climate change counts

STRENGTHENING UNIVERSITY CONTRIBUTIONS TO CLIMATE COMPATIBLE DEVELOPMENT IN SOUTHERN AFRICA

South Africa Country Report

sarua
southern african regional universities association

May 2014

SARUA CLIMATE CHANGE COUNTS MAPPING STUDY

VOLUME 2 COUNTRY REPORT 8 2014

STRENGTHENING UNIVERSITY CONTRIBUTIONS TO CLIMATE COMPATIBLE DEVELOPMENT IN SOUTHERN AFRICA

South Africa Country Report

Series Editor: Piyushi Kotecha

Authors: Heila Lotz-Sisitka and Penny Urquhart

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Note

This is the South Africa Country Report of the Southern African Regional Universities Association (SARUA) ***Climate Change Counts*** *mapping study. It brings together background documentation on climate change in South Africa, insights into knowledge and research needs and capacity gaps (individual and institutional), a mapping of existing university roles and contributions to climate compatible development (CCD); as well as a discussion on possibilities for CCD learning pathways and future collaborative knowledge co-production and use in South Africa.*

This report is one of a set of 12 Country Reports in Volume 2, which inform Volume 1: the integrated regional Knowledge Co-production Framework of the ***Climate Change Counts*** *mapping study, and which includes comparative regional analysis using the outputs of the other SADC countries, as well as the proposed regional framework for collaborative research on climate compatible development.*

Southern African Regional Universities Association (SARUA)
PO Box 662
WITS
2050
SOUTH AFRICA

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Series Editor: Piyushi Kotecha

Authors: Heila Lotz-Sisitka and Penny Urquhart

Project Management and Coordination: Botha Kruger, Johan Naudé, Ziyanda Cele

Research and Workshop Facilitation: Dick Kachilonda, Dylan McGarry

Project Steering Committee: Professor Xikombiso Mbhenyane, University of Venda; Professor Raymond Mande Mutombo, University of Lubumbashi; Professor Mark New, University of Cape Town; Professor Samson Sibanda, National University of Science & Technology; Professor Pius Zebhe Yanda, University of Dar es Salaam

Copy-editing: Kim Ward

SARUA is a not-for-profit leadership association of the heads of the public universities in the 15 countries of the SADC region. Its mission is to promote, strengthen and increase higher education, research and innovation through expanded inter-institutional collaboration and capacity-building initiatives throughout the region. It promotes universities as major contributors towards building knowledge economies, national and regional socio-economic and cultural development, and for the eradication of poverty.

The authors are responsible for the choice and the presentation of the facts contained in this document and for the opinions expressed therein, which are not necessarily those of SARUA and do not make any commitment for the Association.

May 2014

*The **Climate Change Counts** mapping study is the inception phase of the SARUA Programme for Climate Change Capacity Development. The mapping study was made possible through the support of the principal sponsor, Climate Development Knowledge Network (CDKN) as well as professional, financial and in-kind support of multiple partners.*

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Acronyms

ARC	Agricultural Research Council
BID	Background Information Document
CCAM	Conformal-Cubic Atmospheric Model
CCD	Climate Compatible Development
CCS	Carbon Capture Storage
CDKN	Climate and Development Knowledge Network
CDP	Carbon Disclosure Project
CESAR	Centre of Energy Systems Analysis and Research
CGCMs	Coupled Global Climate Models
CGS	Council for Geoscience
CHE	Council on Higher Education
CORDEX	Co-ordinated Regional Downscaling Experiment
CSIR	Council for Scientific and Industrial Research
CSR	Corporate Social Responsibility
DBE	Department of Basic Education
DEROs	Desired Emissions Reduction Outcomes
DHET	Department of Higher Education and Training
DoE	Department of Education
DST	Department of Science and Technology
EMF	Environmental Management Framework
FFEWS	Famine and Flood Early Warning System
GCSSNRP	Global Change Society and Sustainability National Research Programme
GHG	GreenHouse Gases
HEI	Higher Education Institution
HEMA	Higher Education Management Africa consortium
HEQC	Higher Education Quality Committee
HESA	Higher Education South Africa
ICSU	International Council for Science
IEM	Integrated Environmental Management
IGCCC	Intergovernmental Committee on Climate Change
IPCC	Intergovernmental Panel on Climate Change
LTMS	Long Term Mitigation Scenario
Mintek	Council for Mineral Technology
MRC	Medical Research Council
NCCC	National Committee on Climate Change
NCCRS	National Climate Change Response Strategy
NEDLAC	National Economic Development and Labour Council
NEEA	National Energy Efficiency Agency

NEMA	National Environmental Management Act
NGO	Non-Governmental Organisation
NIE	National Implementing Entity
NPHE	National Plan for Higher Education
NRF	National Research Foundation
QCTO	Quality Council for Trade and Occupations
R&D	Research and Development
RECORD	Renewable Energy Centre of Research and Development
RSA	Republic of South Africa
SAAQIS	South African Air Quality Information System
SACCCS	South African Centre for Carbon Capture and Storage
SADC	Southern African Development Community
SADC REEP	SADC Regional Environmental Education Programme
SAEON	South African Environmental Observation Network
SAEOS	South African Earth Observation Strategy
SAIAB	South African Institute of Aquatic Biodiversity
SANAP	South African National Antarctic Programme
SANBI	South African National Biodiversity Institute
SANEDI	South African National Energy Development Institute
SANERI	South African National Energy Research Institute
SANParks	South African National Parks
SANSA	South African National Space Agency
SAQA	South African Qualification Authority
SARCHI	South African Research Chair
SARUA	Southern African Regional Universities Association
SARVA	South Africa Risk and Vulnerability Atlas
SASGI	South African Smart Grids Initiative
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Use
SAWEA	South African Wind Energy Association
SES	Social-Ecological-Systems
SET	Science, Engineering and Technology
SETA	Sector Education and Training Authority
SNC	Second National Communication
TIA	Technological Innovation Agency
TNA	Technology Needs Assessment
TVET	Technical Vocational Education and Training
UNDP	United Nations Development Programme
UNFCCC	UN Framework Convention on Climate Change
Unisa	University of South Africa
WASA	Wind Atlas of South Africa
WfE	Working for Energy
WRC	Water Research Commission

1 INTRODUCTION

1.1 Regional climate risks and climate compatible development in southern Africa

Globally, southern Africa is one of the most vulnerable regions to the impacts of climate change. Current climate variability and vulnerability to extreme events such as floods and droughts is high, and a range of existing stressors, including water availability, land degradation, desertification and loss of biodiversity constrain food security and development. Reduction of the region's structural poverty is further challenged by health threats such as malaria and HIV/AIDS, as well as institutional and governance aspects. Climate change will compound many of these interlinked problems for regional livelihoods, which are often based on subsistence agriculture, and for regional economies, which are often dependent on natural resources. The region's high vulnerability to climate change is a function of the severity of the projected physical climate impacts and this multi-stressor context, which heightens both exposure and sensitivity to the impacts.

In addition to its role as a risk multiplier, climate change introduces new climate risks. Already the observed temperature changes for southern Africa are higher than the increases reported for other parts of the world (IPCC 2007); projections indicate a 3.4°C increase in annual temperature (up to 3.7°C in spring), when comparing the period 1980–1999 with the period 2080–2099. Mean warming over land surfaces in Southern Africa is likely to exceed the average global land surface temperature increases in all seasons.[1] Further projections are for overall drying for southern Africa, with increased rainfall variability; a delay in onset of the rainy season with an early cessation in many parts; and an increase in rainfall intensity in some parts. [See Figure 1.[2]] Additional climate-driven risks, in addition to the direct effects of increased temperature and increased incidence and/or severity of extreme events like floods and droughts, include more wind storms, hot spells and wild fires. Both the heightened and the new risks will act at the local level to compound other stressors and development pressures faced by people, and at the national level on the region's natural resource-dependent economies. The all-encompassing nature of the impacts highlights the fact that climate change is not a narrow environmental problem, but a fundamental development challenge that requires new and broad-based responses.

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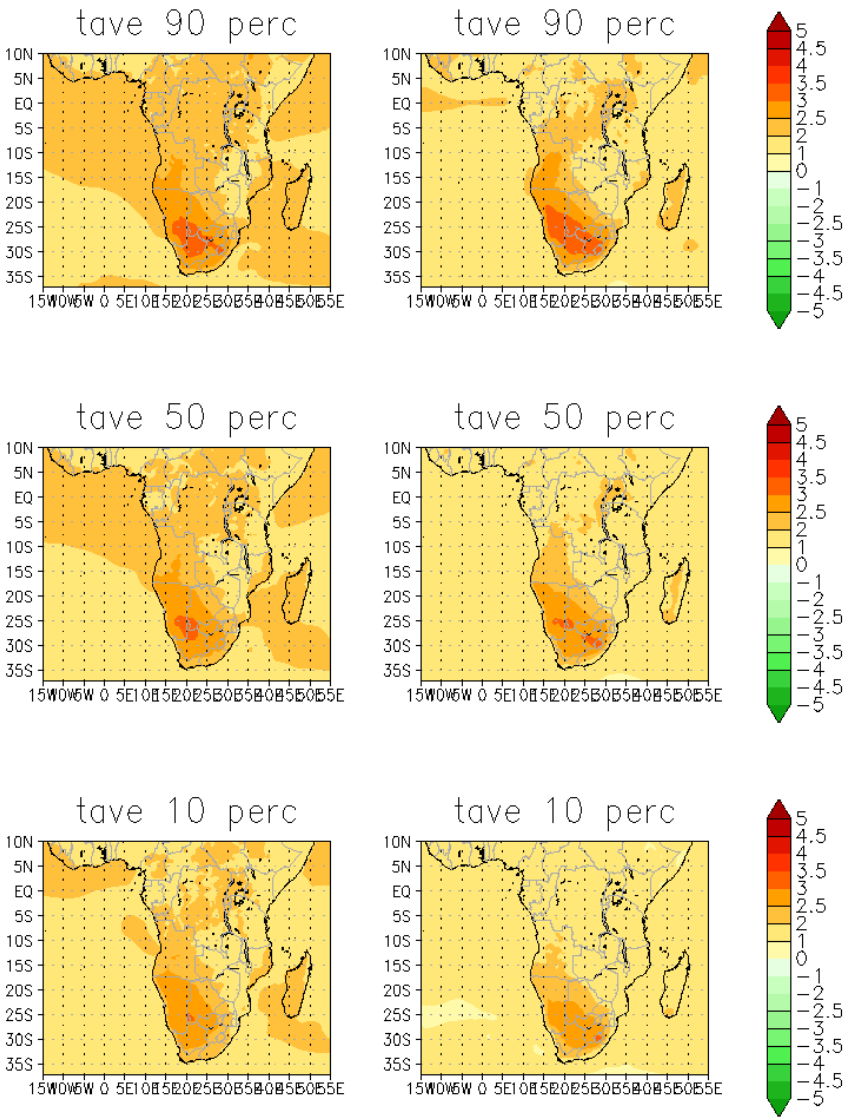
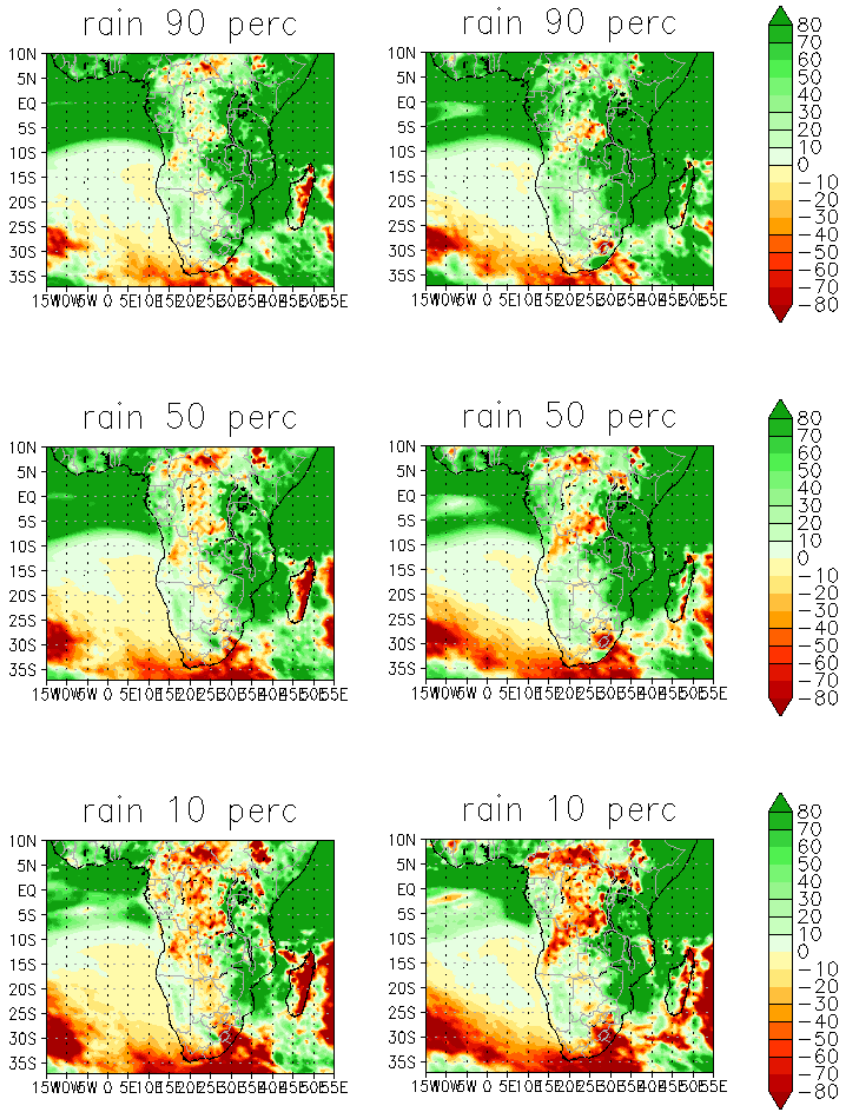
[1] IPCC. 2013. *Impacts, Vulnerability and Adaptation: Africa*. IPCC Fifth Assessment Report, draft for Final Government Review, Chapter 22.

