water security; • Determining limits within which freshwater ecosystems can maintain their integrity, and where are these limits likely to be exceeded; • Sustainable utilization of ground water resources; • Degradation of water quality and water ecosystems resulting from industrial and agricultural development, mining and rapid human settlements in peri-urban areas; • Understanding increased health risks to humans and animals as a result of contamination of water by hazardous pollutants; • Uncertain impacts of climate change on the availability of water; and • Trans-boundary effects.

Area of research	Research topics for the future
Food and fibre security	• Studies into new crop or livestock species, or production methods, which can be developed to offset the effects of climate change; • Determining if cropping systems can be developed to derive multiple benefits from the same area (e.g. using tree crops for food, fodder, energy, and to enhance cash income); and • Research into which wild plant and animal species are important sources of food, how these may be affected by climate change, and understand if alternative sources of food exist to replace such species.
Fisheries	• Develop the current capacity for predicting the impact of future climate change on important marine resources; • Accurate projection of the impact of future climate change on fish production, distribution, and conservation, as well as socio-economic consequences; • Exploring top-down vs. bottom-up approaches to fisheries management that supports social-ecological resilience to the expected increase in variability; • Methodologies for intersectoral (integrated) approaches to management of human activities related to the oceans; • Role of international markets (exports and imports) and aquaculture in the social-ecological system; • Research into the reasons for the lack of agreement between trends in inshore water temperature observed in situ and remotely from satellites; and • Quantification of the effects of ocean acidification on fisheries and marine biodiversity.
Biodiversity and ecosystem services	• Research and development of climate change adaptation plans for all biomes and ongoing refinement of risk and vulnerability assessments; • Assessment of the risks of unmitigated scenarios for biodiversity hotspots and biomes; • Urban ecology and biodiversity research, for example ways in which urban forestry and other vegetation can provide carbon offsets; • Sustainable management of urban ecosystems and how building innovations can facilitate urban greening; and • Urban ecosystems that are adapted to co-existing with human artefacts.
Health	• Strengthen information and knowledge of linkages between disease and climate change; • Magnitude of potential impacts of extreme temperatures and identification of vulnerable communities; • Re-examination of community-based approaches to primary healthcare; • Development of a health data-capturing system that records data both at spatial and temporal scales and which ensures that information collected can be imported into multiple-risk systems such as the South African Risk and Vulnerability Atlas (SARVA); • Improvement of the knowledge of, and find potential alternatives for bio-safety of the current malaria control strategy; • Adaptation strategies for malaria which do not use harmful chemicals (which requires projections of non-climatic factors affecting malaria); • Data to link projected climate and changes in agricultural yields to food insecurity, hunger and malnutrition;

Area of research	Research topics for the future
Health	• Need to understand links between natural disaster data and health risks and impacts in order to project health impacts; • Health data for cholera at high spatial resolution for making environment-health linkages. Cholera modelling needs to take into account a range of factors such as human migration, supplies of potable water, and combining of population and environmental models; and • Development of climate change and weather-related mental health projections.
Settlements	• Effective information, monitoring and assessment tools to evaluate the resilience of cities and towns to climate change and assist urban planners in identifying priorities for scaling-up climate change responses; • Encourage and support the appropriate down-scaling of climate models to provincial and, where possible, metropolitan and district levels to provide climate information at a scale that can be integrated into medium- and long-term spatial development plans and information systems; • Prioritise technologies for climate change adaptation within rural areas, including low water-use irrigation systems, improved roll-out of rainwater harvesting strategies, and drought-resistant seed varieties; • Design and implement economic and livelihood diversification programmes in rural areas; • Support ongoing research to determine the impacts of climate change on artisanal fishing communities and livelihoods in coastal areas and identify appropriate responses; • Carbon sequestration, urban agriculture, biodiversity corridors, and use of urban open space to address the resilience of the city through adaptation and mitigation measures; and • Stronger account of the 'crossovers' that occurred between rural and urban areas within a systems thinking approach.
Renewable energy, waste and carbon emission reduction	**Waste minimization:** • Determine the materials and quantities of materials being recycled; • Determine alternative solutions (policy, economic and technological) for increasing waste minimisation and reuse for priority waste streams (exacerbating climate change, e.g. biodegradable municipal waste) • Determine how new waste minimisation methods and technologies can be diffused to different institutions and stakeholders, especially municipalities in South Africa; **Clean coal technologies:** • Research on fluidised-bed combustion; UCG; fuel characterisation; performance and testing; emission reduction; future fossil fuel conversion technologies; coal quality and processing; real-time coal analysis; characterisation of untapped coal reserves; • Development of a national UCG research strategy for the country, optimised combined electricity/chemical production, better process control and analysis in power generation processes; • Continued research on the carbon capture and storage pilot study; **Gas:** • Research on shale gas resource assessment; coalbed methane and methane hydrate; gas storage and gas transport; national gas infrastructure: planning, development, financing, implementation; environmental challenges related to shale gas exploration; • Implications of Hydraulic Fracturing (especially related to water security and GHGs);

Area of research	Research topics for the future
	Renewable energy: • Development and optimisation of CSP, solar fuel, solar PV technologies and applications; • Development and optimisation of wind, wave and small hydro technologies and applications; • A transition from laboratory-scale studies to pilot-scale demonstration initiatives aimed at commercialising products and processes; • Feedstock qualification and techno-economic and sustainability studies; • Biomass and fossil fuels synergies; • Large-scale biodiesel production from algae; • Developing biogas digester computer prediction models; • Efficient and cost-effective municipal solid waste to energy in plasma gasifiers; • Electricity generation coupled to waste water treatment using membrane-less microbial fuel cells; • The application of genomics and bioinformatics for the molecular genetic characterisation of organisms used as bioagents for the production of biofuels; • Resource quantification for all forms of renewable energy; • Techno-economic analyses of renewable energy pathways and strategies to accelerate the uptake of renewable energy; • Smart grid solutions linked to distributed small-scale renewable energy solutions; • Energy storage solutions suitable for small and large-scale renewable energy applications; **Nuclear energy:** • Techno-economic evaluations and financing mechanisms for nuclear energy; • Nuclear safety, environmental costs and benefits; • Localisation and employment opportunities; • Uranium enrichment and fuel fabrication; **Energy efficiency:** • Technological advances for green buildings; ultra-efficient devices; high-efficiency lighting; customer behaviour research; energy efficiency and demand management enablers; • Maximization of energy efficiency; **Hydrogen and transport:** • Production of hydrogen by water splitting, using either nuclear or solar power as the primary heat source; • Further research into electric, hybrid internal combustion/electric, and hydrogen-fuelled vehicles; • Techno-economic studies to support future work on planning and implementing transport networks.

Area of research	Research topics for the future
Impacts and adaptation	• Continued research into climate impact assessments; • Understanding and quantifying the socio-economic costs of climate change impacts; • Development and testing of approaches that support integrated and flexible adaptation strategies; • Improved understanding of the social, political, governance and financial barriers or enablers of adaptation; and • Research on how adaptation can address the reduction of poverty and inequality.
Climate resilience	• Research to develop the concept of social innovation in the wider context of climate change research and sustainable development.
Complex social-ecological systems research	• Need for more complex, integrated social-ecological systems research that considers the range of issues noted above *in relation to each other,* and *in relation to the context of Climate change development;* • Stronger framework to guide system-based transitioning from one development paradigm to another; and • Focus on stronger synchronisation between indigenous knowledge and climate science, as this lack of synergy makes climate science very unfamiliar to local communities.

5.2.10 Regional and international co-operations

South Africa continues to provide climate related inputs to many regional and international programmes, including:

- IPCC, particularly through its contribution to the IPCC Assessment Reports. For the AR6 report Dr Debra Roberts, head of the Environmental Planning and Climate Protection Department of eThekwini Municipality, was selected as IPCC Co-chair Working Group II;
- International Council for Science (ICSU), with the Regional Office for Africa (ICSU ROA) being based in South Africa;
- GEO, GEOSS and GCOS, through the contributions from SAEOSS and other related Earth Observation programmes;
- African Earth Observation Network (AEON);
- WMO through the GAW station and several other research projects (e.g. atmospheric monitoring station at Welgegund);
- CarboAfrica (and ultimately CarboEurope), FLUXNET and ARS AfricaE through its continuous atmospheric monitoring at several stations across South Africa;
- AERONET and Southern Hemisphere Additional Ozonesondes (SHADOZ) networks through the aerosol data collected at GAW and Irene;
- DEBITS;
- SATREPS through the ACCESS programme;
- SADC Regional Meteorological Development Project;
- SADC-HYCOS – with the first two phases complete, phase 3 is under implementation;
- SASSCAL;
- ASSAR;
- International Coastal Atlas Network (ICAN) which from 2013 was an official project of the International Oceanographic Data and Information Exchange (IODE) programme of UNESCO's IOC;

- Africa Climate Change Adaptation Initiative (ACCAI) which aims to establish and operate a strong network of researchers co-producing, sharing and disseminating scientific knowledge on food systems and climate change in Africa, and to build research capacity amongst the members. Current partners are the University of Ghana, Mekelle University (Ethiopia), University of the Witwatersrand, Stellenbosch University and University of Dar-es-Salaam (Tanzania);
- International Commission on Atmospheric Chemistry and Global Pollution (CACGP) and the International Global Atmosphere Chemistry (IGAC) project through the atmospheric site at Welgegund and the atmospheric deposition sites as part of DEBITS;
- IOC programmes. The IOC works to monitor and document the impacts of climate change on the world's oceans, coasts and marine ecosystems. It has several programmes and of these SA contributes to The Global Ocean Observing System (GOOS), World Climate Research Programme (WCRP), Adaptation Climate Change in Africa (ACC Africa), the Ocean Data and Information Network for Africa, and the Intergovernmental Oceanographic Sub-Commission for Africa and Adjacent Island States (IOCAFRICA);
- South Africa also plays a key role in the IUCN Academy of Environmental Law (the largest professional network of environmental law scholars in the world) and the Academic Partnership for Environment and Development Innovations in Africa (APEDIA). APEDIA is an international network established to stimulate academic collaboration and research in the field of environmental development and sustainable land use in Africa.

In addition to contributing data to regional and global data sets and organisations, many of South Africa's projects are undertaken in collaboration with regional and international institutes. Table 5.13 provides a list of some of these collaborating institutes. This is by no means an exhaustive list but provides an indication of the spread of the collaborating institutions. Appendix D provides the detailed diagrams of the institutions and collaborations the Energy sector research space as provided by The State of the Energy Research Report (ASSAf, 2014).

Table 5.13: Examples of regional and international collaborators in climate change research.

Regional collaborators or projects	International collaborators
SADC	CSIRO, Australia
NEPAD	Thunen Institute
African Earth Observation Network (AEON)	NOAA-PMEL
SASSCAL	WHOI
African Union	CalTech
ACP	Finnish Meteorological Institute
African Development Bank	WCRP
SADC REEP	Laboratoire d'Aerologie
SADC Remote Sensing Centre	Brazilian Space Agency
SARUA	International Research Institute for Climate and Society
Regional Centre for Mapping of Resources for Development	Central Rice Research Institute, India
SADC Regional Meteorological Development Project	Indian Institute for Meteorology FAO NIVA LOCEAN INRA, France World Food System Center, ETH Zurich European-South African Science and Technology Advancement Programme (ESASTAP) National Centre for Atmospheric Research Bureau de Recherches Geologiques et Minieres
Many universities across the continent such as: • University of Bamako • University of Niamey • University of Cotonou • University of Abidjan • University of Botswana • University of Namibia • University of Ghana • University of Addis Ababa • University of Reunion • Mekelle University • University of Dar-es-Salaam • Makerers University	Numerous universities across the globe, such as: • Hamburg University • University of Liverpool • University of Helsinki; • University of Paris; • Technische Universitat Dresden; • Laboratoire Interuniversitaire des Systemes Atmospheriques • University of Washington • University of Minnesota • Colorado State University • South Dakota State University • Goethe-University Frankfurt • University of Twente • Princeton University • Reunion University • Friedrich-Schiller University Jena

5.3 Education, Training, Awareness and Capacity Building

5.3.1 Inclusion of Climate Change Education (CCE) in formal education and training, as well as technical and vocational education and training

5.3.1.1 Climate change in the education and training system

South Africa has given attention to climate change in educational policy. Building on an earlier commitment to integrate an integrated, active learning approach to environmental education into all phases and levels of the education and training system as articulated in the 1995 White Paper on Education and Training (1995), the National Climate Change Response White Paper (Republic of South Africa (Section 11.2) includes a strategic goal of improving climate change education and training in South Africa. It states that *"Climate change is a relatively new issue that has cross-disciplinary and cross-sectoral implications in South Africa. Understanding the concept as well as the options to mitigate it and adapt to it is fundamental to future development pathways and the wellbeing of South African society".*

The National Climate Change Response White Paper (Section 11.2) also sets out some strategic actions for climate change education which include integration of climate change knowledge into curricula at all levels, into the Sector Education and Training system and Technical and Vocational Education and Training (TVET) Programmes, providing bursaries for climate change study and research, and supporting research into the skills required in the labour market for the green transition and climate change adaptation.

As pointed out in the National Climate Change Response White Paper (DEA, 2011) involving South African society in climate change responses involves a range of diverse education and learning processes. It also involves engaging the education and training system in incorporating climate change science and climate resilient development responses into education and training curricula, training programmes, quality management structures, research institutions, and qualifications.

The research undertaken for this review revealed a myriad of diverse initiatives in South Africa that are oriented towards climate change education (CCE), training, and public awareness. It was not possible to describe all of these in detail. Thus, only some of the more prominent initiatives and issues have been noted in this summary.

Overall, the review undertaken for this chapter shows a very active society engaged with climate-change education related concerns and a number of state supported initiatives. Despite the presence of many initiatives, *these can still be enhanced by stronger national government co-ordination to ensure systematic upscaling, co-ordination and expansion of climate change education and training initiative in key areas.*

The key areas are:

- Mainstreaming climate change knowledge into the national education and training quality management system
- Improve alignment of climate change knowledge progression in the National Curriculum and Assessment Policy (CAPS)
- Expand and support the roll out of teacher education initiatives that support teachers' knowledge of climate change
- Support Technical Vocational Education and Training (TVET) curriculum for green economy and climate resilient development programmes, and lecturer training
- Support the Sector Education and Training Authorities (SETAs) and the National Environmental Skills Planning Forum's green skills research partnership to clarify green occupations, and occupations critical for

climate change adaption and mitigation for inclusion in the skills planning system, and align green skills planning with the Department of Higher Education and Training (DHET's) skills planning and intelligence systems

- Strengthen higher education capacity and incentives for systems-based research, and inter- and transdisciplinary approaches, include humanities and social sciences more pro-actively in climate change sciences, and support curriculum innovation platforms

These are detailed further in the sections below for each of the sectors.

5.3.1.2 Mainstreaming climate change education and training across the education and training system

One of the key areas that can potentially have a long term catalytic impact on climate change education is mainstreaming of climate change into the education and training quality management system. The South African formal education system is governed by three quality councils. *Umalusi,* which quality assures education in schooling; the *Council of Higher Education* (CHE) which quality assures all higher education programmes, including teacher education; and the *Quality Council for Trades and Occupations* (QCTO) which quality assures some of the vocational education and training programmes and qualifications. These are illustrated in the Table 5.14 below. Since 2011, there has largely been ad hoc engagement with climate change education across the work of the three quality councils. There is currently no approach or strategy in place for climate change education and training mainstreaming across the national system of education.

Based on the National Climate Change Response White Paper's (Section 11.2) recommendations on climate change education and training, there is need to develop a national strategy to mainstream and integrate climate change and Education for Sustainable Development (ESD) into the national system of education and training in partnership with the South African Qualifications Authority (SAQA) and the three quality councils. This requires a co-ordination mechanism between the environmental sector and the Department of Higher Education and Training, and should include the SAQA. To date, SAQA has supported green skills and green learning pathways research, and has hosted a number of dialogues with the quality councils on the importance of sustainable development. This can be extended to include a stronger focus on climate change education and training in partnership with, and across the three quality councils.

Table 5.14: A simplified structure of the South African National Quality Framework

NQF Level	Sub-framework and qualification types			
10	***Higher Education Qualifications Sub-framework (HEQSF): The Council on Higher Education (CHE)***	Doctoral Degree Doctoral Degree (Professional)	***Occupational Qualifications Sub-framework (OQSF): The Quality Council for Trades and Occupations (QCTO):***	*
9		Masters Degree Masters Degree (Professional)		*
8		Bachelor Honours Degree Postgraduate Diploma Bachelors Degree		*
7		Bachelors Degree Advanced Diploma		*
6		Diploma Advanced Certificate		Occupational Certificate (Level 6)
5		Higher Certificate		Occupational Certificate (Level 5)
4	***General anad Further Education and Training Sub-framework (GFETSF): Umalusi***	National Certificate Secondary school grade 12		Occupational Certificate (Level 4)
3		Intermediate Certificate Secondary school grade 11		Occupational Certificate (Level 3)
2		Elementary Certificate Secondary school grade 10		Occupational Certificate (Level 2)
1		General Certificate *ABET Level 4 Primary school Grade 7 and Secondary school grade 8-9		Occupational Certificate (Level 1)

** Qualification types beyond Level 6 on the OQSF have not been determined pending further advice*
** ABET: Adult Based Education and Training*
Source: Adapted from SAQA (in Togo, Zhou & Kahn, 2013)

5.3.1.3 CCE and Basic Education Curriculum Policy

Climate change has been integrated into the national Curriculum and Assessment Policy Statement (CAPS) for Grades 1-12 via the principle of giving attention to a healthy environment and environmental justice. The CAPS curriculum is a more strongly content driven than the former outcomes-based curriculum, and in such a curriculum it is therefore important that content progression is addressed. Currently, different concepts of climate change are found in different subjects but these are not necessarily linked developmentally or within a clear progression pathway. The curriculum, broadly speaking, seeks to address scientific as well as the social justice related issues associated with environment and sustainability and climate change in South Africa, but climate change topics are currently fragmented across the curriculum. Overall the progression of climate change knowledge needs to be strengthened, and more attention needs to be given to key concepts associated with climate change in South African national policy such as adaptation, mitigation and resilience.

Thus, there is need for a more systematic approach to integrating climate change knowledge into the curriculum including inter- and transdisciplinary orientations to climate change knowledge and learning. The National Climate Change Response White Paper (DEA, 2011) suggests that CCE should be incorporated under the banner of Education for Sustainable Development (ESD). South Africa currently does not have a national Education for Sustainable Development Strategy which could assist with inter-sectoral collaboration on CCE integration.

5.3.1.4 CCE and Teacher Education

With the introduction of new environmental concepts such as climate change, a problem has surfaced with regards to teachers' as well as education department officials' knowledge of these new topics. They find it difficult to effectively approach climate change and other environmental issues as this has not previously been part of their own education, or their teacher education. Teacher education programmes for both initial teacher training and up-skilling are mainly located in universities, as colleges of education were amalgamated into universities post 1994 to improve the quality of teacher education. Some teacher education degrees do not respond to climate change or environmental concerns at all, while others have started to respond to climate change through embracing Environmental Education and Education for Sustainable Development, and initiatives to strengthen teachers' knowledge were therefore fragmented, and lacked systemic impact. All universities can give more attention to how they are integrating climate change and Education for Sustainable Development into existing teacher education programmes.

Supported by the Department of Environmental Affairs and major national environmental organisations and teacher education institutions, a new multi-institutional teacher education development programme was established in 2011. This initiative seeks to address the historical gaps in teacher's knowledge and competences to teach issues such as climate change. This initiative is known as the Fundisa for Change programme (www.fundisaforchange.co.za). It represents a concerted multi-stakeholder effort to deal with the issues of strategic co-ordination and standard setting through an accredited programme. The programme has developed climate change education materials for teachers and for use in teacher education programmes. The programmes have since been endorsed by the South African Council of Educators (SACE), and a number of higher education institutions are currently able to offer these programmes to teachers, both in inservice and preservice formats. While the programme has had some impact via training of teachers, subject advisors and national partners, there is need for upscaling of the initiative and for wider integration into the Department of Basic Education systems of Continuous Professional Development and Professional Learning Communities.

The Education, Training and Development Practices SETA and the Provincial Departments of Education could become more actively involved in supporting the upscaling and mainstreaming of climate change education for teachers in partnership with the Fundisa for Change Programmes.

5.3.1.5 CCE and Technical and Vocational Education and Training (TVET) and Agricultural Colleges

The Technical and Vocational Education and Training (TVET) sector is considered key in building skills for the green economy. These 'green skills' are necessary for advancing mitigation, adaptation and climate resilient development, especially in the agriculture, water, energy, mining, waste, and biodiversity management sectors. As yet the green skills agenda in the TVET sector is under-developed, and is impeded by a re-active approach to green skills planning and development, with inadequate skills intelligence informing the emergence of approaches to CCE and Green Skills development across the TVET landscape.

A process to address this has been started through pilot projects initiated between DEA and DHET which include a process of greening TVET focussing mainly on the greening of campuses, complemented by a greening curriculum process piloted by the DHET with 10 colleges, which is supported via a Green Jobs pilot project that was funded by the GIZ (GIZ, 2014). The above process is being expanded, but the intervention is in initial stages only, and there is need for more substantive and mainstream interventions to support curriculum development competence for climate resilient development in TVET colleges.

Additionally, DHET, through the National Skills Fund, recently allocated substantive funding to green skills to develop the South African Renewable Energy Technology Centre which focusses on TVET skills development for renewable energy at the Cape Peninsula University of Technology (CPUT). This College supports the other TVET colleges in renewable energy training. SARETEC is instrumental in the creation of Renewable Energy curriculum tailored to industry needs and is using new qualifications developed under Quality Council for Trade and Occupations (QCTO): Wind Turbine Service Technician & Solar PV Service Technician. It also offers a wide range of industry recognised short courses and workshops within the renewable energy sector.

Overall, the system of TVET is still not fully set up for responding to climate resilient development imperatives. There is an emphasis on Disaster Risk Reduction in some TVET training, and a focus on renewable energy is growing in the TVET sector. These are, however, generally not well developed as areas of specialisation and there are poor links between supply side training and demand for green skills, a relationship which is still under-researched in the labour market intelligence system. Additionally, TVET colleges are challenged with supplying appropriate up to date technology for the practical aspect of training, and few colleges have integrated a comprehensive approach to CCE into their curricula, campus management and practical demonstration systems.