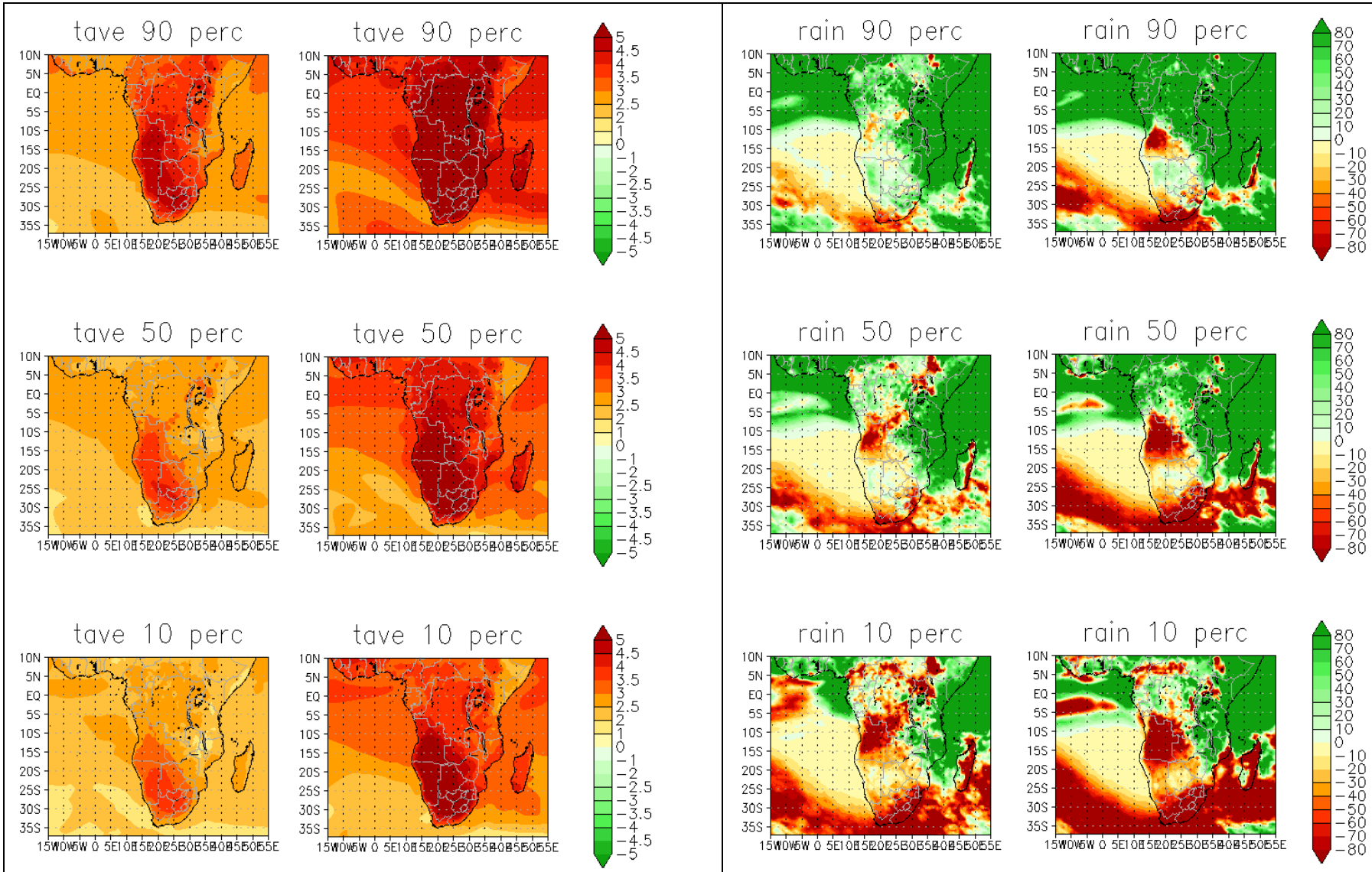
[2] The projections of future climate change displayed in Figures 1 and 2 were provided by the Council for Scientific and Industrial Research (CSIR), and have been obtained through downscaling the output of a number of coupled global models (CGCMs) to high-resolution over Africa, using a regional climate model. All the CGCMs downscaled contributed to the Coupled Model Intercomparison Project Phase 5 (CMIP5) and Assessment Report 5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Details on these simulations are provided in the LTAS Phase 1 Technical Report no. 1. The regional model used is the conformal-cubic atmospheric model (CCAM), developed by the CSIRO in Australia. For various applications of CCAM over southern Africa, see Engelbrecht, F.A., W.A. Landman, C.J. Engelbrecht, S. Landman, B. Roux, M.M. Bopape, J.L. McGregor and M. Thatcher. 2011. "Multi-scale climate modelling over southern Africa using a variable-resolution global model," *Water SA* 37: 647-658.





Note: The 90th percentile (upper panel), median (middle panel) and 10th percentile (lower panel) are shown for an ensemble of downscalings of three CGCM projections, for each of the time-slabs. The downscalings were performed using the regional model CCAM. All the CGCM projections are contributing to CMIP5 and AR5 of the IPCC, and are for RCP4.5.

Figure 1: Projected change in the annual average temperature (°C) and annual average rainfall (mm) over the SADC region, for the time-slab 2040–2060 and 2080–2099, relative to 1970–2005



Note: The 90th percentile (upper panel), median (middle panel) and 10th percentile (lower panel) are shown for an ensemble of downscalings of three CGCM projections, for each of the time-slabs. The downscalings were performed using the regional model CCAM. All the CGCM projections are contributing to CMIP5 and AR5 of the IPCC, and are for RCP8.5.

Figure 2: Projected change in the annual average temperature (°C) and annual average rainfall (mm) over the SADC region, for the time-slab 2040–2060 and 2080–2099, relative to 1970–2005

Figures 1 and 2[3] showed the projected change in the annual average temperature (°C) and annual average rainfall (mm) over the SADC region, for the time-slabs 2040–2060 and 2080–2099, relative to 1970–2005. Figure 1 CGCM projections are for RCP4.5 and Figure 2 projections are for RCP8.5.

Further projections are for overall drying for southern Africa, with increased rainfall variability; a delay in onset of the rainy season with an early cessation in many parts; and an increase in rainfall intensity in some parts. Additional climate-driven risks, in addition to the direct effects of increased temperature and increased incidence and/or severity of extreme events like floods and droughts, include more wind storms, hot spells and wild fires. Both the heightened and the new risks will act at the local level to compound other stressors and development pressures faced by people, and at the national level on the region's natural resource-dependent economies. The all-encompassing nature of the impacts highlights the fact that climate change is not a narrow environmental problem, but a fundamental development challenge that requires new and broad-based responses.

The South African Government recognises this, and the recently published National Climate Change Response White Paper (RSA 2011:11) states in its objectives that:

> *South Africa will build the climate resilience of the country, its economy and its people and manage the transition to a climate-resilient, equitable and internationally competitive lower carbon economy and society in a manner that simultaneously addresses South Africa's over-riding national priorities for sustainable development, job creation, improved public and environmental health, poverty eradication, and social equality.*

Shifting perspective from 'development' to 'climate compatible development' requires significant scientific and social innovation. New forms of learning, leadership, planning, policymaking and knowledge production are needed. New collaboration platforms will be needed within and between countries and their universities. Universities have a key role to play in supporting societal innovation and change for CCD. Not only do they develop the knowledge and competence of future leaders in government, business and civil society, but they also provide immediate societal responses given their pivotal role as centres of research, teaching, knowledge sharing and social empowerment. Given the risk multiplier effect of climate change, coupled with the multiple stressor context, it is clear that the impacts of climate change will be far-ranging, acting upon diverse sectors such as transportation, agriculture, health, industry and tourism. This necessitates a wide-ranging and cross-sector response, in which non-climate-related knowledge fields will be called upon.

Universities need to develop a strong understanding of the knowledge, teaching, research and outreach implications of the external climate change development context in which they operate. This calls for:

[3] Engelbrecht et al. 2014. "Multi-scale climate modelling". Climate trends and scenarios for South Africa. Long-term Adaptation Scenarios Flagship Research Programme (LTAS). Phase 1, Technical Report no. 1.

- New scientific directions and practices;
- New teaching and learning content and approaches;
- Stronger forms of community outreach and policy outreach activities; and
- Enhanced collaboration between universities and other knowledge producers and users in society.

In recognition of the above issues and their longer term implications for society and universities, the Southern African Regional Universities Association hosted a Leadership Dialogue in 2011 which resulted in a vision for a collaborative programme on climate change capacity development, with a defined set of outcomes.

1.2 The SARUA Climate Change initiative: History and Objectives

Arising from the 2011 Leadership Dialogue, SARUA designed a five-year programme for Climate Change Capacity Development, to deliver on its mandate of promoting, strengthening and increasing higher education research and innovation, through expanded inter-institutional collaboration and capacity building initiatives throughout the region. The five-year programme is endorsed by a majority of Vice Chancellors within SARUA's 62 public university members (as at August 2013). The programme aims to build capacity for climate compatible development (CCD), which is emerging as a platform for significant collaboration across the academic sector. The objectives identified are as follows:

- **Collaborative network development** (establishment of six interesting collaborative networks);
- **Policy and community outreach;**
- **Research** (140 PhD students (average 10 per country) in two themed research programmes);
- **Teaching and learning** (integration of CCD into undergraduate and Masters degree programmes);
- **Knowledge management** (regional database and knowledge management systems); and
- **Institutional learning and support** (ongoing reflexive development of programme).[4]

The programme started with an extensive **mapping study** of current climate-related priorities and university capabilities for CCD of countries in the region, supported by funding from the UK and Dutch-funded Climate and Development Knowledge Network (CDKN). The Higher Education Management Africa consortium (HEMA) is coordinating the study on behalf of SARUA. This Botswana Country Report forms part of the mapping study.

The initiative is diagrammatically illustrated below.

[4] Butler-Adam, J. 2012. The Southern African Regional Universities Association (SARUA). Seven Years of Regional Higher Education Advancement. 2006-2012. Johannesburg: SARUA.

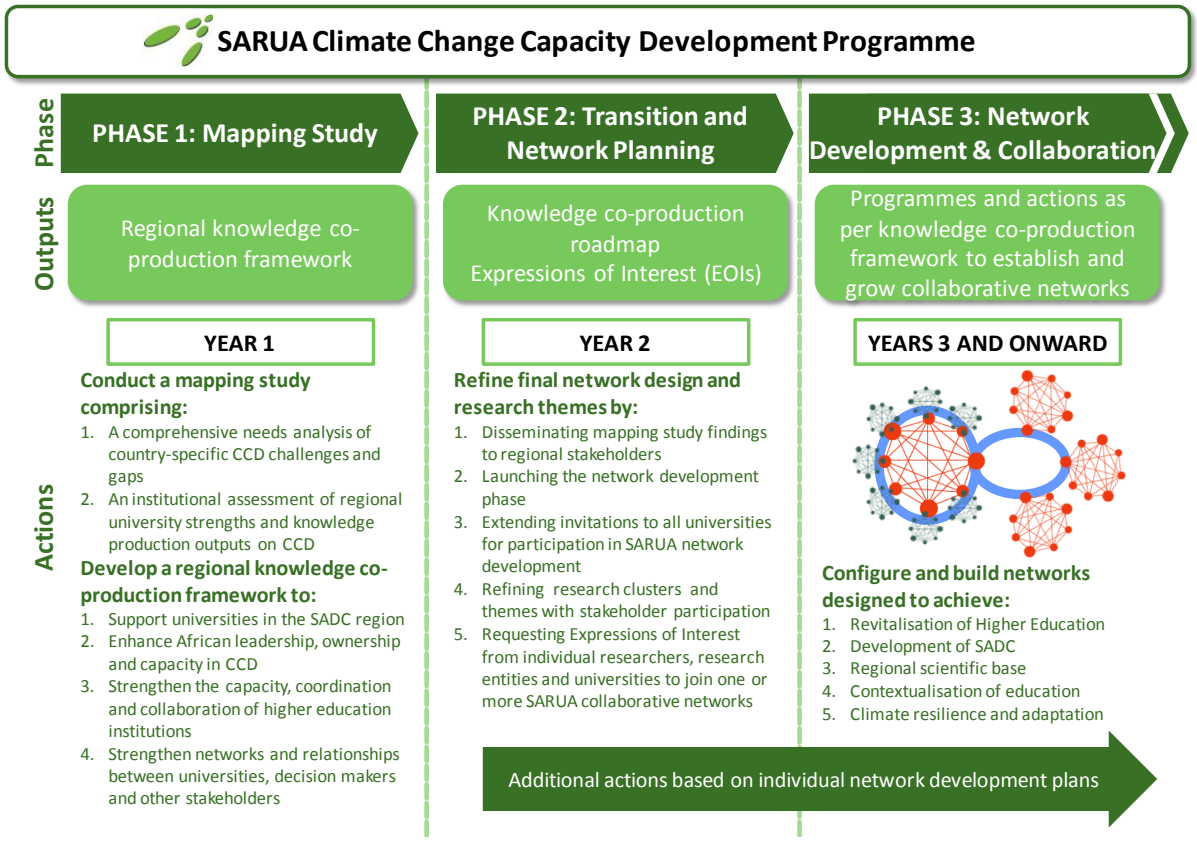


Figure 3: The SARUA Climate Change Capacity Development Programme, showing the mapping study

The intended outcome of the SARUA **mapping study** will be a collaborative research framework to enhance co-production of knowledge on CCD. It will include strategies to strengthen networks for climate compatible development research, teaching, community and policy outreach involving knowledge co-production processes between participating universities and policy and community stakeholders. This framework will form the basis for the realisation of the longer term objectives of the SARUA programme outlined above, as well as for a SADC-level research programme and various country-based partnership agreements. It will provide a 'knowledge platform' for regional and country-based fundraising for research and knowledge co-production. As such the framework seeks to benefit universities themselves, while also strengthening regional interaction and co-operation.

The Regional Knowledge co-production Framework for Climate Compatible Development can be obtained from the SARUA website www.sarua.org.

1.3 The SARUA CCD mapping study: Mapping existing capacity and future possible knowledge co-production possibilities

Climate compatible development (CCD) is low carbon, climate resilient development. While the concept clearly requires integration of development, adaptation and mitigation (see definitions below), specific framing of the concept of CCD may vary between countries, universities and disciplines, according to differing national, institutional and disciplinary goals, needs and values. The scope and strength of existing expertise, networks and capacity for climate compatible development research and knowledge production in SADC is largely unknown or unconsolidated. Despite the

emerging knowledge infrastructure for CCD in the region, opportunities for collaboration involving higher education institutions within and between countries are yet to be fully explored.

To address these factors, the mapping study aimed to:

- Explore diverse understandings of CCD on a country-by-country basis;
- Scope CCD knowledge and capacity needs on a country-by-country basis (a 'needs analysis');
- Identify and map research, teaching and outreach capabilities for CCD that exist in southern African countries (an 'institutional analysis' of SARUA member universities); and
- Produce an up-to-date picture of the extent of knowledge co-production and trans-disciplinary research practices across the SARUA network and identify opportunities for future collaboration.

While the mapping process has used a country-by-country approach, this is supplemented by a regional perspective generated through analysis across countries, to provide a platform for regional collaboration and knowledge co-production. This document contains the country analysis from South Africa.

The mapping process was designed to be scientifically informed, participatory and multidisciplinary. Through the workshop process new collaborative possibilities will emerge, and a stronger engagement and participation in the SARUA five-year programme on Capacity Development for Climate Change will be established.

1.4 Key concepts

Climate Compatible Development

Climate compatible development (CCD) is low carbon, climate resilient development. The concept has been developed in recognition of the urgent need for adaptation, given current climate variability and the severity of projected climate impacts that will affect the region; and the need to reduce emissions as rapidly as possible to avoid more catastrophic climate change in the future. Thus while CCD can be framed in different ways, given nationally and locally specific development trajectories, it does require that current and future climate risks are mainstreamed into development, and that both adaptation and mitigation are integral goals of development, as indicated by Figure 3. Thus CCD not only recognises the importance of both adaptation and mitigation in new development pathways, but, as further explained in Mitchell and Maxwell (2010), "Climate compatible development goes one step further by asking policy makers to consider 'triple win' strategies that result in low emissions, build resilience and promote development simultaneously". In the southern African context, poverty reduction, as an integral component and goal of regional and national development strategies, would be a desired co-benefit. Uncertainties in major drivers of change, including climate, socio-economic and political risks, necessitate that CCD be viewed as an iterative process, in which vulnerability identification and risk reduction responses are revised on the basis of continuing learning. Climate compatible development emphasises climate

strategies that embrace development goals and development strategies that integrate the threats and opportunities of a changing climate.[5] Thus climate compatible development opens up new opportunities for interdisciplinary and transdisciplinary research, teaching and engagement with communities, policy makers and practitioners.