Few of the 12 public Agricultural Colleges currently offer climate change education in their curriculum, but colleges are currently in a restructuring phase, and are transitioning to Agricultural Training Institutes using a competence-based approach which, if combined with climate smart agriculture, and green economy demonstrations and practices, could significantly strengthen this aspect of agricultural education and training in South Africa. Extension officer training is currently being restructured into a four year degree programme, and it would seem critical to incorporate climate change responses and resilience into the restructuring of this degree programme. There is some awareness of this need in the Agricultural Education and Training system, but as yet, not enough has been done to systematically integrate climate smart agriculture into agricultural education and training within a social learning model and approach. This will require that more attention is given to the training of agricultural educators and trainers in the entire agricultural learning system.

Training of College Lecturers in green economy streams, as well as in general knowledge of climate change and climate resilient development, and climate smart agriculture (for agricultural colleges) is a critical area of need to support mainstreaming of CCE into the TVET sector.

5.3.1.6 CCE and Sector Education and Training Authorities (SETA)

The National Climate Change Response White Paper (Section 11.2.2) proposes that there is need to include climate change elements in the review of the National Skills Development Strategy (NSDS) and ensure that all SETAs add climate change to priority skills development programmes in the formal, informal and non-formal sectors of the education and training system. The National Skills Development Strategy III (2011-2016, now extended to 2018) includes a focus on green skills for the green economy, which has catalysed a number of the SETAs to begin with green skills planning. It also led to defining green occupations in the Organising Framework for Occupations (OFO), which is used as a key planning instrument for SETAs. However, the green occupations were transferred mainly from an American version of the OFO, and thus green occupations on the OFO need to be aligned with the South African occupational context. This is crucial, as the NSDS IV, which will be released after 2018 will use an occupational framework to guide skills planning. There is a need to review the OFO to ensure that relevant climate change related occupations are adequately represented. There are currently a number of pilot initiatives underway supported by SETAs to identify and include climate change and green economy related occupations in the OFO codes. Climate change mitigation will require substantial upskilling and reskilling in the energy, mining, petrochemicals and building and construction industries. Similarly, climate change adaptation will require new occupations and enhanced skills in the agricultural, health, ecosystem protection and water services sectors. These areas should be seen as priorities for the identification and incorporation of climate change responsive occupations and thus skills planning at the national level. Work to define and describe these occupations needs to be upscaled.

To add impetus and strength to the need for a more proactive approach to green skills planning, the National Environmental Skills Planning Forum (NESPF), a Forum run by the DEA, has established a multi-institutional Green Skills system capacity building programme (www.greenskills.co.za) which is funded by the DEA Green Fund (2015-2017). This multi-institutional Green Skills programme is addressing skills planning issues at a systemic level, and is working closely with the DHET to ensure that Green Skills concerns are integrated into the national system of labour market analysis and skills planning and monitoring. This need was also articulated in the National Climate Change Response White Paper (Section 11.2.5). While a start has been made by the NESPF's green skills programme, much still needs to be done to develop a comprehensive national green intelligence system. A comprehensive national green skills intelligence system will replace or complement the more informal NESPF which is currently putting the building blocks in place for a more comprehensive national green skills intelligence system. Thus, the country's major green skills planning and strategy programme is currently located within a co-operative structure of the DEA. It should ideally be mainstreamed into the DHET system of skills planning and intelligence operations. This requires stronger systemic co-ordination and close co-operation amongst ministries and SETAs that are seeking to strengthen capacity for climate compatible development, mitigation and adaptation. There is still no major coherent national strategy to meet the skills needs for the green economy.

5.3.1.7 CCE in Higher Education and Research Institutions

The Global Change Grand Challenge National Research Plan (DST 2010) highlights the growing importance of developing skills for risk prediction and risk management, sustainability innovation, complex systems analysis, building system resilience, and adaptive management. Across the South African University landscape are a number of different research Centres and Units that are active in various dimensions of climate change research ranging from Climate and Earth System Sciences to Sustainability Innovations (e.g. renewable technology and green economy innovations). The Southern African Regional Universities Association (SARUA, 2015) recently undertook a comprehensive mapping of the national system of climate change research as found in universities and research centres (www.sarua.org) and a detailed mapping of climate change education in South African universities therefore exists which shows that a number of the South African universities are beginning to engage practically with transdisciplinary research approaches as applied to climate change related concerns.

There are also various climate change related Honors and Masters degree programmes in individual universities, and some universities are beginning to specialize in climate change related concerns. One of the critical areas that requires attention is better support of Honors students from a funding perspective, and also support for their transition into Masters degrees as this appears to be one of the most difficult transitions in the system at present, and many young people with potential to undertake higher degrees exit the system at honors level due to funding and other social pressures.

The 2014 Southern African Research Universities Association (SARUA) study (www.sarua.org) identified the Masters degree as a key innovation point for supporting knowledge co-production on climate change. Subsequent to the mapping study, a new regional Masters degree focussing on climate change and sustainable development is being developed with leading South African universities contributing to the programme. This initiative is supported by the Climate and Development Knowledge Network (CDKN). There are other curriculum innovation developments like the Higher Certificate in Renewable Energy Engineering which being developed by the Nelson Mandela University. This course is articulated between TVET College and university undergraduate degree.

Associated with the production of the need for specialist, scientific and engineering skills in South Africa via Higher Education, is a recognised limitation in terms of supervisory capacity for research students in the region, especially related to new and highly specialized research areas. This is a problem of both quantity and quality and there have not been signs of significant growth in this area for decades, leading to some stasis in terms of graduation rates at post graduate level, despite potential scholars graduating at under-graduate level. The recent National Research Foundation (NRF) South African Research Chairs Initiative (SARChI) Chairs Initiative of the DST aims to address this. The NRF SARChI is designed to attract and retain excellence in research and innovation at South African public universities through the establishment of Research Chairs at public universities in South Africa with a long-term investment trajectory of up to fifteen years. There are a number of chairs associated with the global change sciences, including one focussing on transformative social learning and green skills learning pathways at Rhodes University's Environmental Learning Research Centre, with the specific mandate of strengthening education, training and social learning responses to climate change.

Overall the SARUA South Africa (SARUA, 2014) study shows a vibrant and active scientific community engaged with climate related sciences and capacity building of specialist skills for the many different dynamics associated with climate change in a number of disciplines. Areas for further development identified in the South African SARUA study included:

- Recognition that South Africa has well developed observational research capacity, but there are still gaps in terms of scope and technology associated with this area, and there is need for a more integrated system for observation and monitoring.
- There was need to guard against a science and technology bias to dealing with climate change, and adequate focus and attention should be given to the humanities and social sciences in climate change responses.
- There was also need for curricula and research approaches that could model systems thinking.
- There was also need for pro-active establishment of curriculum innovation forums, and for mobilizing university management support for climate change related research and curriculum innovation, as well as private-public partnerships for climate change research and curriculum innovation.
- Research incentive systems in Higher Education also need to be adapted to recognise multidisciplinary, interdisciplinary and transdisciplinary, as well as community engaged approaches to research.

5.3.2 Climate Change awareness and action

As for climate change education, a range and diversity of climate change awareness and action initiatives were identified. These were found in various sub-sectors of the system that provides for climate awareness and action. Overall, it is suggested that a national strategy on climate change education, awareness and action with indicators that are policy aligned could support a more cohesive approach to climate awareness and action, with potentially also more synergistic impact. Two key areas appear to be under-developed in climate awareness and action provisioning, notably the use of social media, and community radio. Both of these media have potential to reach large numbers of the South African public.

5.3.2.1 Government supported public awareness and action programmes

The South African government has introduced a number of initiatives at different levels of government that are contributing to public awareness and action programmes. These initiatives are being implemented by different government departments and include for example:

- The Department of Science and Technology (DST) science plan and institutional architecture for responding to global change (including climate change) includes a focus on balancing research with the 'science-policy-practice' interface, focussing on the practical applications of knowledge. The recently-created South African Risk and Vulnerability Atlas (SARVA) for example is being distributed to local government throughout the country, and access to further information is being facilitated by the risk and vulnerability network/assessment centres established at universities.
- The Department of Energy are also implementing the Energy and Environment Partnership (EEP) which promotes renewable energy (RE), energy efficiency (EE), and clean technology investments. The EEP Programme supports projects which aim to provide sustainable energy services to the poor and combat the climate change. To qualify for EEP support, projects must demonstrate high innovation in delivering energy services, facilitating technology transfer, encouraging cooperation and local stakeholders' participation in projects. At provincial level, most government departments

have public awareness and outreach programmes in which climate change is embedded.

- At provincial level, various climate change initaitives are being implemented by the Provincial Departments of Environmental Affairs via their community empowerment and outreach programmes. Programmes differ in focus, scope and scale, but there are some excellent examples of practical adaptation programmes involving communities, as well as outreach programmes that are supporting radio programming and other types of information sharing on climate change.

While most municipalities have a challenge of resources to run environmental outreach projects, the larger metropolitan cities have quite sizable outreach programmes on climate change. These are usually imbedded in climate change projects like the GHG Inventory and Reporting Training that involves multiple cities like Johannesburg, Cape Town, Durban and Tshwane, C40 Cities Thematic Workshops whose themes are energy, transport, adaptation and water, sustainable urban planning climate change financing.

While there are many initiatives across the different levels of government, one observation made in tracking these initiatives is that they tend to follow a pattern of short term engagement, rather than longer term, sustained engagement over time. A national strategy and indicator framework on climate change education and awareness could help to create greater synergy, and thus impact across government interventions.

5.3.2.2 NGO public awareness and action programmes

There are also a large number of NGO groups active in the area of climate change education and public awareness, including but not limited to the Association for Water and Rural Development; the Environmental Monitoring Group; Indigo Development and Change; Drynet; Wildlife and Environment Society of South Africa (WESSA); World Wide Fund for Nature (WWF) and Food and Trees for Africa. Their combined work spans the whole country and address different sectors and institutions. Again, there is great diversity in the orientation and approach taken to climate change awareness and action across these programmes, as often dictated by concerns and mandates of the particular organisations. Alignment with national policy could potentially be strengthened within a wider framework of a national strategy on climate change education and awareness. The Climate Change Adaptation Network provides an example of a co-ordinated and networked national platform for sharing experiences and practical approaches, and for promoting focussed co-ordination of national climate change adaptation planning and activities.

A number of international NGOs have also campaigned in South Africa on climate and energy issues, among them BirdLife International, Greenpeace, Oxfam, and the Worldwide Fund for Nature (WWF), and they play a key role in informing the public about climate change and appropriate individual responses. There has also been an increased focus on climate change and climate compatible development issues in the Media (see below), and there have been some innovative programmes to link climate change scientists with journalists to improve the science-media interface.

There are also a number of youth-directed environmental education and training programmes that include a focus on climate change. There is also increasing evidence that social networks and social learning within and across societal groups and networks are critical if adaptation in urban and rural contexts is to be facilitated (e.g. among farmers, water practitioners, the business community, and community-based adaptation and disaster and risk reduction). Efforts to co-ordinate such efforts via social platforms for the engagement of wider civic society while operating actively, remain under-researched for their capacity to enhance human agency, especially forms of collective agency for change and transformation.

5.3.2.3 Internationally funded awareness and action programmes

Internationally funded programmes also contribute to climate change awareness and action in South Africa. South Africa has partnered with USAID to run a project aimed at strengthening public sector-related low emissions development planning and project development capacity for municipalities. This 5 year project started in May 2015.