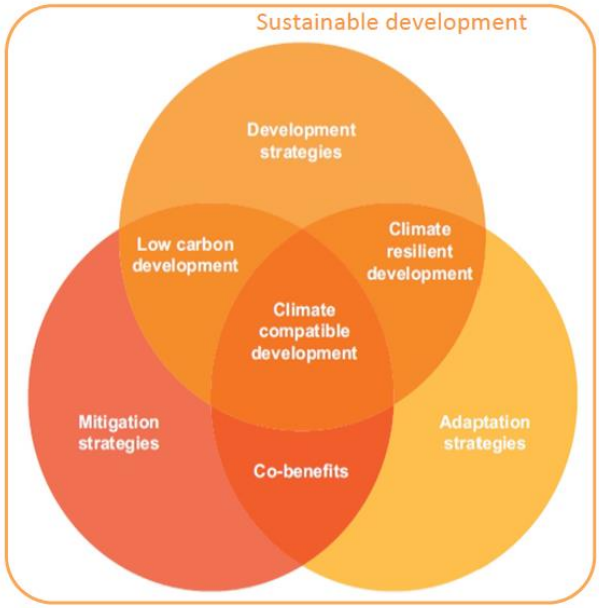


Figure 4: Conceptual framework for Climate Compatible Development (adapted from Mitchell and Maxwell, 2010)

While CCD is the central concept used in the work that is funded by CDKN, it is important that this is understood alongside the concept of climate-resilient development pathways as defined by the Intergovernmental Panel on Climate Change (IPCC) and the wider concept of sustainable development (see definitions below).

Climate-resilient pathways

The following definition of climate-resilient pathways is taken from the glossary of the Fifth Assessment Report prepared by the Intergovernmental Panel on Climate Change (IPCC)[6]:

> *"Evolutionary processes for managing change within complex systems in order to reduce disruptions and enhance opportunities. They are rooted in iterative processes of identifying vulnerabilities to climate change impacts; taking appropriate steps to reduce vulnerabilities in the context of development needs and resources and to increase the options available for vulnerability reduction and coping with unexpected threats; monitoring emerging climate parameters and their implications, along with monitoring the effectiveness of vulnerability reduction efforts; and revising risk reduction responses on the basis of continuing learning. This process may involve a combination of incremental changes and, as necessary, significant transformations."*

[5] Mitchell, T. and S. Maxwell. 2010. *Defining climate compatible development.* CDKN Policy Brief, November 2010.

[6] IPCC. 2013. *Fifth Assessment Report: Impacts, Vulnerability and Adaptation*. Currently in draft form.

The IPCC highlights the need for a focus on both adaptation and mitigation, as indicated by the following sentence: "Climate-resilient pathways are development trajectories that combine adaptation and mitigation to realise the goal of sustainable development. They can be seen as iterative, continually evolving processes for managing change within complex systems."[7]

Sustainable Development

The most widely accepted definition of sustainable development, as formulated in the Bruntland Commission's 'Our Common Future' report in 1987, is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition has been highly influential in shaping international environmental and development policy, since the Rio Earth Summit in 1992, where Agenda 21 was put forward as a global development plan for aligning goals of economic development with social and environmental sustainability. Early discussions on sustainable development tended to focus on the triple bottom line concepts of environment, economy and society separately. More recent discussions on sustainable development foreground the need for 'strong sustainability', in which society, economy and environment are seen as interacting in an inter-related, nested system. The concept of sustainable development as used widely today emphasises that everything in the world is connected through space, time and quality of life, and thus necessitates a systems approach to understanding and solving interlinked social, environmental and economic problems.

In 2002 South Africa hosted the World Summit on Sustainable Development, and the Johannesburg Plan of Implementation re-affirmed commitment to Agenda 21, and the Millennium Development Goals. These are currently under review and will be expanded through Sustainable Development Goals. In 2012 the Rio+20 Conference was held in Rio de Janeiro, and the outcomes of this global summit on sustainable development are captured in a document entitled 'The Future We Want'. One major shift in discourse and objectives from the early 1992 summit and the Rio+20 summit is a stronger concern for climate change and climate compatible development, especially the emergence of a low carbon future, accompanied and partly implemented by Green Economies. These international commitments, together with ongoing assessment of national sustainable development concerns and goals, have driven the development of sustainable development policy and practice. The concept of CCD highlights the necessity of integrating current and future climate risks into development planning and practice, in the ongoing goal of achieving sustainable development.

[7] IPCC. 2013. *Fifth Assessment Report.*

2 METHODOLOGY, DATA SOURCES AND ANALYSIS LOGIC

2.1 Research design

This country-based study has been informed by an interactive and dialogical research design that included document analysis of key national and regional documents focusing on climate change in South Africa and in the SADC region. This produced an initial analysis which was used to plan for and engage university participants and national organisations involved in the climate change and development arenas in a consultation to discuss a) the validity of the analysis, and b) expanded views and perspectives on the analysis, and to generate further insight into knowledge co-production practice and possibilities for climate compatible development.

The following methods were used to compile the mapping study Country Report for South Africa, within an overall interpretive, participatory and consultative and social realist methodology[8]:

2.1.1 Document analysis

A Background Information Document (BID) based on initial document review was produced for each country. The BID provides a summary of needs, priorities and capacity gaps already identified within key country documents (see Section 3 below) for climate change, adaptation and mitigation, and in some cases, where this was available, climate compatible development. The BID documents were used as a source of background information for the stakeholder and institutional consultations held in each country. While the scope of CCD is necessarily wide, the document analysis did not focus on sectoral policy and institutions, but concentrated on overarching policy dealing with mainstreaming climate change into planning and development. The initial document analysis was presented to stakeholders during the workshops, and was revised based on outcomes of the consultations held in the country.

For the South African Mapping Study Country Report, the following key policy and programme documents were analysed through rapid desk review:

- National Climate Change Response White Paper (RSA, 2011);
- South African Development Plan (RSA 2013);
- Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), November 2011;
- The DST Ten Year Innovation Plan (DST, 2007);
- Long Term Adaptation Scenarios: Technical Summary (draft) (SANBI, 2013);
- Long Term Mitigation Scenarios (RSA, 2007);
- Climate Change Adaptation and Preparedness in South Africa, March 2010;
- Human Capital Development Strategy for the Environment Sector (2009-2014) (DEA 2010);
- The Environmental Sector Skills Plan, (DEA, 2010);

[8] A social realist methodology takes account of knowledge that has previously been established via scientific methods before engaging in consultative and participatory knowledge production processes.

- The Biodiversity Human Capital Development Strategy (SANBI / Lewis Foundation, 2010);
- Global Change Human Capital Development Strategy (DST 2010);
- National Scarce Skills Lists;
- TIPS Working Paper Series 2012-02: Green Economy Policy Framework for Employment Opportunity: A South African Case Study (Montmasson-Clair, August 2012);
- South Africa Risk and Vulnerability Atlas (SARVA, 2010);
- Global Change Grand Challenge National Research Plan (DST, 2009); and
- Environment Sector Research, Development and Evidence Framework (June 2012).

As the South African Higher Education landscape involves 23 public universities, it was not possible to engage in individual institution consultations (beyond those described in the workshop and questionnaire sections below) within the limitations of this study. As the initial plan to host workshops regionally was circumvented by the budget cut (see limitations of the study below) and as questionnaire data was limited to a few academics across the 23 universities only, wider Internet research (involving a review of all university websites and research institutions listed – where this information was available) and a review of the 2013 NRF rated researchers database were used as strategies to ensure more substantive data that covered all universities. Very little information on courses and curriculum was obtained, so the main focus of the South African report is on research related to CCD, and areas that are relevant to CCD enquiry.

2.1.2 Stakeholder and university staff consultations (national workshop)

As part of the SARUA Mapping Study Initiative *Climate Change Counts*, a country consultation workshop was held in South Africa on 21 August 2013 at the University of Pretoria Groenkloof Campus[9], to which all universities were invited. Requests for nominations to attend the workshops were made via senior management of the institutions. Twelve of the 23 universities attended the consultative workshop. The consultations were structured as a one-day programme, with a combined group of participants, which included university, government, private sector and NGO stakeholders. See Appendix A for the list of participants. A summary of the content of the different sessions is provided below in Table 1. Data produced in the workshops was verified and added to during plenary sessions. The workshop inputs contribute to data used for this Country Report, combined with document analysis and questionnaire data.

[9] The South Africa consultations were made possible through the kind contribution of the University of Pretoria and Tshwane University of Technology, who co-hosted the workshop at the University of Pretoria campus.

Table 1: Workshop programme outline

Time	Activities
08h00 – 09h00	Coffee and registration
09h00 – 09h20	**WELCOME AND INTRODUCTORY REMARKS** • Prof Stephanie Burton, Vice-Principal: Research and Postgraduate Education, UP
09h20 – 09h40	**SARUA INITIATIVE OVERVIEW** • Piyushi Kotecha, CEO: Southern African Regional Universities Association
09h40 – 11h00	**SESSION 1: FRAMING CLIMATE COMPATIBLE DEVELOPMENT (CCD) IN SOUTH AFRICA** • South Africa's climate change priorities, needs and policy and institutional response (Department of Environmental Affairs) • The Global Change Grand Challenge (Department of Science and Technology) • Climate compatible development and the SA research environment (Dr Achuo Enow, Programme Director for Global Change: National Research Foundation) • Climate change and the university response (Prof Mark New, Pro-Vice-Chancellor and Director: African Climate and Development Initiative, UCT) Short Plenary Discussion
11h00 – 11h20	Tea/coffee
11h20 – 13h00	**SESSION 2: SA PRIORITIES, KNOWLEDGE AND CAPACITY GAPS FOR CLIMATE COMPATIBLE DEVELOPMENT** – Plenary and breakaway discussions
13h00 – 14h00	Lunch
14h00 – 15h00	**SESSION 3: FOCUSING ON BUILDING THE UNIVERSITY RESPONSE TO CLIMATE CHANGE – RESEARCH, TEACHING, POLICY AND COMMUNITY ENGAGEMENT**
15h00 – 16h00	**SESSION 4: STRENGTHENING THE ENABLING ENVIRONMENT FOR KNOWLEDGE CO-PRODUCTION, IMPLICATIONS FOR POLICY** – Plenary discussion
16h00 – 16h15	**WAY FORWARD AND CLOSURE** • Prof Lulama Makhubela, Deputy Vice-Chancellor: Postgraduate Studies, Research and Innovation, Tshwane University of Technology

2.1.3 Questionnaires

Two different questionnaires were prepared to obtain more in-depth data on climate change and CCD knowledge co-production practice and possibilities, and to enable people who were unable to attend the country workshops to participate in the mapping study (See Appendices C and D). One was designed for university professionals and the other for national and regional stakeholders who are involved in climate change and CCD. For South Africa, a total of 39 questionnaires were answered, which included 17 stakeholders and 22 university professionals. Questions covered the following areas:

2.1.3.1 University staff questionnaire

A. **General demographic and professional information** (name, gender, highest qualification, job title, years of experience, years of experience with CC, name of university, country, faculty, department, programme, contact details)
B. **Understandings of Climate Change and Climate Compatible Development** and views on critical CCD issues and responses from universities (staff and university leaders)

C. **Capacity, knowledge and research gaps** (levels of involvement in CC and CCD research – local, national and international; levels of single, inter- and transdisciplinary involvement in CCD research; stakeholder involvement; funding and fundraising for CCD research; policy contributions; major research programmes / projects; active researchers; research knowledge networks)
D. **Curriculum, teaching and learning** (specialist courses; integration of CCD issues into courses; cross faculty teaching; inter- or transdisciplinary teaching approaches; service learning approaches; critical thinking and problem solving approaches; social or technical innovation courses; assessment and examination of CCD issues; staff willingness and staff ability; actual courses and teaching methods).
E. **Policy, community engagement and student involvement**
F. **University collaboration** (inside the university; between universities in country; with partners; regional and international involvement)
G. **University policy and campus management**

2.1.3.2 Stakeholder questionnaire

The stakeholder questionnaire covered items A-C above, with an additional:

H. **Interests, policies, networks and Centres of Excellence or Expertise**

2.2 Limitations of the mapping study

This mapping study was constrained by a) a lack of baseline data on knowledge and research gaps for climate compatible development and university-based responses in South Africa, and b) by time and resource constraints that did not allow for **in-depth field visitation, individual interviewing or observation** before, during and after the consultation process. Moreover, the information generated at the country workshop relates to the number of participants, their expertise and the number of different sectors and institutions present. Further, while every effort was made to obtain questionnaire responses from as wide a range of stakeholders as possible, and follow-ups were made post-workshop to enhance this, the range of questionnaire responses obtained does provide certain limitations to the data set. However, the **best available information was carefully consolidated, reviewed and verified** in the construction of this mapping study Country Report. Overall, the mapping study was further constrained by a budget cut imposed mid-way through the study, which in the case of South Africa affected initial plans to host a number of regional consultations.

While much information could be obtained on climate change- and CCD-related knowledge gaps, research needs and capacity gaps, there is obviously more to be learned about these. Similarly, as much information as possible was obtained on 'who is doing what' and on existing research, knowledge co-construction practice and possibilities, but there is clearly also more to learn about these. This Country Report therefore presents as a useful 'initial document' and it is hoped that South African universities, and associated higher education structures (e.g. Higher Education South Africa, the Council of Higher Education, and the Department of Higher Education and Training) can take this analysis forward in ongoing mapping and planning activities related to CCD research and

knowledge co-production. The study may also be useful in informing curriculum and research planning in the two new South African universities that are currently in development.

2.3 Expanding the mapping study

There are numerous ways to expand this study, most notably by administering the questionnaires (included in Appendices C and D) in a manner that would include every academic / academic department at universities in South Africa, and in a way that would allow for aggregate data within and across faculties and departments (Appendix C). The scope of such a detailed analysis lay beyond the capacity of the current mapping study. Data from questionnaires is therefore indicative rather than conclusive. Similarly, the questionnaire for stakeholders can be administered with additional national and local stakeholders (Appendix D) involved in environment and development initiatives in South Africa to understand the full scope of climate change and CCD responsiveness in South Africa, and to further develop the knowledge co-production capacity for CCD in South Africa. In many ways therefore the SARUA study, as reported in the mapping study Country Report, maps out the pathway forward for more detailed and ongoing reflexive analysis of CCD knowledge co-production capacity in South Africa, and through the questionnaires and analysis provided for in this document, begins to provide for ongoing monitoring and development capability for CCD knowledge co-production in South Africa.

2.4 Analysis logic

The analysis logic informing this Mapping Study Country Report is threefold. It firstly maps out a needs analysis which identifies country based knowledge, research and capacity gaps for key CCD priorities as articulated in documents, workshop and questionnaire responses. Secondly, it provides an institutional analysis providing insight into existing institutional capacity for CCD knowledge co-production. Thirdly, it provides a perspective not only on existing knowledge co-production practice for CCD in South Africa, but also on knowledge co-production possibilities, based on information gathered during the mapping study. It provides a knowledge base for producing knowledge co-production pathways in South Africa, which may also assist South Africa **to co-operate with other SADC countries in regional knowledge co-production processes.**

3 NEEDS ANALYSIS

3.1 Introducing the needs analysis

The needs analysis starts with a brief overview of South Africa's socio-economic context and a summary of the observed and projected climatic changes for the country (section 3.2) as these are key drivers for the 'need' for CCD identified by policy, in workshops and via the questionnaires (section 2.3). The needs analysis then describes **more detailed knowledge, research and capacity** needs (section 3.4) using the following differentiation of knowledge, research and capacity gaps:

- **Knowledge gaps** (e.g. insufficient knowledge of appropriate CCD technologies);
- **Research gaps** (e.g. no research on cultural uptake of CCD technologies);
- **Individual capacity gaps** (skills needed) (e.g. for technicians / systems thinking etc.); and
- **Institutional capacity gaps** (which have inferred knowledge and research gap implications) (e.g. resources to implement large scale technology change programmes).

It is possible that this analysis can be extended in future, and readers of the mapping study are advised to use the information provided here as best available information (produced within the constraints of the mapping study outlined above), rather than as definitive information.