Another large scale USAID funded initiative for climate change response is the programme being implemented by the Association for Water and Rural Development (AWARD) in the Oliphant's Basin in Limpopo Province. This large scale NGO led programme is developing social-ecological system science approaches to assessing resilience at a catchment system scale, and it is also developing a range of social learning approaches to resilience building amongst multi-stakeholder groups including mining, local government, natural resources managers, communities benefitting from land restitution, farmers and others who have critical roles to play in building a more climate resilient catchment. Evaluations emerging from this programme show that social learning and participatory approaches to resilience assessment are helpful for involving a diversity of actors, and for developing inter-related systems understandings of the changes required for climate resilient development. Another climate response project, supported by GIZ in partnership with DEA and COPTA, has been promoting awareness and planning to integrate climate change related responses into the Integrated Development Plans of municipalities, educating councillors and their publics, as well as staff in the municipality to consider the implications of climate change for planning, public services management and public awareness and participation. The 'Let's Respond' programme notes that local government are closely related to, and need to closely engage with citizens and their built and local environment, and as such local government is a cornerstone in climate response actions.

The outcomes, methodologies and tools developed via these programmes need to be more widely shared via a national system or strategy of engagement to upscale and strengthen climate change education and public awareness.

5.3.2.4 Business and business organisation awareness and action

In the context of climate change business leaders have tended to focus on new technologies, continued economic growth, competitiveness and efficiency while labour has emphasised the justice dimension of low-carbon shifts and have called for a 'just transition' that balances job creation and environmental commitments. All parties have agreed, however, that education and training in new technologies, processes and decision making will be required. To this end, both the National Development Plan and the Green Economy Accord make it clear that the green economy skills need, will be elevated as a priority in the National Skills Development Strategy and National Skills Framework. The latest progress report on the implementation of the National Skills Development Strategy III (DHET 2014) noted that because of an absence of explicit guidance the development of green skills, this area of skills development has, in most cases, been driven by sector specific projects rather than a planned approach based on skills needs forecasts aligned to the National Growth Plan and other national strategies.

The mismatch between the challenges and opportunities posed by climate change, the skills required and the skills planning processes has been highlighted by a number of recent green skills studies (greenskills.co.za; Montmasson-Claire 2012). There are various initiatives which have high levels of impact, innovation and importance, such as the National Cleaner Production Centre South Africa (NCPC)'s Industrial Energy Efficiency Improvement Project in South Africa that has been designed to promote and implement energy management systems. It is estimated that this initiative has, since its inception in 2010, saved industry over R1.54 billion in energy costs amounting to 1 343GWh or approximately 1million tons of carbon emissions saved. More than 100 experts in energy-efficiency auditing were trained and over 2 600 people have to date received training in energy efficiency through the programme. While this is a big impact, it was also found that this programme lacked systemic integration into the national system of qualifications and accreditation, and this has been a key area of development for the programme.

Other initiatives with similar impact are the the Gauteng Innovation Hub's Climate Innovation Centre which seeks to support 'clean-tech entrepreneurs' to proactively and profitably develop advanced smart technologies that meet local needs. Capacity development opportunities offered to these entrepreneurs include learnerships and ongoing mentorship by experienced business and green economy experts. National Labour and Economic Development Institute (NALEDI), over the past 3 years NALEDI has, with funding support from the Green Fund, conducted a programme focussed on building the labour movement's capacity to respond to climate change policy and implementation processes in South Africa. Also closely linked to labour and driven by an alliance of labour, social movements and other civil society organisations is the 'One Million Climate Jobs Campaign". This campaign seeks to support "a just transition to a low carbon economy to combat unemployment and climate change". The programme calls for the training of new climate workers and retraining workers where necessary. Specific focus areas are identified and education and training options need to be developed to enhance the skills required to create one million climate jobs.

The National Business Initiative (NBI) brings together South African and multinational companies to work towards sustainable growth and development in South Africa. In addition to a wide range of activities, the NBI supports awareness raising, public and private sector capacity building, further education and training, energy efficiency and other responses to climate change. The development of circular economy within South Africa has significant implications for energy and waste management both of which have potential impacts on greenhouse gas emissions. The Recycling and Economic Development Initiative of South Africa (Redisa) invested over R10 million in 2015/2016 in bursaries for the development of women in the engineering profession. These bursaries are designed to support advancement and innovation in the field of recycling and economic development. Other recycling initiatives in South Africa include PETCO, POLYCO, mpact, ROSE, Collect-a-Can and PACSA to name just a few.

It is evident from the above that a substantial amount of awareness, education and training to support climate change mitigation and adaptation is taking place within and being supported by business and labour initiatives. Even though there is substantial amount of climate change awareness initiatives in South Africa, the government still needs to develop a robust national climate change awareness strategy across all sectors.

5.3.2.5 Media Involvement and Awareness and Action

The media reports on climate change through various channels including printed, electronic, television and radio media. Climate change is rarely reported as a standalone topic but rather as a background element in stories about people, events and broader environmental issues. It is therefore seldom explained, especially in daily newspapers, making the reporting not as educational on climate change as it could be, nor easily recognisable, and at times misrepresented. In the weekly and longer term newspapers, there is more in-depth coverage of climate change.

There are a number of magazines and newsletters that frequently cover the simplified science of climate change, the debates, and opinions. These are mostly published by institutions, sectors and NGOs. Examples of these are the Engineering News, Environment magazine published by a group of environmental NGOs, EnviroKids, Simply Green, Time magazine, and EnviroTeach which publishes materials for teachers to use in support of curriculum change.

South African television screens programmes on sustainable development and sometimes specifically climate change in South Africa. These include 50/50 on SABC and the Weather Channel on DSTV. The majority of these programmes are, however, found on the pay channel. This eliminates a large majority of TV viewers. Magazine programmes like Morning Live feature events such as launches of environmental projects, crises like the current drought, COP meetings and so on.

An area that is as yet un-developed for climate change education and public awareness is use of social media. A few climate change related communication streams were found on social media, with some notable exceptions being the ACCESS Habitable Planet climate change education programme which has a membership of over 2500 university students actively networking via this medium. The 350.org Africa also uses Twitter as a communication and public awareness raising means. Given that South Africa has been found to be one of the highest users of mobile technology and mobile social networking on the continent, with over 11.8 million people who use Facebook, and 8.8 million of these accessing Facebook on their mobile phones. The largest group of Facebook users are the age 13-18, which indicates that this is also a potentially significant medium for strengthening public awareness of climate change amongst youth. Use of social media and the internet can also be significantly expanded to strengthen the social learning potential of citizen science activities that strengthen climate change awareness and action.

Another area of media that seems to be significantly under-utilised for climate change education and awareness raising is radio, especially community radio stations as they have potential to reach communities outside of the metropoles in a range of local languages. Community radio in South Africa garners almost 8.6 million listeners a week, and there are more than 165 community radio stations, most of which are looking for new areas of programming, and information to share with communities.

Added to the above, is the need for further capacity building for journalists, as journalists have been identified as significant actors in shaping public opinion and understanding of climate change. Most tertiary institutions that offer journalism include environmental issues as a topic embedded in developmental and social studies. Climate change journalism or even environmental journalism is not often offered as a full journalism course but as a research or project option, depending on the availability of supervisors and or funding. At postgraduate level there are better opportunities of focussing on environmental reporting research. However, these are highly dependent on the availability of funding for bursaries and availability of appropriately skilled supervisors.

5.3.3 Action plan to prepare awareness and action materials

There are a wide variety of learning and teaching support materials (LTSM) that are being developed and used by the range of programmes that are noted in the reviews above. These include books, booklets, magazines, newsletters, diaries, games, posters and DVD's. Materials are also developed to target specific groups such as primary education, senior and further education and training, teacher education, communities and the wider good. Review of the materials shows that there is further potential to align the materials with policy directions as outlined in the National Climate Change Response White Paper (RSA 2011).

From this it would seem that there is inadequate national dialogue on how to approach climate change education and education materials development in relation to climate change policy in South Africa, as organisations largely tend to favor approaches to climate change based on own agenda's rather than reflexive and clear engagement with policy directions. Rather than recommending specific materials that need to be developed, it seems that a more cohesive approach to materials development is needed.

Actions for further development of learning and teaching support materials (LTSM) for climate change

- **LTSM Action 1: Create a data-base and platform for existing LTSM materials:** Given that there are already many LTSMs available on climate change developed for climate change education and training purposes. Thus, an important starting point for taking further the development of LTSMs in South Africa would not be to develop new materials, but rather to produce a data-base of climate change LTSM's available for use within a South African context, and where possible online access to the materials. This would serve a number of purposes: 1) it would provide information and guidance to prospective developers of climate change education LTSM's (they would know what already exists compared with what the gaps of information and approaches are), it would 2) avoid duplication of materials, and 3) it would assist climate change education practitioners to access materials that could support development or improvement of their climate change education practices.
- **LTSM Action 2: Strengthen the relationship between LTSMs and policy directions:** A second key response would be to strengthen the relationship between LTSMs and policy directions. This could be done by organising the data-base / LTSM platform according to key policy priority areas and directions, which in turn would help to identify gaps, and develop a stronger engagement between LTSM development and policy direction.
- **LTSM Action 3: Provide guidance on how to adapt materials to local climate change conditions, risks and climate resilient development pathways:** There is also need to provide adequate guidance on adaptation of climate change knowledge for local use, given the diversity of climatic regions and the diversity of vulnerabilities and climate compatible development opportunities that are emerging. The platform can therefore provide key resources and guidelines that can be used to inform adaptation of materials for local use.
- **LTSM Action 4: Quality review of content and training for LTSM developers:** Support a programme that can provide training to materials developers to review and upgrade the quality of the LTSMs to avoid outdated content, too superficial or general content, inaccurate information, clear understanding of key concepts such as adaptation, mitigation, climate resilient development, climate justice, resilience. Also support LTSM developers to apply wider systems perspectives and need to strengthen inter- and transdisciplinary approaches to CCE, but also to ensure that climate change information in specific Subjects are of a high disciplinary quality and relevance. Sector specific in-

formation (e.g. to the agriculture sector) also needs to be accurate and up to date and LTSM developers need to be trained to reflect sector demands for climate change knowledge accurately and innovatively.

- **LTSM Action 5: Support new materials that strengthen participation in sustainability practices at community level:** Many of the LTSMs tend towards either sharing scientific knowledge of climate change or clarifying concepts such as adaptation or mitigation, and materials that are targeted at individual behavioral change. There are inadequate materials for supporting practice transformations at community level i.e. for collective action and change. Citizen science tools and citizen journalism support are good examples of the types of LTSMs that can strengthen community level / collective action for change.
- **LTSM Action 6: Strengthen active learning approaches in materials:** Support active, integrated approaches to learning in the LTSMs as recommended in education and training system policy.
- **LTSM Action 7: Continue to expand the materials for teachers under the Fundisa for Change programme:** Continue to support development of Fundisa for Change teacher education materials, including establishing an on-line platform for these materials, as well as development of new modules such as a module on Green Economy.
- **LTSM Action 8: Orientation to websites and how to use them:** Develop a guideline document on good websites that can provide orientation for users on the strengths and types of information on climate change that is hosted on websites, and how this can be used for education and training purposes. Ask all websites mentioned in the guidelines document to share this resource on their websites so as to facilitate cross website interaction.

5.4 Capacity Building Needs

Based on the reporting on climate change education and training in Section 5.3 of this chapter, and on specific capacity building needs associated with GHG inventory compilation; tracking and reporting on mitigation and its effects; tracking and reporting on adaptation measures as well as capacity needs for technology transfer and development, research and systematic observation and climate change knowledge and awareness. The capacity building needs are oriented to strengthen GHG inventory capacity development, climate change mitigation, climate change adaptation, climate change research and systematic observation, as well as climate change education, training and social learning at a systemic level, as this was found to be a major gap in the current South African climate change capacity building and climate change environmental education and training systems of activity. To achieve a systemic approach to capacity building, a longer term approach and strategy for climate change research, education, training and capacity building is needed as current short term initiatives tend to lead more to fragmentation than substantive systemic development and integration.

5.4.1 Capacity Building Needs and Gaps for Developing National Greenhouse Gas Inventories

Related to the above, there are three main constraints related to the GHG inventory update process at the moment, namely activity data, emission factors and capacity. Currently the most limiting of these is the lack of capacity. There is a need to develop training courses to cover the various aspects of the GHG inventory update process, such as IPCC guideline methodologies for all four sectors, QA/QC process and methods, uncertainty analysis, key category analysis and even general coordination and management of the GHG inventory update process. These courses could be developed as short courses to support immediate needs and as a post graduate university course to develop longer term capacity for the future. Short courses could be provided as they are required (e.g. beginning of each year, beginning of each inventory cycle, or whenever new staff are brought into the inventory team), while a post graduate university course would be offered every year.

Activity data and country specific emission factors are two important requirements for the inventory. Projects providing information on country specific emission factors in all sectors need to be supported. The new GHG regulation will assist with the improvement and updating of information for the energy and IPPU sectors, however there is an urgent need to improve data in the transport and waste sectors in particular. Currently there are two projects in the transport sector which are underway which will assist in filling some of the gaps, and it will be important to ensure this data gets incorporated into the inventory.

There are also numerous gaps in the AFOLU sector. An urgent issue that needs to be addressed in this sector is the production of land use change maps. This data is a requirement to complete the land sector inventory and currently the change maps only extend to 2014. Ideally change maps need to be produced every 4 or 5 years, and they need to be consistent and have a standard classification to maintain continuity over the years. A task team or a project needs to be set up to (a) determine the best data and methodology to use for land use change maps, (b) develop a standardised classification system that is consistent with existing classifications, includes all categories relevant to the inventory and ensures category definitions are consistent with related projects (i.e. FAO and REDD+ definitions), and (c) assess costs, funding sources and data providers for the continuous supply of land use change data. In terms of the agricultural data there is a need to improve the manure management data; nitrogen excretion rates for all livestock; and lime, urea and nitrogen fertiliser consumption rates. There are also some issues of consistency in terms of the crop harvested areas and livestock numbers provided by various sources which needs to be investigated.

The above-mentioned gaps and projects could be supported through the GHG Improvement Programme, so it is essential to ensure continued funding support for this programme. In addition funding support is required for the inventory team to incorporate new data and update the inventory. It is important to ensure that the inventory input data and calculations are of a sufficient granularity so as to incorporate the reductions brought about by the mitigation actions implemented in the country. If the mitigation actions are not incorporated into the GHG inventory then South Africa's mitigation efforts will not be correctly reflected.

Lastly, there is a need to assess the mitigation activities being carried out and ensure that these actions and reductions are being incorporated into the inventory. South Africa needs to ensure that their emission reductions are being reflected and show that South Africa is moving towards its emission reduction targets.

5.4.2 Capacity Building Needs for Adapting to Climate Change

South Africa's existing capacity to adapt to climate change is of importance to focus on. More specifically the discussion below is intended to evaluate South Africa's capacity to develop appropriate climate change adaptation strategies and to translate these strategies into adaptation action. This assessment is based on a review of post-2011 studies and reports that have undertaken some form of analysis of South Africa's existing capacity to adapt to climate change. The assessment considered the key determinants of adaptive capacity that include an enabling regulative environment, adequate financial resources, human capacity, access and availability of relevant climate change related research and information, as well as the institutional capacity for cross-sector integration and stakeholder coordination.

For the purposes of this report, the focus was confined to the three spheres of government (national, provincial and local), as well as an assessment of the adaptive capacity of key actors including agriculture, water resources, and settlements, amongst others. The critical role that these actors play in contributing to the country's ability to respond effective to climate change is however acknowledged.[28] In the Section 1, key determinants of adaptive capacity at the national, provincial and local scale are discussed with some reference to key sectors in the research and information section. The second of the report collates the various sector specific constraints[29] identified in the sectors review component of the TNC and groups them into 11 categories in order to give an overall sense of the current perceptions of South African adaptation constraints. Capacity needs are discussed in reference to each of the constraints as it is often seen as an overarching limit or barrier to the successful implementation of climate change adaptation.

5.4.2.1 Adaptive capacity of national, provincial, and local government

5.4.2.1.1 The regulatory environment

Climate change adaptation policies and regulatory frameworks are important for mainstreaming climate change considerations/responses into all spheres of government, and for identifying roles and responsibilities. An enabling regulative environment is furthermore an important prerequisite for providing guidance to adaptation planning and creating enabling conditions for adaptation interventions within the public as well as private sector.

Sector specific climate change adaptation strategies have been developed for water; agriculture, forestry and fisheries, health, biodiversity (biomes) and human settlements ,and substantial progress has been made with regard to the development of provincial climate change response strategies. While the development of provincial climate change response strategies is an important step towards understanding and responding to current and future climate change impacts, the SANAs Report (DEA, 2015c) highlights that the capacity to develop and implement such strategies at the provincial level remains limited. In particular the lack of competencies to support or conduct vulnerability assessments and climate risks analyses were emphasised. This problem links back to skills and knowledge deficit in the provincial departments (See human capacity (Section 5.4.2.1.3) as well as research & information (Section 5.4.2.1.4) below).

At a local government climate change response strategies exist for all metropolitan municipalities or are in draft form (DEA, 2016). All have also several targets and key performance indicators for climate change adaptation in their Integrated Development Plans (IDPs). Ten district municipalities have climate change response strategies; these include Chris Hani, uMgungundlovu, Amathole, Alfred Nzo, West Coast, Eden, Capricorn, Bojanala, Namakwa and Nkangala (DEA, 2016c). Some of these municipalities make reference to climate change considerations through the mentioning of the establishment of

28. Both, civil society and the private sector are proactively engaging with the topic of climate change and started to respond through innovative measures aimed at increasing South Africa's resilience to climate change. NGOs, for example, have been instrumental in capacitating local government throughtargeted skills development interventions. Representatives from the private sector have started to establish public–private partnerships aimed at building greater resilience at the landscape level.

29. Adaptation constraints refers to a factor or process that makes adaptation planning and implementation more difficult" (Klein, 2014:906).

climate change forums, research, options for financing the strategy etc. Six local municipalities have climate change response strategies, three of which have performance indicators for climate change in their IDPs (DEA, 2016c).

Overall the integration of climate change considerations into municipal development planning tools such as the IDPs and Spatial Development Plans (SDPs) remains limited and requires more attention and strategic assistance from provincial government (DEA, 2016c, Ziervogel *et al*., 2014).

5.4.2.1.2 Financial resources

Access to and availability of financial resources dedicated to climate change adaptation planning (e.g. for the development of impact and/or vulnerability assessments) and for the implementation of specific adaptation actions and programs are key determinants of adaptive capacity.

It has been reported in the SANAs Report (DEA, 2015c) that no funding is provided to provincial environmental departments for climate change adaptation planning and development. The report highlights that in particular Limpopo, the Northern Cape, Gauteng, the Free State and Mpumalanga have found it challenging to finance adaptation initiatives. The Western Cape is currently the only province that has a budget allocated for the provisions of climate change response initiatives through its environmental department (DEA, 2015c). However, according to the NAS provincial chapter the funding remains minimal. Several provinces have been able to secure funds through the Green Fund (e.g. the Eastern Cape and KwaZulu-Natal) and some are in the process of developing strategies for accessing international funding options (Urban Earth, 2016). The Western Cape and Gauteng have started to investigate potential climate change response funding options such as green and climate bonds, commercial finance through debt and equity, municipal revenue sources or a carbon tax (Urban Earth, 2016).

The SANAs Report (DEA, 2015c) states that fiscal mechanisms and incentives that would motivate municipalities to mainstream climate change responses are currently missing. According to the DEA M&E Annual report municipalities receive financial support from SALGA, DEA and civil society for mainstreaming climate change adaptation into municipalities (DEA, 2016c). While some of the larger metropolitan municipalities and one district municipality[30] have been able to secure international funding for initiating adaptation activities, small municipalities have almost no direct financial resources for implementation of climate change activities available (Ziervogel *et al*., 2014). Due to the fact that climate change continues to be framed as an environmental issue rather than a developmental challenge, climate change related responsibilities at the municipal level continue to be referred to as unfunded mandates creating an additional burden for municipalities (Ziervogel *et al* 2014; DEA 2016c).

5.4.2.1.3 Human capacity

The importance of having people with the necessary awareness, skills and knowledge available to develop climate change responses, mainstream and implement climate change adaptation interventions, and access larger networks and partnerships is recognised in the NCCRP.

It is recognised that outside the existing national and provincial climate change units/ directorates there is almost no personnel with formal training on climate change (including adaptation) (DEA, 2015c). This presents an obstacle to mainstreaming climate change considerations into the day-to-day activities of the different departments. It further hampers the ability to access and interpret avail-

30. The uMgungundlovu District Municipality has been able to secure $ 7.5 million for the implementation of the "Building resilience in the Greater uMngeni Catchment, South Africa" Project from the Adaptation Fund.

able climate information, and to develop, prioritize and execute appropriate adaptation interventions. Chapter 5, Section 5.3.3 describes approaches to strengthen climate change education, training and social learning in South Africa and provides an action plan with specific action areas, priority actions and recommendations on who could be involved in each action area.

In addition to sufficient knowledge on climate change and climate change adaptation, government officials responsible for the implementation of concrete adaptation measures need to be equipped with the necessary skills that allow them to make robust decisions in light of uncertainties and with long term climate change in mind. Hence, in particular, learning, systems thinking and experimentation needs to be fostered and further enhanced by monitoring and evaluating techniques and systems that help to assess the impact of specific adaptation interventions.

Several studies (Pasquini *et al.*, 2014, DEA, 2016c) have also highlighted the important role that climate change awareness plays for the development of leadership in form of climate change adaptation champions in administrative and political positions. These champions are a vital for getting the necessary buy-in from their home departments, pioneering innovative initiatives, creating collaborative partnerships with the private sector and civil society as well as for connecting to exiting knowledge networks.

5.4.2.1.4 Research and information

South Africa benefits from having a well-established earth system research program and climate science expertise which is situated across a number of universities and national research institutions (Ziervogel *et al.*, 2014). This expertise has allowed for the development of region and sector-specific climate change scenarios and climate impact assessments, leading to a better understanding of projected climate change impacts. Yet it needs to be noted that a major constraint to climate change impact modelling in South Africa is the lack of a robust national system that provides spatially extensive climate data (Ziervogel *et al* 2014). Of particular concern is that national data for hydrology are becoming difficult and costly to obtain (Ziervogel *et al* 2014). In the sector-reviews of the TNC, the lack of adequate impacts modelling is also identified with emphasis on data and monitoring.