3.2 Socio-economic context and projected climate change impacts and vulnerabilities: Drivers of CCD needs

3.2.1 Socio-economic context

South Africa lies between 22-35° south of the equator and covers an area of 1 221 000 km^2, with a population of about 50 million in 2011 according to the Second National Communication (SNC 2011). It has a coastline of about 2 500 km. The climate is generally semi-arid and warm, with steep gradients in both temperature and rainfall. It has widespread aridity, and a mean annual rainfall is 450 mm. It experiences winter rainfall in the west and south-west, and summer rainfall in the interior and eastern regions. South Africa experiences periodic droughts and floods. South Africa is a water-scarce country (annual freshwater availability is less than 1 700m^3 per capita). It has three of the 34 internationally recognised biodiversity hotspots and these contain high concentrations of endemic plant and animal species. South Africa is a middle income country that has historically depended on its mineral resources and primary sectors but is now shifting towards tertiary sectors for GDP generation. The tertiary sector now contributes the most to the economy (65 percent in 2007), with declining contributions from the primary sector, and to a lesser extent from the secondary sector. Its economy is heavily dependent on coal, with coal providing an estimated 72 percent share of the country's total energy supply, making energy supply carbon intensive (SNC 2011). South Africa's GNI per capita in 2011 was US$6 960 (Atlas method) according to the World Bank Country Data Profile. In 2005, about 40 percent of the population lived on or below the international poverty datum line. The high social inequality in South Africa, which can be traced to the history of separate development / apartheid, is evidenced by the Gini coefficient of between 0.66 and 0.69. HIV/AIDS continues to threaten human capacity in the country, and has resulted in a current life expectancy of 52 years, down from 61.5 years in 1994 (UNDP 2010). Educational quality

is a major problem, and SA has repeatedly come last in international benchmarking tests in literacy, science and mathematics education in recent years.

3.3 Observed and projected climatic changes, impacts and vulnerabilities

3.3.1 Observed climatic changes

The SNC and SARVA note that there has been high inter-annual, decadal and multi-decadal variability of weather patterns in the country. The warming trend is already well established in South Africa, with surface temperatures increasing noticeably since 1950 at the same rate and sometimes above the global mean temperature rises. Between 1961 and 2000, the number of extreme cold days and nights decreased by 3.7 and 6.0 days/nights per decade respectively; and the number of hot days and nights increased by 8.2 and 8.6 days/nights per decade, respectively. The UNDP Climate Change Country Profile (n.d.) notes that South Africa's mean annual temperature has increased by 0.6 °C between 1960 and 2006. Warming trends have been observed in the western interior, western and southern coastal regions. Evaporation and windiness have declined in the Western Cape while surface wind speed has increased in the southern coastal areas from 1982 to 2007. The UNDP Climate Change Country Profile (n.d.) also notes that the mean annual rainfall over South Africa has decreased by 1.5 mm per month per decade since 1960. The rainfall trends show decreasing rainfall in parts of the summer rainfall region and increasing rainfall in parts of the winter rainfall region since 1950. The sea level has been rising at a rate of 1.87 mm, 1.47 mm, and 2.74 mm per year along the west, south and east coasts respectively. Groundwater levels have been falling in semi-arid regions due to higher levels of use compared to rate of recharging.

3.3.2 Projected climate changes

Assuming a moderate growth in the emission of GHG, South Africa is projected to experience greatest warming in the interior and the least along the coast, with the former increasing by 2-3 °C and the latter by 1-2 °C by 2050 (SNC 2011). The UNDP Climate Change Country Profile on the other hand projects mean annual temperatures of 1.1-2.4 °C by the 2060s and 1.6-4.3 °C by the 2090s. SARVA projects that the median duration of dry spells for the mid 21st century will increase in northern and western margins of South Africa. The same report projects more intense rainfall events over eastern South Africa in particular. Official estimates of shortages of water requirements range from 2-13 percent to 19-33 percent, the latter taking into account climate change and other uncertainties.

3.3.3 Impacts and vulnerabilities

The east coast, northern KwaZulu-Natal, northern Limpopo and Mpumalanga have high concentrations of poverty, limited access to employment, livelihoods and socio-economic services that pose resilience challenges (SARVA 2010). At least 30 percent of South Africa's population is vulnerable to sudden and harmful climatic shocks and has low levels of resilience, adaptation and coping capacities. Widespread aridity renders South Africa vulnerable to water limitations and associated effects. Other climate change challenges are floods, increased spread of vector and water borne diseases and reduced air quality in urban centres and areas of residence. The most vulnerable

groups are people with a unique disease complex burden (Human Immunodeficiency Virus – HIV, tuberculosis in poor sanitary conditions, waterborne diseases and malnutrition), highly mobile, living in informal settlements, living from hand to mouth, women[10], and small-scale resource-poor farmers. The SNC (2011) identifies the rural and peri-urban poor as vulnerable, especially because they rely on untreated water.

Predicted impacts of climate change for South Africa, include among others, increases in the distribution and intensity of drought, reduced agricultural crop yields impacting on food security, potential species extinction, increased growth rates of invasive species, potentially catastrophic coral bleaching, and an increase in the areas affected by vector-borne diseases. It is also clearly stated in the SNC (2011) that, in all of these circumstances, it is the poor who would be worst affected. Specifically, projected impacts (summarised from the National Climate Change Response White Paper, 2011 and the SNC 2011) include:

- **Water shortages**: South Africa is a water scarce country with a highly variable climate and has one of the lowest run offs in the world. Official estimates suggest that South Africa faces shortages of between 2 and 13 percent of total water requirements by 2025, but some estimates that include climate change projections and other uncertainties, suggest that these could run to as high as 19 to 33 percent by 2025; and that South Africa will exceed limits of economically viable land-based water resources by 2050.
- **Agriculture and commercial forestry:** Climate change significantly impacts agriculture and commercial forestry. Agriculture is the largest consumer of water (through irrigation) and is vulnerable to changes in water availability, increased water pollution and soil erosion. Under-resourced, small-scale and subsistence farmers are particularly vulnerable to the impacts of climate change. Commercial forestry in the form of alien plantations reduces streamflow and so impacts scarce water resources. It also reduces biodiversity.
- **Health and well-being:** There are several emerging and potential links between climate change and human health, particularly related to water scarcity and water quality as well as the geographical spread of vector and waterborne diseases such as malaria, rift valley fever and schistosomiasis, as well as reduced air quality and heat stress. The links between the environment, food security and infectious profiles of communities and regions have been well-established, and risks are greater in such contexts.
- **Biodiversity and ecosystems:** Climate change will compound the pressures on already stressed ecosystems that have resulted from the unsustainable use and inadequate management of many of South Africa's ecosystems and so potentially reduce the quantity and quality of the services that ecosystems currently provide (they underpin South Africa's socio-economic activities). Roughly 30 percent of endemic terrestrial species in South Africa may be at increasingly high risk of extinction by the latter half of this century if climate change is not mitigated.
- **Coastal areas**: Vulnerabilities of coastal areas have been identified as increased storm damage; damage to coastal infrastructure (including infrastructure such as breakwaters); threats to the erosion levels of shorelines; and changes in the salinity levels of estuaries,

[10] Gender and Climate Change Study on South Africa, 2010.

which will affect breeding grounds of many marine species. A significant proportion of South Africa's metropolitan areas, as well as numerous towns and smaller settlements, are situated along the coast, making them vulnerable to any dramatic sea level rises.

- **Human settlements (urban, rural and coastal):** More than 60 percent of South Africa's population lives in urban areas. Urban areas are vulnerable to environmental health risks, and have a number of climate related challenges. Rural settlements in South Africa remain characterised by inequalities and high levels of poverty, especially in former 'homeland' areas. This is also where most small scale and homestead food production is practiced, with roughly 1.3 small-scale farm units, which are also home to 70 percent of the country's poorest households. They face several climate change challenges, especially increased vulnerability. Coastal settlements (home to about 40 percent of South Africans) are also vulnerable to climate change, as they are vulnerable to sea level rise, storm surges, coastal erosion, sea level rise and extreme weather events.
- **Energy and GHG emissions:** South Africa is a relatively significant contributor to global climate change with significant GHG emission levels from its energy-intensive, fossil-fuel powered economy. In term of SA's latest GHG inventory (base year 2000), energy use emissions constituted 80 percent of emissions. This is almost double that of average energy use emissions of developing countries which at the same time was at 49 percent. The National Climate Change Response White Paper states that currently available analyses indicated that, unchecked by climate mitigation action, South Africa's emissions could grow rapidly by as much as fourfold by 2050. South Africa therefore has significant mitigation challenges, in addition to adaptation challenges.
- **Temperature rise and general impacts:** Temperature rise (as outlined above), will result in parts of the country being much drier; increased evaporation will ensure and overall decrease in water availability. This will in turn affect human health, agriculture, other water-intensive economic sectors such as the mining and electricity generation sectors as well as the environment in general. Increased occurrence and severity of veld and forest fires; extreme weather events; and floods and droughts are also projected to have significant impacts, and biodiversity and coastal infrastructure will be affected.

All of these issues are drivers of the need for CCD and CCD knowledge, research and capacity development in South Africa. South Africa has started developed national policy for climate change responses and a clearly defined set of short to medium national priorities have been set for CCD in the South African Climate Change Response White Paper (RSA 2011), as will be seen below.

3.4 Identified needs: Short to medium term national priorities for CCD in South Africa

3.4.1 Identified adaptation and mitigation priorities articulated in policy and strategy

The National Climate Change Response White Paper (RSA 2011) commits the country to making the transition to a climate-resilient and low-carbon economy and society. This is to be achieved through balancing mitigation and adaptation responses and, in the long-term, redefining competitive advantage and facilitating structural transformation of the economy by shifting from an energy-intensive to a climate-friendly path, as part of a pro-growth, pro-development, and pro-jobs strategy. This is to be supported by building the knowledge base and capacity to adapt to the

inevitable impacts of climate change in key affected sectors, and by enhancing early warning and disaster reduction systems amongst other cross-cutting measures such as mainstreaming climate resilience into governance systems and structures; establishing incentive structures; facilitating behaviour change; and mainstreaming climate change into education and training systems.

The following **adaptation** measures are taken from the National Climate Change Response White Paper (RSA 2011). They *exclude* research and education-based adaptation measures, which will be discussed later in more detail:

- **Water:** Integrating climate change considerations in the short-, medium- and long-term water planning processes across relevant sectors such as agriculture, industry, economic development, health, science and technology; giving attention to transboundary water related issues within a regional framework. Improve and use the best catchment and water management practices. Reduce vulnerability and enhance resilience to climate change in communities most at risk; and provide resources and capacity to address climate change in this sector. Conduct appropriate research and training programmes, and strengthen the research base.
- **Agriculture and commercial forestry:** Integrate agriculture and forestry into climate-resilient rural development planning to address job creation, food security and livelihoods with a particular emphasis on building climate resilience through leveraging synergies between adaptation and mitigation. Conduct appropriate research, education and training programmes (see research and knowledge section).
- **Health:** Reduce the incidence of respiratory diseases and improve air quality through reducing ambient particulate matter, ozone, and sulphur dioxide concentrations by legislative and other measures; ensure that food security and sound nutritional policies form part of an integrated approach to health adaptation strategies; and design and implement "Heat-Health" action plans including plans in respect of emergency medical services, improved climate-sensitive disease surveillance and control, safe water and improved sanitation. Conduct appropriate research, education and training programmes.
- **Biodiversity and Ecosystems:** Conserve, rehabilitate and restore natural systems that improve resilience to climate change impacts or that reduce impacts; enhance existing programmes to combat the spread of terrestrial and marine alien and invasive species; expand the protected area network where it improves climate change resilience, and manage threatened biomes, ecosystems, and species in ways that will minimise the risks of species extinction; encourage partnerships for effective management of areas not under formal protection, especially freshwater ecosystem priority areas, critical biodiversity areas, ecological support areas and threatened ecosystems; In the medium-term, expand existing gene banks to conserve critically endangered species that show increasing vulnerability to climate change trends. Conduct appropriate research, education and training programmes.
- **Human settlements – URBAN:** Investigate how to leverage opportunities presented by urban densification to build climate-resilient urban infrastructure and promote behavioural change as part of urban planning and growth management; In the implementation of low-cost housing, ensure access to affordable lower-carbon public transport systems, incorporate thermal efficiency into designs and use climate-resilient technologies; encourage water-sensitive urban designs; and ensure that land-use zoning regulations are enforced and that urban land-use planning considers the impacts of climate change and the

need to sustain ecosystem services when considering settlements and infrastructure development proposals.

- **Human Settlements – RURAL:** Design and implement economic and livelihood diversification programmes in rural areas and target adaptation programmes to build resilience among the most vulnerable sections of the rural population and ensure that disaster management architecture includes the provision of safety nets for rural communities most vulnerable to the impacts of climate change. This includes enhancing their knowledge of sustainable environmental conditions and optimising the ecosystem services that these provide. Conduct appropriate research, training, education and community empowerment programmes.
- **Human Settlements – COASTAL:** Ensure that national, provincial and municipal coastal management plans incorporate relevant climate information and adopt a risk-based approach to planning that anticipates the consequences of the continued migration of communities into high risk coastal areas; take account of the potential impact of sea-level rise and intense weather events, such as storm surges, on infrastructure development and investment in coastal areas, particularly in terms of the location of the high-water mark and coastal set-back lines that demarcate the areas in which development is prohibited or controlled; protect and rehabilitate natural systems that act as important coastal defences; develop Disaster Risk Management plans that take into account the potential consequences of climate change along the coast, particularly the increased incidence of extreme weather events.
- **Disaster Risk Reduction and Management:** There is commitment to continue to: develop and improve early warning systems for weather and climate (especially severe weather events) and pest infestation events; include regional applications and benefits; undertake and support risk and vulnerability research and services; and develop mechanisms for the poor to recover after disasters, including micro-insurance.

In December 2009 the President announced that South Africa will implement **mitigation** actions that will collectively result in a 34 percent and 42 percent deviation below its 'Business As Usual' emissions growth trajectory by 2020 and 2025 respectively. The extent to which this can be achieved, is said to be linked to financial, capacity building, technology and technology transfer interventions and commitments from developed to developing countries. This sets the platform for a number of key elements in the overall approach to **mitigation** (as reflected in the National Climate Change Response White Paper (RSA 2011), which include[11]:

- **Setting the performance benchmark** – Using the National GHG Emissions Trajectory Range, against which the collective outcome of all mitigation actions will be measured.
- **Identifying desired sectoral mitigation contributions** – Defining desired emission reduction outcomes for each sector and sub-sector of the economy based on an in-depth assessment of the mitigation potential, best available mitigation options, science, evidence and a full assessment of the costs and benefits.

[11] These are summarised from the National Climate Change Response White Paper (RSA 2011).

- **Defining carbon budgets for significant GHG emitting sectors and/or sub-sectors** – Adopting a carbon budget approach to provide for flexibility and least-cost mechanisms for companies in relevant sectors and/or sub-sectors.
- **Mitigation plans** – Requiring companies and economic sectors or sub-sectors for whom desired emission reduction outcomes have been established to prepare and submit mitigation plans that set out how they intend to achieve the desired emission reduction outcomes.
- **Use of different types of mitigation approaches, policies, measures and actions** – Developing and implementing a wide range and mix of different types of mitigation approaches, policies, measures and actions that optimise the mitigation outcomes as well as job creation and other sustainable developmental benefits.
- **Using the market** – Deploying a range of economic instruments to support the system of desired emissions reduction outcomes, including the appropriate pricing of carbon and economic incentives, as well as the possible use of emissions offset or emission reduction trading mechanisms for those relevant sectors, sub-sectors, companies or entities where a carbon budget approach has been selected.
- **Monitoring and evaluation** – Establishing a national system of data collection to provide detailed, complete, accurate and up-to-date emissions data in the form of a Greenhouse Gas Inventory and a Monitoring and Evaluation System to support the analysis of the impact of mitigation measures.