For example, the Coastal zone sector highlighted the limited availability of models that link hydrological regimes to ecosystem processes and large scale ocean current changes, and the Urban and rural settlements sector emphasising how impacts modelling approaches are currently incomplete. For the Human health sector a gap is identified in terms of the need develop scenario-based modelling to project future health related risk, with the inclusion of both climatic and non-climatic factors. The Disaster risk management sector highlights the need to expand the scope of the provisional modelling work conducted as part of the LTAS in relation to the possible increase in flooding risk and related impacts on dams, bridges and powerline crossings.

At the national level, sectoral planning has been able to build upon detailed impact modelling and the output from processes such as LTAS. However, at a provincial level it is reported that some provinces require guidance in terms of how to access climate change information relevant for their specific province (DEA, 2015c).

At local level, in comparison to district and local municipalities, metropolitan municipalities tend to be better equipped to access and interpret climate related data and develop robust risk and vulnerability assessments. Metropolitan municipalities (such as the City of Cape Town) have a strong knowledge base (made up of various universities and consultancies) within or in close proximity to their municipal boundaries (Pasquini *et al.*, 2014). The collaboration goes beyond information provision (free and paid), and extends into various fora and initiatives that foster long-term partnerships and lead to knowledge sharing and capacity building. These forms of partnerships are critical for mainstreaming climate change information into the local scale planning, and therefore need to be extended to local and district municipalities. Provincial and national government should also provide information on existing channels that municipalities can utilize to access relevant climate change data and information.

Specific gaps in risk and vulnerability assessments at the local level include the understanding of the environmental exposure of residence of informal settlements. The Disaster risk management sector for example highlights the lack of vulnerability assessments that consider increased population concentrations in the context of climate change and increasing informal urbanization.

5.4.2.1.5 Institutional capacity

At a national level, dedicated departmental climate change units exist in the DAFF, DWS, DST (DEA 2016c). Their role is to assist other relevant departmental units on issues of climate change and to mainstream climate change considerations into strategic long term planning.

Key structures for coordinating climate change issues at the national level are the Intergovernmental Committee on Climate Change and the National Committee on Climate Change (DEA 2016c).

At a provincial level, currently only the Western Cape Province has a dedicated climate change unit which is situated under the environmental department (DEA 2016c). Yet as already discussed in the human capacity section climate change units are critical for capacity building at the municipal level (including technical support). They are also important support structures for other departments and can facilitate better cross-sector integration.

Other important mechanisms for cross-sectoral integration are the provincial climate change forums and strategic working groups. These bring together representatives from various departments and meet at a regular basis to discuss climate change related topics as well as the progress on specific interventions prioritized in the climate change response plans and strategies.

The Eastern Cape, KwaZulu-Natal, Gauteng, the Northern Cape and the Western Cape have established climate change foras (DEA 2016c). Whereas in some provinces these fora and working groups are situated with senior management and therefore have influence on strategic decision making processes, other fora lack this influence or are no longer functional (DEA 2016c). To improve the coordination and alignment across the three spheres of government more effort needs to be made to share the outcomes of the work of the provincial fora with the fora at national and municipal level. At a local level it was found that the City of Cape Town and eThekwini have dedicated climate change units as well as climate change committees/forums.

5.4.2.2 Adaptation constraints and capacity needs of key sectors in South Africa

5.4.2.2.1 Lack of or insufficient co-ordination and/or communication

Given the cross-cutting nature of climate risks, responses necessarily involve a wide range of actors and thus require alignment of policies, plans and activities, clear allocation of responsibilities and consistent reporting – all of which can be considered important aspects of good co-ordination and communication. The lack thereof can thus be perceived as an adaptation barrier, as in the Agricultural sector where the lack of co-ordination with related sectors such as water, land development and land reform, is highlighted as a possible barrier. For Human health poor communication and coordination between government departments and the public is emphasised. The lack of policy coordination and alignment is also recognised for Urban and rural settlements as well as for the Water sector. In Disaster Risk Management inconsistent reporting on natural disasters, as well as the lack of clearly defined roles and responsibilities, are identified as further barriers.

5.4.2.2.2 Climate change being seen as a low priority and/or being treated as a separate environmental issue

There is still a tendency for climate change being boxed as an environmental issue, thus preventing broader engagement around the related issues. More immediate or seemingly pressing issues also tend to get priority, particularly in the developing country setting where government actors generally have a large number of immediate pressures. In the Disaster risk management sector historical emphasis on short term and reactive responses to disaster means that disaster risk reduction tends to be considered a low(er) priority. In the Estuarine environment and the Urban and rural settlement sectors it is noted that climate change is often seen as a separate or environmental issue, rather than a development issue or an issue that should be integrated and addressed together with other non-climate issues.

5.4.2.2.3 Financial and economic constraints or limitations of the current financial system

The lack of access to financial capital, larger scale macroeconomic aspects that relate to for example economic development and globalization trends, and the ways in which financing frameworks operate can act as barriers to adaptation actions. For a number of South African sectors finance and economics related barriers were highlighted. This includes a general lack of financial resources for implementation, especially at the local level. It includes the limited access and affordability of insurance cover in relation to agriculture and forestry, and a challenge stemming from the fact that government is reliant on revenue from resource consumption and basic services including energy, water and waste removal. Additional challenges highlighted as a barrier to adaptation at the local level linked to financial constraints include the need for (i) development of new infrastructure such as small scale irrigation schemes, and (ii) regular maintenance of infrastructure such as urban storm water drainage systems.

5.4.2.2.4 Lack of or insufficient human and institutional capacity

The lack of capacity can include the general lack of staff and expertise, as well as shortage of technical staff specifically. This has implications in terms of the ability of sectors to carry out planning, as well as the implementation of policies, plans and frameworks. Capacity issues are identified here as a barrier experienced in a number of sectors, including Agriculture and forestry, Human Health, Terrestrial ecosystems, Urban and rural settlements and Water.

5.4.2.2.5 Lack of or insufficient training and capacity building

Climate change adaptation may for example require application of new technology or new implementation frameworks, or the need for people previously not engaged with issues of climate to start building an understanding of how climate interacts with their lives or with their line of work. Insufficient training and capacity building is identified as potentially causing a slow uptake of conservation agriculture, a climate change adaptation response strategy that is commonly identified in the agricultural sector.

5.4.2.2.6 Lack of or insufficient data, information and M&E

Systematically monitoring progress through time and consistent collection of a variety of data and information supports the evidence base for research and action. In the South African context the lack of data on climate-health linkages, reduced monitoring and availability of climate change information for Agriculture and Forestry and insufficient reporting on disaster events are highlighted.

5.4.2.2.7 Research gaps

As detailed in Section 5.2, the lack of research on various aspects of climate change can be considered an adaptation barrier. The Human health sector identifies a variety of health related research gaps as a barrier, while Urban and rural settlements specifically highlights the lack of relevant research at a local scale.

5.4.2.2.8 Different local contexts, ethical implications and the lack of integration of different knowledge systems

For disaster risk management a multifaceted barrier is noted in relation to addressing risk drivers that are interconnected with cultural beliefs, behaviour and economic factors, and the ethical implications of possible adaptation responses. This leads to an emphasis of the importance of improving all stakeholders' understanding of disaster risk reduction and climate change adaptation, and the incorporation of a variety of knowledge systems in this understanding.

Barriers do not necessarily act in isolation, and while generic categories are provided here the way in which adaptation barriers manifest is context specific (IPCC, 2014: 908). The way in which adaptation barriers are outlined and unpacked here is relatively simplistic, and does not reflect the breadth of most recent definitions and understanding of the IPCC.

Given the relatively limited and diverse approaches to sectoral unpacking of adaptation barriers in previous chapters, there seems to be a need for further exploration to develop a better understanding of South African adaptation barriers. Furthermore, there is a need to make a shift, from a focus on *if* barriers to adaptation exist and *which* they are, towards an approach that analysis *why* and *how* identified barriers emerge (Biesbroek, 2013).

Table 5.15: Summary of cross-sectoral linkages for modifying factors

	Agriculture	Coastal zone	Estuarine environment	Human health	Terrestrial ecosystems	Urban and rural settlements	Disaster Risk Management	Water
Lack of or insufficient co-ordination and/or communication	■			■		■	■	■
Climate change being seen as a low priority and/or being treated as a separate environmental issue			■			■	■	
Financial and economic constraints or limitations of the current financial system	■			■	■	■	■	
Lack of or insufficient human and institutional capacity	■			■	■	■		■
Lack of understanding and expertise				■		■		
Lack of or insufficient training and capacity building	■						■	
Lack of or insufficient data, information and M&E	■			■			■	
Research gaps				■		■		
Inadequate or inappropriate maintenance of infrastructure	■							■
Different local contexts, ethical implications and the lack of integration of different knowledge systems							■	

5.4.3 Capacity Building Needs and Gaps for Climate Change Mitigation

In this section two main constraints related to mitigation of climate change were identified which relate to reporting and data generation for reporting on mitigation, and capacity building for mitigation.

5.4.3.1.1 Reporting on mitigation in national communications

Alignment with the latest approved national studies or reference documents was a constraint in reporting on mitigation in the Third National Communication. For example, Chapter 4 of the South African Third National Communication is based mainly on *South Africa's GHG Mitigation Potential Analysis*, published in 2014, as well as the approved *National GHG Inventory: 2000-2010*. Work is currently ongoing to update the scenarios and results of these reference documents, however the relevant studies have yet to be finalised and/or approved by government. Updated data sets relating to mitigation activities in South Africa will be reported on in subsequent communications.

In addition, the potential greenhouse gas mitigation briefs outlined in Chapter 4 are based on approved national projects. Further efforts could be focussed on developing greenhouse gas mitigation projects which are material but outside of the national scope or those that support the Sustainable Development Goals.

5.4.3.1.2 Mitigating climate change in South Africa

South Africa requires sustainable funding and technological support for initiatives in both the public and private spheres in order to make a significant contribution towards a global effort to reduce greenhouse gas concentrations in the atmosphere. Funding is required for climate change research programmes and policy development in the public sphere. In particular, support is required to build capacity around tracking of mitigation policies and measures as well as assessment of mitigation policies and measures (ex-post and ex-ante) as well as the development of greenhouse gas inventories across all sectors. The provision of a range of short training courses over a period of three years has been identified as a possible measure to achieve this goal, which may be undertaken through the Capacity Building Initiative for Transparency established under Article 13 of the Paris Agreement (see further detail below). South Africa has applied for funding in this regard, the outcomes of which will be basic and complex training courses on conducting mitigation assessments as well as GHG inventory development. In addition, some of the inventory related gaps will be addressed through the Greenhouse Gas Inventory Improvement Programme that South Africa is implementing already (see below for further detail).

Furthermore, private sector funding is also required to assist companies (ranging in size from small, medium and large enterprises) to decarbonise their activities in a sustainable manner, while growing the South African economy.

5.4.4 Capacity building needs and gaps - Research and Systematic Observation

A review of the literature and research reports highlights two main areas of climate change research which are lacking, namely social studies and integrative system studies. Research outputs indicate that currently the source and patterns of climate change, as well as mitigation actions, are fairly well understood. There is, however, a lack of understanding of the social dimensions of climate change and the responses at a local scale. Climate change research is required around sustainable social-ecological systems, improving social learning around sustainability and resilience, and human dimensions of adaptation. The second aspect that needs attention is the development of more integrative and systemic approaches to studying climate change which link the land, air and ocean components of climate change. These systems could also bring in the human dimensions. Other research needs that have been identified (ASSAf, 2017; DST, 2010; SARUA, 2014; GHG Inventory Chapter 2) are:

- Climate change and impacts on human health
- Agriculture and food security
- Impacts of climate change on water resources – water security
- Human settlements – sustainable urban development and urban resilience
- Waste management and minimisation

The constraints on social studies are financial, technological and infrastructural. Funding is often linked to annual budgets and cycles, and there is a lack of long term research cycles (around 10yrs). Due to response times, climate change impacts, adaptation and resilience measures need to be monitored over several years to fully understand the consequences at local scales. The short funding cycles are a general problem for all climate change studies. Social studies can also be costly to run due to the requirement for support staff and expensive infrastructure, and current funding does not extend to these supporting structures. Current funding for climate change studies therefore need to be extended in terms of both time and amount in order to obtain useful, long term outputs. Support also needs to be provided for technological innovation around social-ecological systems and sustainability. Climate change funding mechanisms should be extended to enable large scale interdisciplinary, multi-site, multi-scale programmes to address the integrative research needs (SARUA, 2014).

Climate change research requires long term monitoring and, while South Africa has some of the best observational research capacity in southern Africa, there are still gaps and constraints which need to be addressed:

- Inadequate long term, high quality monitoring of basic meteorological, oceanographic, ecosystem and human system variables. The poor availability of observational data is a constraint to the implementation of a wide variety of climate research, particularly adaptation studies (ASSAf, 2017).
- Lack of permanent observation and monitoring sites. There are also key areas (such as arid and semi-arid sites, agro-ecosystems, mountainous areas, rural areas) which are underrepresented in the long term monitoring networks (SARUA, 2014).
- Lack of integrated monitoring and observation systems which include sensing imagery; data processing and analysis hardware and software; and robust and accessible information management systems.
- Poor data accessibility. Observational data and records, particularly long term records, are often unavailable, incomplete or dispersed across various departments. This means costly data-capture is required before datasets are able to be used.
- Costly data. A constraint to climate research which is often mentioned is the cost of critical datasets, such as climate data and high resolution satellite imagery (ASSAf, 2017).

Finally the issue of gender equality in climate change research should be mentioned as it is a topic which is often discussed in international negotiations. UNESCO Institute for Statistics (2016) indicates that South Africa is doing well in terms of the number of women in science, with 44% of science researchers in 2015 being women. This is higher than the Africa average of 30%. There is, however, little information in terms of the fields of study that these women are involved in and how much of the increasing climate change research outputs are contributed by women. It is therefore difficult to make a full assessment of the gender balance in climate change research in South Africa. It is recommended that an in depth study be conducted to enable a full analysis of the progress in the next NC. There is also little research focussing on climate change and gender in South Africa (SARUA, 2014) which relates to the capacity gaps associated with inadequate social dimensions of research mentioned above.

5.4.5 Capacity building needs and gaps for improving climate change education, training, social learning and public awareness

Based on the reporting in Section 5.3 above, a number of capacity building needs were identified for expanding participation in climate change adaptation and mitigation via improved climate change education, training, social learning and public awareness initiatives. As reported in Section 5.3, the education, training and social learning system in South Africa is a large and complex social system with potential to reach millions of South African learners, as well as their teachers, and other education and training sector actors. By engaging with the public media system and public awareness programmes, the potential impact of climate change education, training and public awareness can be expanded into wider society if systemically and strategically approached. Section 5.3 reported that such initiatives are currently fragmented and lack cohesive alignment with policy directions. Table 5.16 outlines a more comprehensive approach to address capacity building needs for improving climate change education, training and public awareness. It targets critical groups in the wider education, training and public awareness system who could have a catalytic and systemic influence on integrating climate change more systematically into the education, training and public awareness system such as the South African Qualifications Authority and qualification councils, the Sector Education and Training Authorities, teacher educators, school teachers and TVET college heads, campus managers and lecturers, Universities, media practitioners (especially journalism training), NGOs and CBOs, as well as local and provincial government departments. Textbook producers and publishers are also critical role players who have a strong influence on the learning and teaching materials used in the education and training system. Educational researchers are also a critical group as they have capacity to develop in-depth insights into how best to integrate climate change into the education, training and public awareness system, and how to support wider social learning, and social learning in inter-disciplinary and transdisciplinary formations. Currently, participation of the educational research community in climate change education, training, public awareness and social learning research is extremely limited, and organisations such as the South African Education Research Association need to be supported to become more actively involved in supporting high quality climate change education and social learning research. Further detail on suggested capacity building initiatives are included in Table 5.16.

Table 5.16: Capacity building needs for improving climate change education, training and public awareness

Group	Capacity Building Need	Suggested Type of Capacity Building Programme
South African Qualifications Authority and Qualifications Authorities	Orientation to the need for a systematic, articulated policy aligned approach to mainstreaming of climate change in the national system of education, training and quality assurance	Seminar series and deliberation on how to integrate climate change across different levels of the education and training system within a wider sustainable development framework
Teacher educators	To extend engagement with the Fundisa for Change programme more widely across TE institutions to service both Continuous Professional Development (CPD) and in-service teacher education	Engagement with DHET Teacher Education Directorate, Dean's Forum, and in-house seminars across all Teacher Education faculties in the country
School teachers	The Fundisa for Change programme and related climate change teacher education programmes need to be extended to all teachers via the SACE endorsed programmes for Continuous Professional Development (CPD)	Ongoing training of teachers by Teacher Education Institutions and Provincial and National Departments of Education, supported by SACE, the Education and Training Development Practices Sector Education and Training Authority and the Department of Basic Education (DBE)
CBOs and NGOs (including youth organisations)	To re-orient and strengthen policy direction and alignment of programmes, and extending action orientation of programmes	National and provincial workshop / training programme for CBOs and NGOs to align their programmes more closely with climate change policy (not only institutional / sectoral interests)
Sector Education and Training Authorities (SETAs)	To undertake green skills research and planning at sector and employer levels to inform Sector Skills Planning, and to understand green occupations, and occupations required for climate resilient development (adaptation and mitigation).	Ongoing Green Skills research and planning training programme for SETAs especially to capture and understand needs for new green occupations and the greening of existing occupations in response to climate resilient development policies and priorities
TVET College heads and campus managers	Green Campus development and Practical Demonstration Development for Climate Resilient Economy and Society	Green Campus and Green Practice Training and Strategic Planning Programmes, Sustainable Development leadership programme for Campus Heads and Managers
TVET lecturers	Specific applied training for various Green Economy TVET learning pathways and occupations	Green Economy and Green Occupations Training, with associated content and practice training oriented towards climate resilient development (including mitigation, adaptation and resilience with a whole systems approach)

Group	Capacity Building Need	Suggested Type of Capacity Building Programme
Universities	Mainstreaming of climate change content across the programmes, and strengthening of systems-based, inter- and transdisciplinary approaches to research and teaching. Strengthen involvement of humanities and social sciences in climate change responses.	Contact based courses and change projects Support curriculum innovation forums and capacity for climate social sciences.
Media practitioners	Interactive training of journalists to deal with both content and events related to climate change; Interactive training to strengthen the use of tools (social media and others such as community radio) that facilitate the accessibility of climate change science and the positioning of climate change knowledge; Strengthening the training of trainers; Support of funding for mainstreaming and up-scaling of journalist training	On-line courses on climate change journalism including contents, its demystifying and the potential tools for accessibility
Local government	Continuous planning for climate change within diverse contexts – size of municipality and geographic placing of municipality (urban / peri-urban / rural contacts); Support of enabling environment for understanding climate change policy processes	Processes and tools for engaging with business and civil society on issues of climate change
Provincial government	Stronger support of integrated planning and climate change policy implementation	Processes and tools for engaging local all spheres of government, civil society and business
Textbook authors and materials developers	Understanding of climate change, and national climate change policy directions	Training on how to design materials that reflect science, action and policy directions for climate change
Education Research sector	Strengthen environmental education and training system research capacity by including a strong focus on climate change education into these programmes. The NCCRP provides for a specific objective for education and training, which will require applied research to inform the implementation of the objectives, given the current generally *re-active and fragmented* approach to dealing with such issues in the national education and training system.	Education research community (South African Education Research Association - SAERA)

5.4.6 Capacity building needs and gaps for technology transfer

Categories of typical barriers to technology transfer include technical, economic, social, organisational or institutional, and policy and regulatory barriers. Institutional and organisational barriers include entrenched norms, procedures and routines (established or prevailing ways of doing things) that make it difficult for an agency (within public and private sector) to develop and/or adopt as well as implement new technology. Organisational barriers also include entrenched business models, limited in-house skills (technical skills and management and organisational skills), finances for and knowledge on the development and use of new technologies.

Understanding the skills required in installing, operating and maintaining a technology is important to consider when evaluating and prioritising technologies among the sectors in a technology needs assessment since technologies may vary widely in terms of the level of skill needed to install, operate and maintain the technology. Where specialised skills are needed to support the use of a particular technology, it is necessary to identify the measures needed to develop these skills (e.g. addressing skills shortages through expanding technical training initiatives) and thus supporting human capacity development in that sector and increasing the socio-economic benefits in terms of potential for livelihood improvement, job creation and economic empowerment.

The barrier analysis component of the updated Technology Needs Assessment was underway at the time of the TNC being completed and will include an overview of barriers to climate innovation and a detailed analysis of barriers that will be undertaken on specific sectors and technologies.

5.4.7 An action plan[31] for climate change capacity building, education, training and social learning

The following action areas are outlined to guide national action planning for improved climate change research, capacity building and education, training, public awareness and social learning. Government departments will need to co-operate and align their mandates and strategies with the National Climate Change White Paper (2011) and with the findings of the Third National Communication in order to address these action areas. For this reason 'action areas' are recommended.

5.4.7.1 Action Areas for Research and Systemic Observation Capacity building

Action Area 1.1: *Strengthen climate change social science research*

As mentioned above, there is a lack of understanding of the social dimensions of climate change and the responses at a local scale. Climate change research is required around sustainable social-ecological systems, improving social learning around sustainability and resilience, and human dimensions of adaptation. Social science research requires more substantive investment and longer time frames for especially engaged social science involving communities and multi-actors in the social system.

Action Area 1.2: *Support the development of more integrative and systemic approaches to studying climate change*

As noted above, there is need for development of more integrative and systemic approaches to studying climate change which link the land, air and ocean components of climate change. These systems could also bring in the human dimensions. There is need to support integrative and systemic approaches to research that include:

31. The action plan presented below is a strategic plan that highlights broader areas that need attention.

- Climate change and impacts on human health
- Agriculture and food security
- Impacts of climate change on water resources – water security
- Human settlements – sustainable urban development and urban resilience
- Waste management and minimisation
- Gender and climate change (including gender representation in climate change science)

Action Area 1.3: *Develop more sustained and sustainable funding frameworks for climate change research and systemic observation*

As noted above, current funding for climate change studies need to be extended in terms of both time and amount in order to obtain useful, long term outputs. Support also needs to be provided for technological innovation around social-ecological systems and sustainability. Climate change funding mechanisms should be extended to enable large scale interdisciplinary, multi-site, multi-scale programmes to address the integrative research needs.