South Africa is already engaged in a number of actions for both adaptation and mitigation. The National Climate Change Response Strategy (RSA 2011) identifies a number of 'Near-term priority flagship programmes' that include:

- Climate Change Response Public Works Flagship Programme (involving consolidation of a range of EPWP programmes for climate resilience purposes);
- Water Conservation and Demand Flagship Programme (accelerated National Water Conservation and Water Demand Management Strategy in industry, mining, power generation, agriculture and water services sectors; includes provisioning of rainwater harvesting tanks in rural and low income settlements);
- Renewable Energy Flagship Programme (scaled up renewable energy programme, inclusive of the DoE's solar water heating programme expansion);
- Energy Efficiency and Energy Demand Management Flagship Programme (aggressive energy efficiency programme in industry, covering non-electricity energy efficiency as well, including a government building energy efficiency programme);
- Transport Flagship Programme (enhanced public transport system development);
- Waste Management Flagship Programme (investigation of waste-to-energy opportunities within the waste management system);
- Carbon Capture and Sequestration Flagship Programme (partnership with the SA Energy Research Institute to establish a carbon capture and sequestration demonstration plant); and
- Adaptation Research Flagship Programme (led by SANBI – to design a regional and national research programme to scope adaptation requirements and costs, and to identify adaptation strategies and cross sectoral links).

The SNC (2011) identifies the following **barriers to adaptation** to climate change:

- **Knowledge:** Lack of information in all sectors, including interactions and feedbacks of activities; lack of accessible information on climate change; vulnerability and impact;
- **Political and institutional:** Inadequate social structures for civil society engagement with climate change issues; inadequate planning, integrated and spatial development; and poor climate disaster risk management; insecurity of property rights; and limited free and reliable extension services; and institutional inertia in relation to acquisition of new technology;
- **Socio-cultural barriers:** Pervasive social vulnerabilities; cultural preferences; low education levels; technology has not yet been proven for local use; lack of knowledge about use of technologies; and
- **Financial barriers:** Lack of market access; lack of appropriate financial systems; payments required for intellectual property rights; and new technology for local application too costly to develop.

The **barriers to mitigation** include: costs of obtaining intellectual property rights for the technologies; the cost of switching to alternative energy sources (renewable and nuclear); low back-up capacities for renewable energy schemes; and lack of knowledge by potential clean/green technology users.

3.4.2 Identified needs associated with CCD articulated in workshop interactions

Workshop presentations and input from workshop participants prioritised the following climate change and CCD-related needs, which indicated a strong level of engagement with the issue. Discussions around these specific identified needs, led participants to highlight the following key aspects:

- **Water** – South Africa's water is already fully allocated; CC brings reductions in water availability; there is a decline in water quality, increase in extreme events.
- **Agriculture** – most scenarios suggest adverse impacts, particularly for small-scale farmers who are also most vulnerable to multiple stressors, increasing food insecurity risks.
- **Natural resources** – degradation trends likely to worsen without addressing sustainable management issues; opportunities need to be developed for increasing resilience of rural and urban communities.
- **Focus more on Health** – South Africa is already facing adaptation deficit and additional stressors due to current disease burden.
- **Emissions reduction is a key priority** – South Africa's energy emissions are increasing, not decreasing (energy use emissions now at 85 percent).
- **Human settlements and livelihoods** – emerging understanding suggests significant and adverse impacts.
- **Extreme events** – weather-related impacts are already exacerbated by poor land management in parts of South Africa.
- **Economic transitioning** (from a carbon intensive to a low carbon economy) – research, policy, technology innovation and practice is weak; more needs to be done here to effect the economic transition; also includes public participation and awareness. National Development Plan Vision 2030 suggests that there is a need to improve adaptation measures, mitigation measures, governance systems and capacity (e.g. creating an enabling

environment and civil society; investment in governance systems and skills; policy alignment)

- **Integrated approaches to CCD** (conceptualisation and implementation); **use of Social-Ecological-Systems (SES) approaches** to CCD; **development of integrated resilience practices** (e.g. use of urban open space to address the resilience of the city as SES through integrated approaches to adaptation and mitigation; ensure **policy alignment** at all levels, objectives of the transitioning process must be integrated into all plans of all departments and sectors (also emphasised in the National Development Plan Vision 2030.
- **Contradictions between the neo-liberal economic system and CCD** were raised in discussion a number of times in the workshop; and the issues of the trade-off between development and climate change were raised; as were questions about the efficacy of the current development paradigm as it continued to fail the poor. It was suggested that CCD should become a key driver of new development paradigm thinking and that the inherent tensions and contradictions that exist between the 'triangular goals' of development, adaptation and mitigation should not be ignored but actively engaged with. It was noted that the concept of 'trade off' (i.e. choosing one option above the other) was not particularly useful, and that the notion of dealing with contradictions and conflicts to find novel solutions may be more useful. It was said that this should be the 'substance' of the policy-science-practice interface in the context of CCD.
- **Scientific innovation** was also raised as an issue that needed more critical engagement. It was said that "SARUA has an agenda to base policy on evidence that comes from a science platform" but this was questioned and it was asked "how much thinking has gone into defining the science platform to include specifically a notion that we need to interrogate the model of science itself – are we to present science as it is produced – or can we question science and its models of production itself?". It was felt that it was important, within CCD to be questioning the nature of science itself, and that social sciences and other disciplines should be included in the conversations from the very start; it was not an adequate response from CCD to frame the conversation from the natural and earth system sciences and then expect policy and social institutions to respond.
- **Social learning, education, training, skills development and social innovation** were highlighted throughout the workshop.

Participants felt that there is a strong policy context for CCD, but that the tendency to treat issues in 'silos' or as separate aspects for sectoral attention did not address the integrated and trans-sectoral nature of many of the CCD issues. There was therefore a strong demand for more integrative approaches to CCD related concerns, especially in policy implementation processes and programmes. There was also a sense that while policy was good and 'forward thinking' significant issues associated with policy implementation need to be addressed. Capacity related issues were also mentioned a few times. **Social innovation and social learning** was also foregrounded as an important focus for CCD, which cuts across all of the identified adaptation and mitigation priorities as outlined in policy.

The presentation from the Chief Director of Climate Change, Dr Judy Beaumont from the Department of Environmental Affairs showed that the government are putting place measures to work towards a more integrated approach to CCD, and that the following adaptation, mitigation and integrated planning was taking place (see annotated Figures 1, 2 and 3 below from the presentation of Judy Beaumont, Chief Director for Climate Change, DEA).

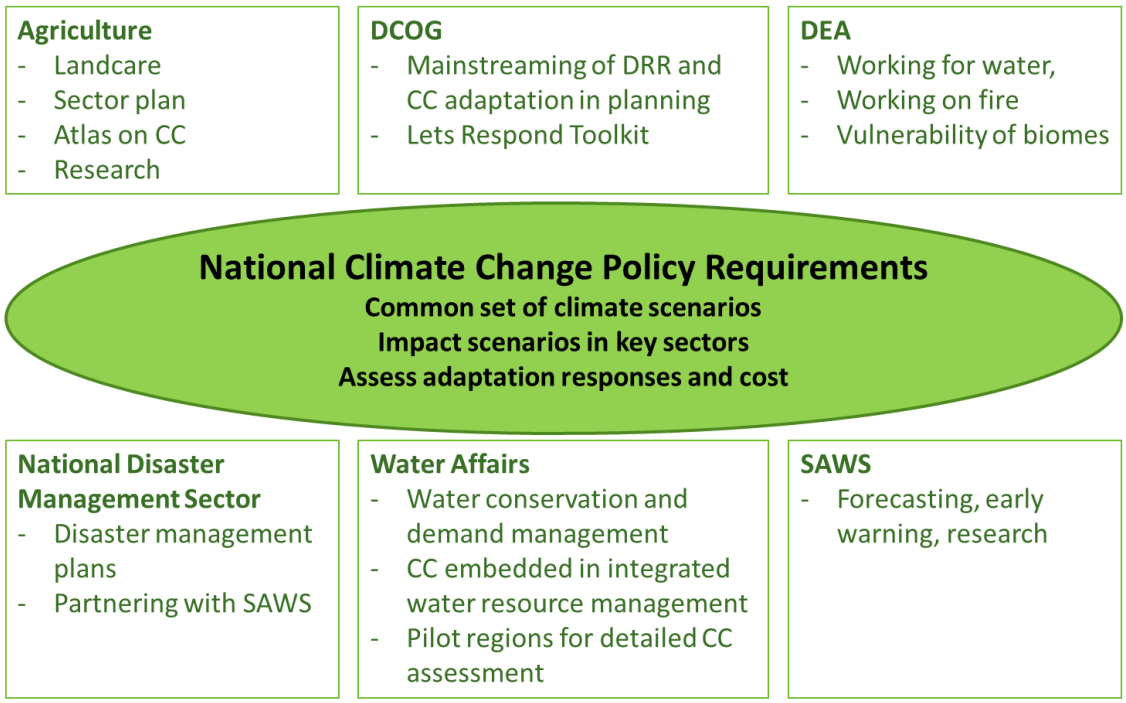


Figure 5: South African government-led work contributing to Adaptation

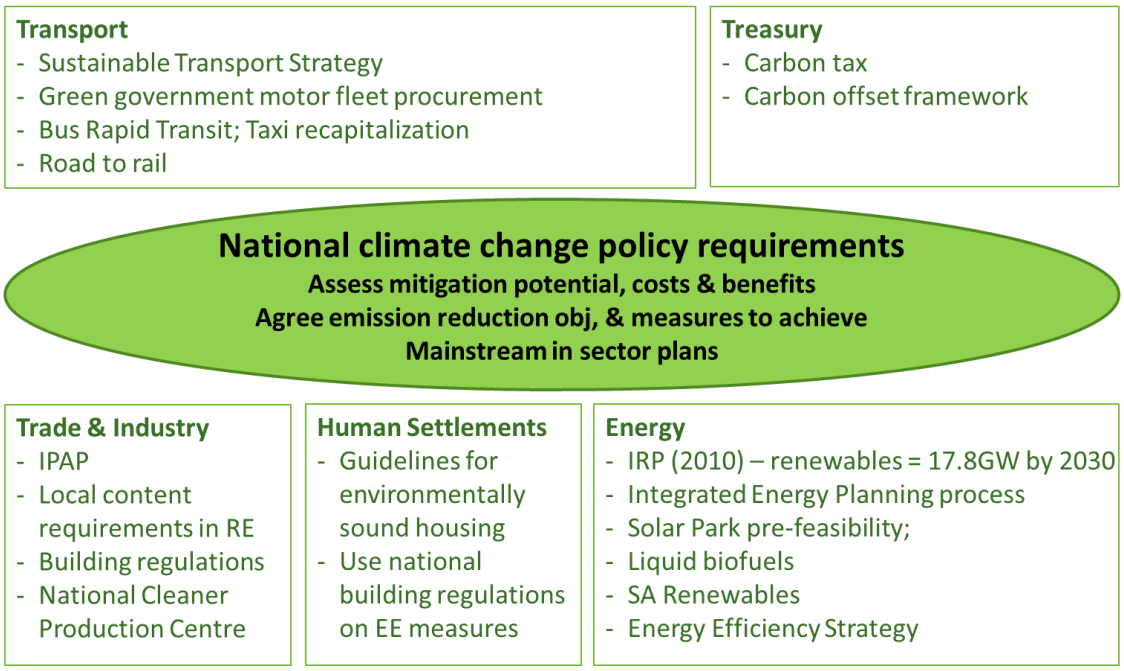


Figure 6: South African government-led work contributing to Mitigation

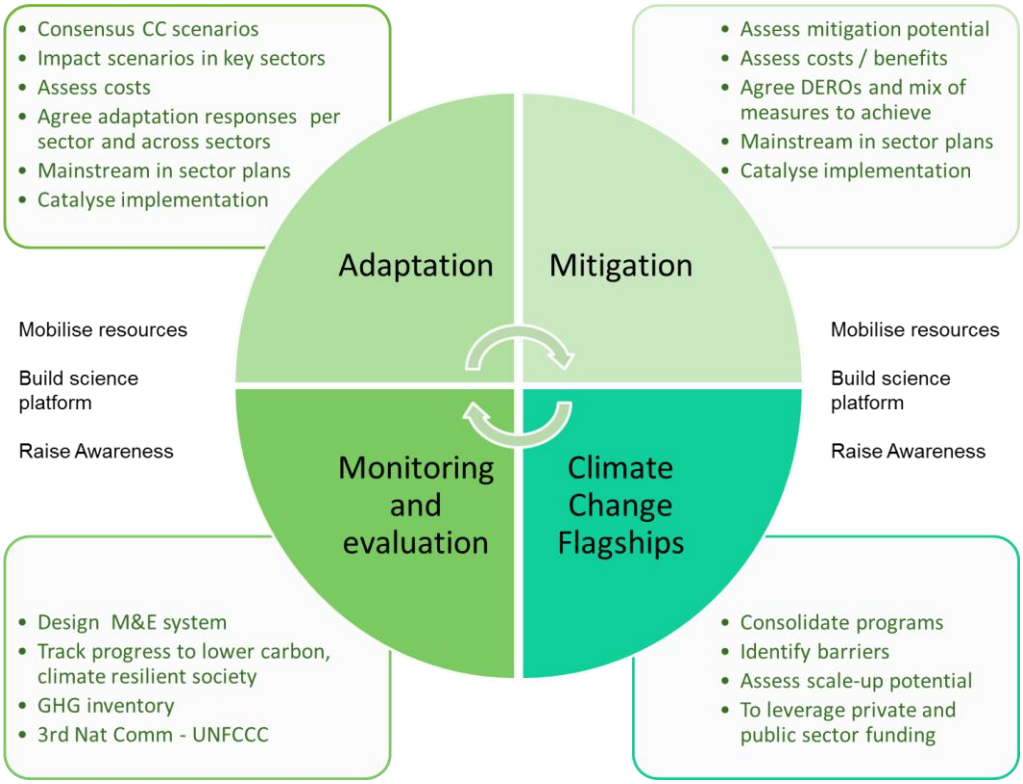


Figure 7: Integrated approach to CCD

It was noted by Judy Beaumont that "extensive CCD work is underway, across government and other organisations", but that the key issue was to *organise, achieve coherence, monitor impact, and move towards a collective national response* involving:

- **Adaptation:** Programmes need to use a common set of climate scenarios, and likely impact scenarios, and build in systems for scaling up, and for monitoring impact and outcomes;
- **Mitigation:** Programmes need to contribute to a single agreed set of desired emissions reduction outcomes (DEROs); build in systems for scaling up, and contribute to a single system for measuring outcome (emissions reductions);
- **Monitoring and evaluation:** Coherent system to monitor outcomes of collective response is needed;
- A **finance and technology platform** was needed; and
- A substantive **skills building programme** is needed.

Dr Beaumont also noted that the following policy requirements were currently being given attention, with annual deliverables that lead towards achievement of these requirements:

- Climate risk analysis on sectoral plans involving the identification and prioritisation of key short and medium term adaptation interventions; identification of adaptation responses that require co-ordination between specific sectors and/or departments;
- Methodology to downscale climate information and impact assessments to specific geographical areas was being developed;
- Desired emission reduction outcomes were to be defined;

- The optimal combination of mitigation measurements (including carbon budgets) was to be drawn up, to achieve the DEROs. Such measures must have the least cost to and the greatest sustainable development benefits relevant to the sector and or national economy;
- A draft climate change response monitoring and evaluation system would be designed and published; and
- The emissions inventory would be set up as a web-based GHG emission reporting system that will form part of the National Atmospheric Emission Inventory component of SAAQIS. It will be developed, tested and commissioned.

It was also noted by Dr Beaumont that **informed decision making and planning** was a 'key element' in the overall strategic approach as set out in the National Climate Change Response White Paper (RSA 2011) and in the National Development Plan Vision 2030 where CCD related issues were also prioritised. Such an informed decision making approach "prioritises *research, systemic observation, knowledge generation, information management and early warning systems,* all of which increase our ability to measure and predict climate change and the implications of its adverse effects on the economy, society and the environment". Workshop participants also emphasised the need for informed decision making and planning, noting the importance of research, knowledge, knowledge management, communication, social learning and social innovation as part of such an approach. From this, it is clear that CCD decision making needs are strongly research-linked. Specific knowledge and research needs are discussed throughout section 3.4.

3.4.3 Identified needs for CCD articulated in questionnaire data

Questionnaire data showed that there is a relationship between institutional interest / mandate and/or disciplinary interest / mandate and the definition of priority needs (see Table 2 for responses from stakeholders and Table 3 for responses from universities)

Table 2: Needs identified by different stakeholders (derived from questionnaire data)

CCD needs	Organisation
Data. Without sustainable long-term data describing various physical environments and biological processes, we will not be able to predict impacts of climate change on our natural environments, communities, economy, or development. How could we strive towards climate compatible development without prior knowledge of the process or direction of climate change itself? Establishing planned biological corridors and maintaining sufficiently sized protected areas for the preservation of biodiversity. Creating an inherent appreciation for biodiversity in the hearts and minds of fellow citizens.	South African Environmental Observation Network/National Research Foundation (NRF)
Community-level capacity to adapt to change; energy efficiency; fossil-fuel use reduction; ameliorating impact amongst most vulnerable (e.g. through cross-subsidisation, sliding-scale tariffs and taxes, targeted adaptation programmes, etc.)	Environmental Monitoring Group (national NGO)
The carbon intensive energy system	Council for Scientific and Industrial Research (CSIR)

CCD needs	Organisation
To achieve climate compatible development, policy makers need to: 1. Develop national and sub-national governance systems, including legislative, institutional architecture, regulatory and accountability measures that can take advantage of combining efforts to lower emissions or keep emissions low, build resilience, grow and develop. 2. Integrate measures to build resilience and reduce risk into development and low emissions growth strategies at all scales. 3. Ensure that transitions to resilient low emissions growth have significant benefits for poor people. 4. Acknowledge and plan for the threats and opportunities associated with a new international, climate-related development landscape.	International Council for Science (ICSU) Regional Office for Africa (implementing the regional component of the Future Earth Programme)
Accountability, efficiency, and good governance.	World Health Organisation
The main prerequisite for CCD is understanding of climate risks (and opportunities) and willingness to incorporate this awareness into forward planning. In my experience, national level is more likely to have awareness of this than at local level, which is an impediment since policy implementation takes place at the local level.	Kulima Integrated Development Solutions (Pty) Ltd (and visiting at Wits)
Mainstreaming the CCD across the economic sectors of society.	Department of Environmental Affairs
Understanding development needs and trajectories, cross sectoral linkages, and how these relate to climate resilience	South African National Biodiversity Institute (SANBI)

Of interest in the above responses (in Table 2) is the emphasis on strategic issues such as good governance and cross sectoral linkages and informed decision making. Community-based adaptation was mentioned by a national NGO.

Table 3: University questionnaire responses to CCD needs in South Africa

CCD Needs	Name of Faculty (F) Name of Department (D)
Sustainable households. Disaster management strategy.	F: Engineering and Built Environment D: Architecture and Planning (University of the Witwatersrand)
Fuels and energy should be extracted from sources (wind, the sun, biologically based) other than fossil fuels.	F: Science D: Mathematics and Applied Mathematics (University of the Western Cape)
Education and training of farmers by doing action research - learning by doing.	F: Natural and Agricultural Sciences D: Soil, Crop and Climate Sciences (University of the Free State)
Ensuring crop-climate matching and agricultural management practices are optimal, and that it adapts to changing climatic conditions.	F: Natural and Agricultural Sciences D: Soil, Crop and Climate Sciences (University of the Free State)
Changing social values and aspirations from 19th century political ideologies to a political ideology that is relevant to the challenges of the 21st century.	F: Engineering Built Environment and Information Technology D: Construction Economics (University of Pretoria)
Education – change legislation.	F: Engineering D: Graduate School of Technology Management (University of Pretoria)
Developing a general public understanding/awareness of the negative aspects of climate change. A resilient response is not dependent on one or a few actions but on a combination of many actions/strategies	F: Engineering Built Environment and Information Technology D: Architecture (University of Pretoria)
The key will be good governance as defined by the UN, but also to incorporate the principles of IWRM and Adaptive Management into daily decision making of ALL stakeholders. Cooperation, Responsiveness and Flexibility in jointly making sense of impacts, designing interventions and the implementation thereof will be crucial.	School of Agricultural, Earth and Environmental Sciences (University of KwaZulu-Natal)
South Africa is one of the major emitters of greenhouse gases, such as through burning coal. A reduction in such emissions would be ideal. Understanding climate impacts on food production in different areas and for different types of farming. Expertise in climate modelling is needed for CCD. Adaptation strategies such as conservation agriculture, water harvesting, development of varieties of plants that can adapt to various agro-ecologies, or extremes of temperature and rainfall availability, etc. Also, vulnerability understandings are needed. Collaboration between professionals in different disciplines, including gathering of indigenous knowledge and resources that can assist.	F: Science and Agriculture D: Agronomy (University of Fort Hare)

CCD Needs	Name of Faculty (F) Name of Department (D)
Food and water security	F: Science and Agriculture (University of Fort Hare)
Crop improvement programmes; Livestock development/improvement programmes; Water development programmes	F: Science and Agriculture D: Livestock and Pasture Science (University of Fort Hare)
Understanding place-based and sector specific thresholds to the combinatory impact of non-climate stressors coupled with climate variability and change. This requires, as one element, actionable information on scale-relevant climate variability and change.	F: Science D: Environmental and Geographical Science (University of Cape Town)
In my field: livestock and forage production – studying more productive animals and plants to cope with a changing climate	F: Science D: Animal Science (Tshwane University of Technology)
More effort has to be made to sensitise the public to climate change, many people still do not know about it or do not understand it, and are consequently not doing anything to change the situation or placing pressure on others.	F: Science D: Environmental, Water, Earth Sciences (Tshwane University of Technology)
The neo-liberal model	F: Arts D: Fine and Applied Arts (Tshwane University of Technology)
Replace thermal power stations with other sources of energy	F: Science D: Environment, Water and Earth (Tshwane University of Technology)
Reducing the carbon intensity of the country's energy carriers (mitigation) in the context of drastic reductions in water availability (adaptation)	F: Engineering and Economic and Management Sciences D: School of Public Leadership (Stellenbosch University)
Ensuring people have the capacity and assets to adapt, especially the most vulnerable – includes addressing food security concerns, poverty alleviation, basic development concerns (education, land distribution and rights, health services, etc.), whilst at the same time ensuring that the country makes efforts to reduce GHG emissions. Integrated approaches that do not isolate climate change from other areas of development and drivers of vulnerability.	F: Science D: Environmental Science (Rhodes University)
Education, awareness and serious governmental support in terms of development capital for sustainable projects	Community Engagement and sustainability (North-West University)
Restructuring of law and economics and social change with a specific emphasis on poverty alleviation and protection of vulnerable people to increase human and environmental security and resilience Alignment of policies, programmes and legislation	F: Faculty of Law (North West University)

CCD Needs	Name of Faculty (F) Name of Department (D)
The most critical aspects to deal with if climate compatible development is to be achieved are the reduction of greenhouse emission.	F: Law School of Undergraduate Studies (North West University)
Change present mode of living, educating and decision making	Nelson Mandela Metropolitan University

Responses from university partners shown in Table 3 above show a range of responses: some address wide societal change and development paradigm shift issues, some consider critical priorities such as reduction of greenhouse emissions, others address critical research needs such as understanding of place-based and sector thresholds, while others look at social change concerns such as education, public awareness and skills development. Some responses are quite discipline / sector specific.

Tables 2 and 3 above show that stakeholders and university staff observe a wide range of priority needs that require attention for CCD in South Africa. The diversity of responses shows that while there are many common views of what needs to be done to address CC and ensure CCD, different institutions / disciplines and levels of interdisciplinary management often shape the perceptions and knowledge of the most important climate compatible development 'needs'. It is important to identify and recognise these different perspectives in knowledge co-production processes and approaches, as personal experience, disciplinary knowledge, institutional interest, mandate and context can shed light on the specific priority areas that need to be addressed. The diversity of responses from such a varied range of experts in their field show the interdisciplinary and multi-sectoral nature of climate change. *How to harness such perspectives, and the associated expertise that informs such perspectives is the ultimate challenge of a knowledge co-production framework and process.*

3.5 Specific knowledge and capacity needs: CCD research, knowledge and individual and institutional capacity gaps (related to CCD priorities)

A second important part of the needs analysis undertaken in the context of the SARUA mapping study involves more detailed analysis of CCD knowledge, research and capacity gaps, with a focus on those identified in key national documents, and as articulated by stakeholders and university staff attending the workshops and completing questionnaires.

3.5.1 Needs analysis: Specific research needs and knowledge gaps

The prioritised needs for CCD were developed through an in-depth review of documentation, research programme frameworks, the National Climate Change Response White Paper (RSA 2011) and the DST 10 Year Innovation Plan which identifies two national 'Grand Challenges' that are relevant to CCD. The document analysis is supplemented by workshop and questionnaire data analysis. South Africa already has a well defined national research agenda for CCD as can be seen from the document analysis below.

In South Africa, climate change related observation, monitoring and research programmes are guided by national policy frameworks such as South Africa's National Research and Development Strategy (DST 2001), the 10 Year National Innovation Plan and most recently by the National Climate Change Policy Response White Paper. Within these broad research frameworks, are more detailed research strategies and action plans. For example, the 10 Year National Innovation Plan identifies five 'Grand Challenges', of which the Global Change Grand Challenge and the Energy Grand Challenge form the two that are most closely associated with climate compatible development. The Global Change Grand Challenge National Research Plan (DST 2010) has identified four 'knowledge challenges' with specific knowledge needs identified (see Figure 4; further detail associated with these knowledge challenges below).

A **Understanding a changing planet**	B **Reducing the human footprint**	C **Adapting the way we live**	D **Innovation for sustainability**
1. Observation and monitoring 2. Dynamics of the oceans around southern Africa 3. Dynamics of the complex internal earth systems 4. Linking the land, air and sea 5. Improving model predictions at different scales	1. Waste minimisation methods and technologies 2. Conserving biodiversity and ecosystem services 3. Institutional integration to manage ecosystems and ecosystem services 4. Doing more with less	1. Preparing for rapid change and extreme events 2. Planning for sustainable urban development in a South African context 3. Water security for South Africa 4. Food and fibre security for South Africa	1. Dynamics of transition at different scales - mechanisms of innovation and learning 2. Resilience and capability 3. Options for greening the developmental state 4. Technological innovation for sustainable social-ecological systems. 5. Social Learning for sustainability, adaptation, innovation and resilience.

Figure 8: Global Change Grand Challenge National Research Plan framework (DST 2010)

The Energy Grand Challenge has identified the following major thrusts:

- Clean coal technologies for environmentally friendlier processes;
- Nuclear energy revisited to have 20 to 25 percent of electricity produced by nuclear power;
- Renewable energy technologies with focus on commercialisation and coherent policy interventions; and
- Hydrogen: the goal is to place South Africa – which holds 87 percent of the known platinum reserves – in the emerging fuel cell market.

A more detailed analysis of the research and knowledge needs for CCD in South Africa is provided below. This presents *a best available synthesis of CCD related knowledge and research needs as of December 2013*. It expands previous analyses in the Global Change Grand Challenge National

Research Plan (DST 2010) and the Second National Communication (SNC 2011) and includes those knowledge and research needs identified and specified in the National Climate Change Response White Paper (RSA 2011) and in the draft Long Term Adaptation Scenarios (released in 2013). This detailed document analysis was presented for discussion at the national workshop, where additional perspectives were offered, and is summarised below in 11 research themes.

3.5.1.1 Research Theme 1[12]: Understanding a changing planet: Observation, monitoring and Earth System Sciences

This key research focus area in the Global Change National Research Plan (DST 2010) seeks to build an understanding of how our ecosystems are changing; where that change is taking place; and how rapidly the change is happening. It also seeks to understand complex interactions that take place within ecosystems, and how changing certain aspects of any of them will affect other aspects. This is basic research that does not necessarily result in technologies or applications. The understanding will be necessary to improve predictive capability and to plan appropriate adaptive responses. The focus area has identified four themes, discussed below.

Observation and monitoring

- Understanding the nature of change – what are critical thresholds that, if exceeded, will precipitate significant and possibly irreversible changes; what would the consequences of such changes be; and what indicators can be used to detect them?
- Ensuring ongoing benefits – what Earth observation network models are best suited for detecting critical thresholds and promoting appropriate knowledge dissemination and action?

Dynamics of the oceans around southern Africa

- The main gaps in regional understanding centre on the natural variability of the climate in southern Africa. Strengthening the capabilities of the 'coupled' ocean-atmosphere-biosphere is needed to improve weather and seasonal climate predictions, with benefits to ecosystem services affecting food and water security, protection from extreme events and, more broadly, human well-being.
- There is also uncertainty about the regional effects of large-scale global climate change. While it is understood, for example, that the Earth will become warmer if concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHG) continue to rise at their present rates of 1 to 3 percent per annum, regional responses to such a rise remain unclear.
- The strong links between local climate and the three oceans surrounding the southern African landmass, make any seasonal and decade-scale forecasts dependent on the changing

[12] Note, these 'research themes' broadly follow the logic of the Global Change National Research Plan (DST 2010), but are also aligned with the Adaptation and Mitigation priorities outlined in the National Climate Change Response White paper (RSA 2011) and the Long term mitigation and adaptation scenario research needs (RSA 2007; RSA 2013), and are inclusive of workshop discussion on research priorities.

nature of these links. This is a key knowledge gap for South Africa and the southern African region.

- The role of the region's oceans is of global importance in driving the global climate system through their biogeochemical and biophysical behaviours. For example, the Southern Ocean provides a 'sink' for some 50 percent of all natural and anthropogenic CO_2 taken up annually by the world's oceans – a key 'ecosystem service' providing vast carbon sequestration capacity. It is unclear how this ecosystem service will be affected by global warming.
- Also insufficiently understood is the role of the Southern Ocean in modulating albedo (i.e. the ability of the Earth to reflect solar radiation). The ocean emits trace gases, which help to seed low clouds that increase reflectivity; but some of these gases also reduce stratospheric ozone, allowing more radiation to reach the Earth's surface.

Research focus areas / priorities include:

- How will the large-scale Southern Ocean ocean-climate systems such as the Antarctic oscillation, frontal zones, overturning circulation, and surface mixed layers respond to global warming?
- How will the Southern Ocean's capacity to take up anthropogenic and natural CO_2, and to provide the required energy supply to its ecosystems, change in response to climate change?
- How will the Southern Ocean respond to climate change through changes in ecosystem function and structure that modify food webs and climate feedbacks such as atmospheric albedo?

Linking the land, the air, and the sea

- To increase understanding of the ways in which ecosystems are linked, and how changes in one system will affect others, studies that cross traditional boundaries are needed.

Research focus areas address the following gaps:

- What are the priority forms of change on the land that will directly or indirectly affect atmospheric, estuarine, and marine dynamics?
- Can any thresholds be identified beyond which changes in one system will cause irreversible or sudden change in another system? If so, how can reaching such thresholds best be avoided?

Improving model predictions at different scales

Global models focus on broad-scale changes to the Earth's climate, and their predictions are often too coarse to be useful at a regional or local level. It is also true that, by adding understanding generated at a local level, it is possible to improve global models, their predictions, and therefore their usefulness.

Research focus areas to be addressed in this theme are:

- What is the relative importance of southern Africa's biomes in terms of their influence on climate and on carbon storage?
- Which were the global climate changes that favoured the evolution of the impressive diversity of flora and fauna of southern Africa? More specifically, what were the climate

changes over the past five million years that saw the rise of African hominids, fynbos, and many other life-forms?
- What are the relationships between bushfires and greenhouse gases and carbon storage?
- Are fire regimes likely to change and, if so, how will the relationships change?
- To what degree do the land and the oceans around southern Africa act as sources and sinks for carbon and other important elements?
- How will changes in sea surface temperature and ocean currents affect rainfall patterns?