Action Area 1.4: *Continue to support research into systemic observations, with emphasis on gaps and needs for further research*

Climate change research requires long term monitoring and, while South Africa has some of the best observational research capacity in southern Africa, there are still gaps and constraints which need to be addressed. There is need to continue to invest in this type of research, with emphasis on current gaps and constraints including:

- Inadequate long term, high quality monitoring of basic meteorological, oceanographic, ecosystem and human system variables. The poor availability of observational data is a constraint to the implementation of a wide variety of climate research, particularly adaptation studies (ASSAf, 2017).
- Lack of permanent observation and monitoring sites. There are also key areas (such as arid and semi-arid sites, agro-ecosystems, mountainous areas, rural areas) which are underrepresented in the long term monitoring networks (SARUA, 2014).
- Lack of integrated monitoring and observation systems which include sensing imagery; data processing and analysis hardware and software; and robust and accessible information management systems.
- Poor data accessibility. Observational data and records, particularly long term records, are often unavailable, incomplete or dispersed across various departments. This means costly data-capture is required before datasets are able to be used.
- Costly data. A constraint to climate research which is often mentioned is the cost of critical datasets, such as climate data and high resolution satellite imagery (ASSAf, 2017).

5.4.7.2 Action Areas for GHG Inventory development, Climate Change Adaptation and Climate Change Mitigation Capacity Building

Action Area 2.1: *Improve capacity for updating data and associated reporting capacity*

There is need to update the data on mitigation efforts. Continue to support and expand the work that is currently being undertaken to update the scenarios and results of the main reporting instruments for mitigation reporting so as to ensure timeous and updated data sets relating to mitigation activities for use in forthcoming communications.

Action Area 2.2: *Provide sustained funding and support to mitigation efforts, including the GHG Inventory Improvement Programme*

There is need for research to improve the GHG inventory, with several sector specific needs having been identified and which are highlighted in the inventory report. Overall, there is a need to develop country specific emission factors for all sectors. The categories that need to be prioritised currently are transport and the waste sector. Data availability and improved mechanisms for data collection need to be prioritised. Ensure that the inventory input data and calculations are of a sufficient granularity so as to incorporate the reductions brought about by the mitigation actions implemented in the country. If the mitigation actions are not incorporated into the GHG inventory then South Africa's mitigation efforts will not be correctly reflected.

Funds need to be made available to support the ongoing GHG Inventory Improvement Programme. Funding is also required for climate change research programmes and policy development in the public sphere. In particular, support is required to build capacity around assessment of mitigation policies and measures (ex-post and ex-ante) as well as the development of greenhouse gas inventories across all sectors, as noted above.

Furthermore, private sector funding is also required to assist companies (ranging in size from small, medium and large enterprises) to decarbonise their activities in a sustainable manner, while growing the South African economy.

Action Area 2.3: *Support the development of a range of training programmes to strengthen the GHG Inventory Programme*

There is need for designing and provisioning a range of training courses on conducting mitigation assessments as well as GHG inventory development. There is a need to develop training courses to cover the various aspects of the GHG inventory update process, such as IPCC guideline methodologies for all four sectors, QA/QC process and methods, uncertainty analysis, key category analysis and even general coordination and management of the GHG inventory update process. These courses could be developed as short courses to support immediate needs and as a post graduate university course to develop longer term capacity for the future. Short courses could be provided as they are required (e.g. beginning of each year, beginning of each inventory cycle, or whenever new staff are brought into the inventory team), while a post graduate university course would be offered every year.

Action Area 2.4: *Support sector-specific priority data generation processes to improve the GHG inventory*

Activity data and country specific emission factors are two important requirements for the inventory. Projects providing information on country specific emission factors in all sectors need to be supported. There is an urgent need to improved data in the transport and waste sectors in particular.

There are also numerous gaps in the AFOLU sector. An urgent issue that needs to be addressed in this sector is the production of land use change maps. This data is a requirement to complete the land sector inventory and currently the change maps only extend to 2014. A task team or a project needs to be set up to (a) determine the best data and methodology to use for land use change maps, (b) develop a standardised classification system that is consistent with existing classifications, includes all categories relevant to the inventory and ensures category definitions are consistent with related projects (i.e. FAO and REDD+ definitions), and (c) assess costs, funding sources and data providers for the continuous supply of land use change data.

In terms of agricultural data there is a need to improve the manure management data; nitrogen excretion rates for all livestock; and lime, urea and nitrogen fertiliser consumption rates. There are also some issues of consistency in terms of the crop harvested areas and livestock numbers provided by various sources which needs to be investigated.

Action Area 2.5: *Support South Africa's capacity to adapt to climate change*

Since the SNC, South Africa has made noticeable progress in creating an enabling environment for climate change adaptation through the development of sector and location specific climate change response plans and strategies. This has been aided by a growing body of climate change research and the establishment of structures and platforms intended to create the necessary institutional capacity for mainstreaming climate change considerations into all spheres of government and for facilitating cross-sectoral integration.

It is essential that if South Africa wants to successfully translate existing and forthcoming climate change response strategies and plans into adaptation action greater attention needs to be paid to strengthening its existing adaptive capacity. All three spheres of government require more resources (in terms of finances, human capacity, access to information and research) and institutional capacities (cross-sectoral climate specific fora and working groups, partnerships and learning possibilities). New skills sets and dedicated climate change personnel are particular important for addressing long term climate change. Until now little practical experience for implementing interventions related to long term climate change exists (with the exception of some interventions focussing on topics such as sea level rise) (Ziervogel *et al*., 2014). However this will be critical for taking advantage of arising opportunities and for moving South Africa into a climate resilient future. Local governments, who have the primary responsibility for planning and management at the urban and local scale, need to be given more support.

While this capacity assessment tried to identify some of the major constraints that currently prevent South Africa at a number of different scales to reach its full potential in the adaptation space, it needs to be noted that strong differences between the provinces, among the municipalities as well as between difference sectors exists in terms of available capacities. A more nuanced and systematic investigation needs to be conducted in order to get a better understanding of how the adaptive capacity of specific provinces and municipalities could be strengthened.

5.4.8 Action areas for climate change education, training, public awareness and social learning

As reported on in Section 5.3, there are many different contexts and initiatives in which climate change education, training and social learning is taking place in South Africa already. However, much more can be done to strengthen these approaches and to expand them. As suggested in Section 5.3, a national strategy to strengthen climate change education and public awareness may be needed. The following action areas can inform the development of such a national strategy.

Action Area 3.1: *Development of a clear conceptual framework for climate change education, training and social learning in South Africa*

Education programmes for climate change differ in their orientation, scope and content. Different programmes reflect multiple ways of knowing about climate change, and multiple perspectives on climate change issues. Most programmes appear to be driven by the resources and / or the concepts and experience favoured by the facilitators. This shows a possible lack of national dialogue on climate change education and its relationship to climate change policy. Leadership from the education sector (DBE and DHET) is also needed to facilitate such dialogue at a national level, but this requires adequate structure and dialogue at national policy level amongst different sectors, as pointed out above.

There appears to be need for a more coherent conceptual framework for climate change education that allows for a clear pathway for developing foundational knowledge of climate and earth systems; and associated and emergent concepts such as social-ecological risk, adaptation, mitigation and societal relevance and responsiveness and/or climate compatible development for long term resilience.

Action Area 3.2: *Development of clear knowledge pathways to guide progression in the CAPS curriculum and teacher education*

The disjointed nature of the climate change curriculum in the schooling system creates a complex context for development of knowledge and skills amongst different groups within a sector. The approach overall is fragmented and lacking national synthesis and systemic engagement.

Like with the school curriculum, it seems that there is need to develop clear knowledge pathways for coherence and progression oriented learning pathways on climate change/climate compatible development so as to support teachers to develop holistic understandings which can then inform their own educative responses as they plan for teaching practices. These should also be aligned with national climate change response policy.

Action Area 3.3: *Policy alignment and dialogue*

The interesting role of climate change education, training and social learning or awareness raising is not adequately reflected in major climate change policies, although the National Climate Change Response White Paper includes a strong focus on education, but this is yet to be implemented through a strong partnership with the DBE and DHET. Likewise, environment and climate change are not adequately reflected in education policies, and this makes it difficult to ensure curriculum coherence. This, in turn, requires more in-depth research and analysis of the changing knowledge environment associated with climate change and climate compatible development, which in turn will inform curriculum development. It is important to support harmonisation of climate change policies and policy implementation and to strengthen environment and sustainability and education for sustainable development in all policies.

Action Area 3.4: *TVET curriculum development and lecturer training*

Although there is a favourable White Paper for Post School Education and Training, the major gaps in curriculum and knowledge of climate change in the TVET system is also cause for concern, and few agricultural colleges have integrated knowledge of climate smart agriculture into extension training programmes as yet. There is need for both TVET curriculum development including appropriate learning materials and technology, and lecturer training.

Action Area 3.5: *Improve skills intelligence and planning for climate change related occupations*

There is need for better understanding of green skills learning pathways, and occupations, especially also demand side information to inform skills planning and supply side responses. It would be useful to expand the work of the NESPF's Green Skills Programme in this regard including framework for developing a whole systems approach to determining and supporting green skills development and education, and to align this with business sector programmes and employer demand discourses. Green skills system planning should also integrate into the DHETs national system of skills intelligence.

Action Area 3.6: *Continue integration of CCE into teacher education*

The project based work that is being done through Fundisa for Change and other teacher support projects is proving to be effective. This needs to be extended and iteratively mainstreamed into programmes of Education Faculties, while the framework of continuous professional development is strengthened by the Department of Basic Education's professional learning programmes and professional learning community structures. This requires training of subject advisors to support and implement the programme.

Action Area 3.7: *Strengthen university engagement*

Encourage the expansion of inter- and transdisciplinary approaches in addition to specialist sciences development. Include social science and humanities in climate change response course development and research. Support curriculum innovation platforms, including innovative strategies for research and course delivery. Also expand student engagement in climate change related concerns within campuses, and through community engagement.

Action Area 3.8: *Expand public engagement in climate change through expanded social learning approaches*

As indicated, there are a number of civil society organisation activities that are engaged with climate change related concerns. However, there is little consolidated information on this work and its impact, or its partnership structure. Further research is needed to develop a clear action plan / point for this sector, including use of the media. It is important to identify and strengthen institutions and programmes already working on climate change education instead of starting new programmes. A national strategy with indicators could help to catalyse commitments to longer term programmes.

Action Area 3.9: *Build capacity of policy makers and develop a national focal point for CCE*

Continue to build capacity to enable policy makers to have a more integrated and transdisciplinary approach to policy planning. This will lead to cross-cutting issues being included in all related policies within a synergistic orientation. The education and training recommendations in the National Climate Change Response White Paper (RSA 2011) need to be aligned with Education and Training Sector policy. Development of a national strategy on climate change education and training, within a wider Education for Sustainable Development Strategy framework could potentially assist with this policy need.

South Africa also currently does not have a 'national champion' organisation for climate change education at national policy level. The Department of Environmental Affairs has an active and engaged Education, Training and Development Practices Directorate (ETDP) which may be an appropriate arm of the DEA to take up the educational aspects of the National Climate Change Response White Paper, in partnership with the DBE and the DHET.

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NOTES

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