The Second National Communication (RSA 2011) reports that South Africa is making good progress in developing scientific competence for observation, monitoring and climate change projection. It, however, identifies the following knowledge needs, in addition to those identified above:

- More detailed modelling of regional differences associated with sea level rise, especially related to areas that are more susceptible; and
- More detailed future rainfall projections, which require further knowledge of complex rainfall generating processes such as cloud formation and land surface-atmosphere interactions in climate modelling.

The NCCRWP (RSA 2011) suggests the following needs for ongoing research and knowledge needs related to **monitoring and evaluation, and also makes a strong commitment to ongoing modelling and observation research:**

- Ensure that climate change impacts are monitored at appropriate spatial density and frequency, where feasible, of changes in spatial distribution and incidence of climate-sensitive diseases; ecosystems and the goods and services they supply; key species responses (including invasive alien species); wildfire hydrology and water resources; and agricultural and forestry production; and
- Medium- and long-term climate projections that represent the full range of possible climate outcomes, including the risk and scale of projected impacts, the costs and benefits of possible responses, and the risks of their failure.

This requires:

- Developing and piloting a methodology to downscale climate information and comprehensive impact assessments to specific geographical areas, including provinces and municipalities. This methodology will avoid inappropriate treatment of fine-scale information as indicating greater certainty in climate outcomes, allow for plans that can respond to unfolding climate trends, and lower the risk of mal-adaptation.
- Roll out of the downscaling work, with appropriate monitoring and evaluation safeguards.

Adaptation scenario development and sector specific engagements with climate change and climate compatible development pathways are showing more refined, and sector specific modelling requirements (discussed under the specific priorities below).

Workshop participants noted the importance of integrating indigenous and local knowledge into monitoring research to facilitate stronger uptake and better understanding of climate information that is being produced.

*3.5.1.2 **Research theme 2: Water Security / Water and Adaptation***

The Global Change Grand Challenge National Research Plan lists the following research questions related to the research theme **WATER SECURITY.** These research needs are also supported in the Second National Communication (RSA 2011).

The first order effects of climate change (such as the amount of rainfall) are often the focus of discussion on mitigation measures and adaptation strategies. It is, however, very likely that secondary effects could be much more significant, and a lack of understanding in this regard is a key gap. Research focus areas are:

- Can we develop dynamic predictive models that will allow water planners to move away from a dependence on data from the past 50 years (which will not reflect future trends)?
- What are the important secondary effects of a changing climate on water security?
- What are the limits within which freshwater ecosystems can maintain their integrity, and where are these limits likely to be exceeded?
- What trans-boundary effects can be expected, considering that a number of South Africa's major river systems are shared with our neighbouring countries?

The Second National Communication (RSA 2011) additionally lists the following research and knowledge needs:

- Water related climate change risks and impacts, and demand and supply adaptation measures **implementation and monitoring** (including of technological and structural measures, system maintenance, improvements in operation rules, sustainable surface and groundwater use, early warning systems, pollution control, risk mapping, risk sharing, policy instruments and their enforcement, and application of protective land use regulations).
- The sustainable use of several trans-boundary aquifers requires improved scientific understanding informing improved management.
- Improved quality and availability of data on groundwater resources and their recharge rates compromise sound management decisions.

The NCCRP (RSA 2011) lists the following:

- Sustaining state-of-the-art, water-related research and capacity development in all aspects of climate change in order to ensure the availability of relevant high quality, complete and current data, and tools with which to analyse the data;
- Exploring new and unused resources, particularly groundwater, re-use of effluent, and desalination; and
- Undertaking focused monitoring and research in order to ensure the efficacy of water adaptation approaches over the long-term.

The draft LTAS Phase 1: Technical Summary (2013) lists the following three main research needs:

- Supporting the development of tools, approaches and case studies of the way in which water planning may consider long-term climate change through bottom-up stress testing of:
  - Water management strategies, particularly at the WMA and catchment scale, supported by institutional, organisational and physical interventions that increase long-term adaptation capacity;
  - Water resources infrastructure projects that provide robust and operationally flexible supply augmentation as part of broader systems; and
  - Water services and infrastructure that are robust to alternative climate futures, while being flexible within a broader municipal services and infrastructure system.
- Understanding the way in which climate driven changes in water resources availability or demand may constrain (limit) or enable (catalyse) different development pathways in different parts of South Africa, particularly in terms of agricultural production and energy generation:
  - Trade-offs related to allocation between different sectors and their impacts on economic and rural development priorities; and
  - Opportunities and risks related to regional (SADC) trade in food and energy, thereby importing more water intensive (lower-value) products (i.e. with higher water footprint) considering the implications for trade balance, food security and energy security.
- Exploring the long-term non-stationary hydrological implications of climate change on the appropriate definition of the reserve as well as on the implications for catchment management in different systems in order to maintain the reserve.

*3.5.1.3 **Research Theme 3: Food and Fibre Security, Agriculture, Forestry and Fisheries***

The Global Change Grand Challenge National Research Plan lists the following research and knowledge needs in relation to the research theme **FOOD AND FIBRE SECURITY**, which are also included in the Second National Communication (RSA 2011) as research and knowledge needs. The effects of climate change on food security are difficult to predict at present, and research is needed to deepen our understanding of the issue. This theme focuses on the following:

- How and where will southern Africa's main crops and livestock be affected by climate change? Can the most vulnerable crops and livestock types be identified with a view to replacing them, or ensuring ongoing production?
- What new crop or livestock species, or production methods, can be developed to offset the effects of climate change?
- Can cropping systems be developed to derive multiple benefits from the same area (e.g. using tree crops for food, fodder, energy, and to enhance cash income)?
- Which wild plant and animal species are important sources of food? How will these be affected by climate change, and do alternative sources of food exist to replace such species?

The Second National Communication (RSA 2011) further lists the following knowledge needs related to **AGRICUTURE AND ADAPTATION**:

- Climate change impacts on crops;
- Climate change impacts on food production and food security, especially related to future water supply constraints, declines in water quality, and competition from non-agricultural sectors; and
- Implications of climate change vulnerability on small-scale and urban homestead dryland farmers.

The NCCRWP (RSA 2011) lists the following research and knowledge needs related to **AGRICULTURE and COMMERCIAL FORESTRY**:

- Using the results of available risk and vulnerability studies, develop and update short-, medium- and long-term adaptation scenarios to identify climate-resilient land-uses;
- Invest in and improve research into water, nutrient and soil conservation technologies and techniques, climate-resistant crops and livestock, as well as agricultural production, ownership, and financing models to promote the development of "climate-smart agriculture" that lowers agricultural emissions, is more resilient to climate changes, and boosts agricultural yields; and
- Early warning systems for farmers' resilience.

Additionally to the above, the draft LTAS Phase 1: Technical Summary (2013) lists the following key future research needs:

- The promotion of climate-resilient rural development planning to address job creation, food security, sustainable livelihoods and contribute to biodiversity;
- A holistic assessment of future needs relating to climate change impacts and adaptation in the agriculture sector. Such an assessment could usefully distinguish needs at a range of scales of implementation (i.e. from national and regional governance issues) through to local scale needs for specific agricultural activities conducted in a variety of commercial and non-commercial contexts.

FISHERIES

The draft LTAS Phase 1: Technical Summary (2013) includes **FISHERIES** (which is not directly addressed in the Global Change National Research Plan, the Second National Communication, or the NCCRWP identified research needs. It identifies the following future research needs:

- Current capacity for predicting the impact of future climate change on important marine resources is inadequately developed, but a number of opportunities exist to make rapid progress. These lie in the area of data collection, data synthesis and model development using available and newly collected data.
- Overall, South Africa needs to strengthen the science base for the detection and prediction of changes and provide science-based advice to support CC adaption. Research is needed to aid in the accurate projection of the impact of future CC on fish production, distribution, and conservation, as well as socio-economic consequences:
  - Downscaling of models to simulate inter-annual and decadal variability;

- Link drivers and responses by improving observations and models of regional Net Primary Productivity (NPP) and how changes in NPP cascade up the marine food-web to fisheries;
- Develop understanding of the consequences of changes in biodiversity on the stability, resilience, and productivity of marine systems;
- Consider the interaction between aquaculture and capture fishery and improve understanding of the consequences of future increases in aquaculture production on the production of aquatic ecosystems; and
- Investigate the socio-economic consequences of climate change impacts on the fisheries sector and other sectors of the economy dependent on fisheries.

- There is also a need to research the human dimensions of fisheries adaptation, including:
  - How to progress towards scenario planning with a variety of stakeholders in which mutual trust can be built;
  - Research into current adaptive strategies: what works and why?
  - 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 ocean (fisheries in a setup of many sectors locally/regionally);
  - Tradeoffs between the hake and small pelagic fishing industries under ecosystem variability and change;
  - Role of international markets (exports and imports) and aquaculture in the social-ecological system; and
  - Social and economic challenges of threatened fisheries in a local and regional perspective.

- Links with oceanographic research:
  - Impacts on fisheries may depend on distinct oceanographic scenarios that could be dominated either by projected changes in southerly and westerly winds, or by changes in the strength of the Agulhas current. However, there are currently no regional oceanographic models at a stage of development that could reliably inform future scenarios for SA marine areas due to climate change. Providing period-specific projections of potential impacts over the short (2025), medium (2050) and longer term (2100) is thus not currently feasible;
  - There is a lack of agreement between trends in inshore water temperature observed *in situ* and remotely from satellites and this limits the development of conclusions about observed trends that are key to projecting impacts on fisheries; and
  - The effects of ocean acidification on fisheries and marine biodiversity remain a poorly quantified risk.

3.5.1.4 Research Theme 4: Biodiversity and Ecosystem Services

The Global Change Grand Challenge National Research Plan (DST, 2010) identifies the following knowledge challenges under the theme '**CONSERVING BIODIVERSITY AND ECOSYSTEM SERVICES**':

- **Savanna ecosystems** – Savannas are globally extensive, important for carbon storage, and sensitive to variation in rainfall.

- **The Southern Ocean** – The oceans south of southern Africa are important in shaping the greenhouse-gas feedbacks that influence global warming. Their other equally important roles – such as modulating albedo – are less well understood.
- **Winter rainfall ecosystems** – Although the winter rainfall region (fynbos and succulent Karoo) occupies less than 10 percent of South Africa, it has one of the richest concentrations of biodiversity anywhere on the planet; ongoing experimental research that addresses important global change questions is needed.
- **Biodiversity based economies** – The challenge is to determine how South Africa can maximise the opportunities provided by its wealth of biodiversity to enhance the well-being of the vulnerable while ensuring the continued survival of this globally significant biodiversity.

Research on the conservation of biodiversity and ecosystem services in South Africa and the region addresses three high level questions:

- Understanding ecosystems and their services – how have the region's ecosystems and the societies that live within and depend upon them evolved; what are the links and what do changes in ecosystems mean for their resident societies?
- Managing ecosystems – what, and how much, needs to be protected where; and how is a continued and equitable supply of ecosystem services to be ensured?
- Ensuring ongoing benefits – what management and governance models would be best suited to the management of the ecosystems and their services; and how can these models be promoted?

The Second National Communication (RSA 2011) identifies the following research needs:

- Further verification and development of modelling methods for assessing risks to biodiversity, especially on endemic species in the winter rainfall biomes – the fynbos and succulent Karoo, and associated adaptation options;
- Monitoring and experimental studies at national and sub-national scale to evaluate future risk;
- More information and capacity for assessing possibilities and effectiveness of ecosystem-based adaptation (using biodiversity in assisting societal adaptation);
- More knowledge of the interactions between climate change and the management of invasive alien species;
- Quantitative and spatially integrated evaluations of future climate change scenarios need to be undertaken in almost all marine systems. This requires production of accurate regional climate models, which adequately consider ocean, atmospheric, and terrestrial influences, as well as the production of reliable regional scenarios; and
- Understanding change in marine and coastal environments and ecosystems.

The National Climate Change Response White Paper (RSA 2011) identifies the following research and knowledge needs:

- Prioritise climate change research into marine and terrestrial biodiversity and ecosystem services, and institute effective monitoring to enhance the understanding and forecasting of critical future threats. Monitoring efforts at national and sub-national scale, supported by experimental studies that quantify future risks to biodiversity and that improve projections of impacts, will help to design and refine adaptation responses.

The draft LTAS Phase 1: Technical Summary (2013) identifies the following future research needs:

- Ongoing research and development of climate change adaptation plans for all biomes (starting in 2014) and ongoing refinement of risk and vulnerability assessments; and for the second and third phases of the Biome Adaptation Framework, where projected changes need to be integrated with spatial data relating to ecosystem services and conservation features that provide climate resilience.
- Changes for the end of this century under an unmitigated emissions scenario require careful consideration and further modelling in order to assess the risks of such a scenario for biodiversity hotspots and biomes; especially those most vulnerable: Grassland; Indian Ocean coastal belt (highest priority for action); Fynbos; Forest (high priority for action); and Nama Karoo, Succulent Karoo (medium priority for action).
- Implementation aspects of the Framework which include strong stakeholder engagement and a focus on implementation at the local level; prioritising multi-beneficial, low-cost approaches (e.g. Ecosystem-based adaptation; biodiversity stewardship etc.) integrating adaptation and mitigation responses; and making use of indigenous knowledge.

Workshop responses suggested more focus on urban ecology and biodiversity research, for example ways in which urban forestry and other vegetation can provide carbon offsets; how urban ecosystems can be managed sustainably and how building innovations can facilitate urban greening. There is also a need to understand urban ecosystems that are adapted to co-existing with human artefacts.

3.5.1.5 Research Theme 5: Climate Change and Health

The NCCRWP (RSA, 2011) suggests the following research and knowledge needs:

- Knowledge of the health risks of high temperatures and appropriate responses including improved ventilation;
- Strengthen information and knowledge of linkages between disease and climate change;
- Develop a health data-capturing system that records data both at spatial and temporal scales and that ensures that information collected can be imported into multiple-risk systems such as the South African Risk and Vulnerability Atlas (SARVA); and
- Improve the knowledge of, and find potential alternatives for bio-safety of the current malaria control strategy. Although the current strategy, which includes the use of the persistent organic pollutant, DDT, has proven effective in reducing the incidence of malaria, there are significant concerns about its long-term impacts on environmental and human health.

The draft LTAS Phase 1: Technical Summary (2013) suggests that research in South Africa is not yet at the stage where climate change impacts on health are well understood or where reliable projections between climate change and health risks and adaptation strategies can be made. There are however, existing models and research that could be used to begin to create projections for some of South Africa's key health risks but not for all. In all cases there are data and research needs. The key research needs include:

- **Heat stress** – Projections of the number of hot days into the future are available. However, an understanding of the relationship between these factors and health in South Africa is

lacking, and the vulnerability factors applicable to the South African population are not well understood.

- **Vector-borne diseases** – Malaria: overall, to characterise the impact of climate change on malaria, projections of non-climatic factors in addition to spatially and temporally resolved climate projections are required. Research is lacking on adaptation strategies that do not use harmful chemicals (e.g. DDT).
- **Food insecurity, hunger and malnutrition** – Projections of malnutrition are not available for South Africa, nor are current climate projections (e.g. heat / rainfall etc.) and projected changes in agricultural yields, being linked to food insecurity, hunger and malnutrition. Such links are not clear.
- **Natural disasters** – Data related to projections of natural disasters is in production. However, links between this data and health risks and impacts is needed in order to project health impacts. Existing surveillance systems, reporting systems, and communication related to natural disasters needs to be improved for improved monitoring, responses and projection of health risks related to CC.
- **Communicable diseases** – Cholera: Health data at high spatial resolution is needed for making environment-health linkages. A vulnerability assessment of communities and socio-economic pathways to cholera is needed. 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.
- **Mental health** – Climate change and weather-related mental health projections are not available for SA, representing a gap in the current body of knowledge.

It was also noted that it is important to include non-climatic factors in projections, as these often play a more important role in the transmission / spread of diseases than climatic factors. Workshop participants agreed that climate change and health risk was under-researched and poorly understood in South Africa. They noted that there was a very poor knowledge base in the country on CC and health, and that there was no cross pollination, with very few collaborative or integrative studies taking place that centre on CC and health.

3.5.1.6 Research Theme 6: SETTLEMENTS (Urban, Rural, Coastal)

The Global Change Grand Challenge National Research Plan (DST 2010) lists the following research and knowledge needs related to the theme "**PLANNING FOR SUSTAINABLE URBAN DEVELOPMENT IN A SOUTH AFRICAN CONTEXT**". From a knowledge needs perspective, it states that:

- The great challenge of 21st-century urban development lies in finding ways for city planning and management to address the needs of urban dwellers in large, rapidly growing, and mainly poor cities, but also to do so in a manner that acknowledges the interdependence of cities and the ecosystems of which they form part, including global regulating services such as climate regulation, and
- The application of the concept of resilience (well developed in ecological studies) to urban social-ecological systems is still immature (both locally and internationally) and the opportunities it presents needs further definition.

Research focus areas / questions defined by the GGCCNRP include:

- What are the factors that would determine urban resilience? Such research should consider the ways in which ecosystem concepts such as diversity, redundancy, vulnerability and ecological variability apply to the urban social-ecological system, and would include biophysical factors as well as social factors such as regulations, values and aspirations.
- How does a city's physical form and infrastructure affect its resilience?
- How can cities, their infrastructure, and the control and management systems that regulate their functions be designed so to improve the resilience of the conurbation?
- What would be appropriate monitoring and assessment tools with which to evaluate a city's ongoing resilience?

The NCCRWP (RSA 2011) broadens the focus to include rural and coastal settlements, and lists the following research and knowledge needs related to urban, rural and coastal settlements:

Human Settlements: URBAN

- Develop 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. Strengthen and enhance decision support tools and systems such as the *Toolkit for Integrated Planning* and develop geographic information systems that include, but not limited to, asset management components for public infrastructure.
- Research, encourage and develop water-sensitive urban design to capture water in the urban landscape and to minimise pollution, erosion and disturbance. Urban infrastructure planning must account for water supply constraints and impacts of extreme weather-related events.
- Acknowledging the current modelling limitations, 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.

Human Settlements: RURAL

- Within the country's research and development system, 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;
- Educate subsistence and small-scale farmers on the potential risks of climate change, and support them to develop adaptation strategies with on-farm demonstration and experimentation (include conservation agriculture practices including water harvesting and crop rotation, and prioritise indigenous knowledge and local adaptive responses);
- Empower local communities, particularly women who are often primary producers, in the process of designing and implementing adaptation strategies; and
- Design and implement economic and livelihood diversification programmes in rural areas.

Human Settlements: COASTAL

- Support ongoing research to determine the impacts of climate change on artisanal fishing communities and livelihoods in coastal areas that are directly connected to coastal and marine resources and identify appropriate responses.

Workshop inputs also highlighted the need for research on carbon sequestration, urban agriculture, biodiversity corridors, and use of urban open space to address the resilience of the city through adaptation and mitigation measures as *a social-ecological system*. There was a strong feeling amongst workshop participants that CCD issues should be dealt with within a social-ecological systems perspective, and not be dealt with as 'separate issues'. Workshop participants also noted that there was a need to take stronger account of the 'blurring' and 'crossovers' that occurred between rural and urban areas within a systems thinking approach.

3.5.1.7 Research theme 7: Disaster and risk reduction

The Global Change Grand Challenge National Research Plan suggests the following research questions under the theme **'THEME: PREPARING FOR RAPID CHANGE AND EXTREME EVENTS'**. It states that research in this theme needs to focus on the areas in South Africa that are most at risk, including – the coastal zone (especially the east and south coast's where most people live); water-stressed ecosystems and regions, where freshwater resources are "over-allocated", and where climate predictions suggest that rainfall will decrease; riparian and other low-lying areas that could be subject to flooding; areas of high fire danger, especially where climate predictions suggest that weather conditions conducive to the spread of veld fires will increase.

Research focus areas / questions:

- Which areas are most at risk from rapidly changing conditions?
- What can be done to avoid, or ameliorate, adverse effects of change?
- How can South Africa's biodiversity – especially threatened, rare, or otherwise important species – be protected from adverse change?

The NCCRP (RSA 2011) suggests the following research and knowledge needs related to this theme.

- Maintain, update and enhance the South African Risk and Vulnerability Atlas (SARVA) as a tool that provinces and municipalities may use to inform their climate change adaptation planning.

3.5.1.8 Research Theme 8: Technology Innovation, Renewable Energy and Waste and Carbon Emissions Reduction

The Global Change Grand Challenge National Research Plan (DST, 2010) includes a theme on 'TECHNOLOGICAL INNOVATION FOR SUSTAINABLE-SOCIAL-ECOLOGICAL SYSTEMS' which addresses the pragmatics of finding new technological pathways that address national strategic priorities and development goals. This calls for "holistic solutions that seek to reconnect the creative processes of humans and nature in technological systems that support the functioning, regeneration and evolution of the global social-ecological system" (DST, 2010). There are three main strands of research that drive this agenda:

- Ecological Engineering;
- Industrial Ecology; and
- Biomimicry.

Research focus areas identified are:

- Ecological engineering / industrial ecology approaches to providing municipal services;
- Developing the management / control systems and business models for such approaches to the provision of municipal services and harvesting of resources; and
- Developing novel 'ecological' technologies, systems of technologies and design solutions that respond to the pressures and problems introduced by global change, especially climate change.

The Global Change Grand Challenge National Research Plan (DST 2010) also includes a theme on '**WASTE MINIMISATION METHODS AND TECHNOLOGIES'**. The LTMS identified the waste sector is a significant contributor to GHG, and identified that a research agenda that aims to improve waste minimisation methods and technologies must address reduction, reuse, recycling and the recovery of waste. Such a research agenda would aim to generate relevant science to inform policy making around waste minimisation methods and technologies.

The following research focus / questions were identified:

- What waste minimisation methods and techniques are currently being applied? Which materials are currently being recycled and in what quantities across the country?
- What are the alternative solutions (policy, economic and technological) for increasing waste minimisation and reuse for priority waste streams (exacerbating climate change, e.g. biodegradable municipal waste)?
- How can new waste minimisation methods and technologies be diffused to different institutions and stakeholders, especially municipalities in South Africa?

The Global Change Grand Challenge also identifies a research theme '**DOING MORE WITH LESS'** that focuses on **decoupling of growth from material resources**. This relates to the flow of materials that are extracted from the earth, processed via production and consumption processes to meet human needs, and then disbursed as wastes generated by the extraction, production and consumption processes. The most important materials extracted for use are biomass, fossil fuels, ores, industrial minerals and construction minerals. Relative and absolute decoupling are possible, with the former more applicable to developing economies, and the latter more applicable to developed economies. Relative decoupling signifies increased efficiencies and resource productivity.

Identified research focus areas in the Global Change Grand Challenge National Research Plan include:

- Quantify the limits to the quantities of materials that can be extracted are, including declines in the quality of deposits and thus the projected increases in costs of extraction;
- Determine the historical patterns of domestic material consumption relative to economic growth as a point of departure for a base-case scenario in terms of what is currently being extracted and used and what is most likely to occur in the future under a "business-as-usual scenario;
- Develop context-specific interventions (policy, technological, institutional, and integrated approaches) that will facilitate the decoupling of economic growth from rates of resource extraction and use (dematerialisation) , including the role that decoupling plays in the overall economic development strategy of reducing dependence on primary production by shifting over to a knowledge economy;

- Provide evidence-based research that will assist policy-makers, businesses and trade unions to understand how it will be possible to dematerialise industrial sector strategies (by making greater use, for example, of cleaner production approaches, life cycle management, zero waste, and resource substitution); and demonstrate, using various modelling techniques, the linkage between decoupling and 'green collar jobs', i.e. jobs that are created through investments that will ensure long-term sustainability and resource security (e.g. public transportation systems that are less dependent on oil, solar energy alternatives for cities, sustainable agricultural production using organic farming techniques, embedded knowledge networks that link R&D generators to SMMEs with respect to sectors like construction, infrastructure, eco-system services, fishing and food processing).

The following research needs have been identified in the SNC (RSA 2011):

- **Clean coal technologies** are under consideration by the South African Government and the coal-mining industry, and Eskom has commissioned an underground coal-gasification pilot plant—both are technology issues identified in the IRP2010 as research and development priorities.
- **Carbon Capture Storage (CCS):** The Long Term Mitigation Scenario (LTMS) identified CCS as a key element in making the clean-coal technologies such as coal gasification climate-friendly There are significant research needs relating to CCS, and challenges regarding implementation at large scale. The largest potential reduction of industrial process emissions is from applying CCS to new coal-to-liquid syn-fuel plants, where approximately half the CO_2 emissions are already in >90 percent concentrated form. South Africa considers only geological carbon storage. Work is underway to produce an atlas of potential storage sites.
- **Biomass** is currently estimated to meet about 8 percent of South Africa's primary energy supply, mainly in rural areas but also produced for own use by pulp mills and sugar refineries—this source is also identified as a research priority in IRP2010. The potential for biomass exploitation and co-generation is substantially higher than current status quo levels. The development of biomass energy is being highlighted in 'Working for Energy' (WfE), South Africa's national renewable energy programme, the purpose of which is to develop and apply practical approaches for sustainable, labour intensive, renewable energy and energy management type projects in rural areas. Research is needed to fully realise this purpose and potential.
- **Wind energy:** South Africa has high potential for solar and wind energy, but so far only between 2 and 5 MW of electricity in the national grid is generated from wind. Wind energy resources of South Africa are estimated by the South African Wind Energy Association (SAWEA) to exceed 30 GW. While South Africa only has 10 MW of installed wind energy capacity at this time, wind energy is projected to contribute 700 MW by 2013 to the 10 000 GWh target stipulated in the White Paper on Renewable Energy (DME 2003b), making this a research and development / new technology development priority for CCD.
- **Solar energy:** Theoretical renewable energy potential in South Africa is vast, with about 280 TW of solar energy typically impinging on South Africa's land surface (Eberhard and Williams 1988)—more than 6 000 times the country's current capacity of 41 GW. Solar photovoltaic panels are widely used in rural areas, with an estimated 70 000 households, 250 clinics, and 2 100 schools employing photovoltaic panels for their energy needs (ERC 2007). Western and north-western parts of South Africa are particularly well-suited to solar energy, due to the high incidence of cloud free days, again making this a research and development / new technology development priority area for CCD.

- **Transport:** Both the Technology Needs Assessment and the LTMS identified the transport sector as one with priority technology research and development needs. Modest improvements in the efficiency of vehicles using conventional (internal combustion) technology would yield substantial emissions reduction relative to the baseline, at a cost saving. Electric, hybrid internal combustion/electric, and hydrogen-fuelled vehicles all deserve consideration. A South African company is developing an electric vehicle, making this an area for joint research and technology development. According to the LTMS, the potential for biofuels is limited. More potential exists in a modal shift in passenger and freight transport (e.g. from road to rail).

Additional to these, workshop participants identified the following research needs:

- Research into **Energy Efficiency** and how it can be maximised;
- The implications of **Hydraulic Fracturing** (especially related to water security and GHGs) needs to be researched.

3.5.1.9 Research Theme 9: Climate Resilient Development / Governance and Sustainability Innovation

The Global Change Grand Challenge National Research Plan (DST 2010) includes research foci that address various aspects of climate resilient development, governance and sustainability innovation research. These are not as prominent in the Second National Communication, nor are they very prominent in the actual NCCRWP, but for the NCCRWP to be implemented, research on innovation for sustainability and climate resilient development will be needed. The Global Change Grand Challenge National Research Plan (DST 2010) outlines the following key knowledge challenges under the theme 'INNOVATION FOR SUSTAINABILITY' and sub-themes: 'DYNAMICS OF TRANSITION AT DIFFERENT SCALES, OPTIONS FOR GREENING THE DEVELOPMENTAL STATE', and 'RESILIENCE AND CAPABILITY':

- The decoupling of economic growth rates from rates of resource consumption (for example, by means of materials and energy flow analysis, calculating South Africa's GDP per capita and Human Development Index, and ecological footprinting);
- Innovation processes and outcomes;
- Institutional innovations for development (that is, modalities of the developmental state);
- The resilience of ecological, social and social-ecological systems (future-proofing, increasing reliance on local resources, autonomism, the role of indigenous knowledge systems); and
- Dynamics of transition at different scales – mechanisms of innovation and learning.

Research questions include:

- Tracking the trends in global change with special reference to innovations that spur and catalyse transitions – What innovations are emerging, how they are being applied, and what kinds of transition are under way? To what extent is "decoupling" happening, with special reference to resource inputs, resource productivity, waste outputs, and the potential for a transition to "non-material" economic growth?
- Tracking emerging trends within the South African context – What relative and absolute decoupling is occurring at a national scale (in terms, for example, of the effect of greener budgets) and at a city–region scale (in terms of, for instance, the effects of improved public transport, energy efficiency, renewable energy, and water re-use)? How is the decoupling

manifesting within production and consumption systems as businesses respond to mounting resource threats combined with government incentives and penalties?

- The dynamics of innovation processes are central to resilience and capability building: How do we determine progress towards creating the most appropriate environment for innovation as a means for building resilience and capabilities for sustainable living?
- Low-carbon, post-oil sustainable national and local economies: What are the various ways and best options, including policy frameworks, available to South Africa, of promoting a developmental state that is committed to a sustainable economy that leads to the eradication of poverty and the resilience of social-ecological systems?

The Second National Communication (RSA 2011a) suggests specific research on

- **Socio-economic impacts and establishing adaptation pathways and practices, including**:
  - Processes of adaptive governance;
  - Effectiveness of institutional arrangements;
  - Social networks and the role of advocacy and information in decision making;
  - Addressing barriers such as: lack of accessible and reliable information, lack of market access, and few social platforms for civil society engagement;
  - Addressing capacity to deal with extreme weather-related events including: pervasive vulnerability, inadequate planning, constrained integrated and spatial development, and poor climate and disaster risk management;
  - Understanding how climate change affects and impacts on assets, abilities and activities of people at household level, and how their response capacity and capability sets can be enhanced and expanded; and
  - Implementation mechanisms and processes associated with mainstream planning of climate responsiveness in urban configurations, the business and energy sector, and the integrated water resources management sector, where good progress has been made on sector wide planning.
- Workshop participants emphasised the need for research on effective and 'good' governance and ethical decision making (at all levels) with potential/real relevance to climate change (responses).
- **Costing Adaptation**: Finding effective ways to cost adaptation, particularly for the future (e.g. planned and/or purposive adaptation).
- **Integrated planning and implementation:** Research into various existing planning and other useful frameworks and legislation and how these can be used to enhance adaptation to climate change without creating new and additional silos of activity. Integrated Environmental Management (IEM) and Environmental Management Frameworks (EMF); the National Environmental Management Act (NEMA, Act no. 107 of 1998); Corporate Social Responsibility (CSR); IWRM; and DRR are examples of such existing frameworks within which a range of choices for adaptation and mitigation can be evaluated. Workshop participants also emphasised the need for research on the efficacy of the legislative framework and its synergies and integration structures.
- **Expanded sector research**: Research is also needed into understanding about existing and future vulnerabilities, and adjustments and adaptation in sectors that have not received adequate attention so far: e.g. **various business sectors;** labour and the trade union sectors, including benefits for labour and in the employment sectors.

- **Role of technologies:** CCD research should include the role of technologies (small and large, soft and hard) in bolstering emerging sectors – To what extent may these technologies become mal-adaptations? How can these technologies become useful and where are the synergies and the trade-offs between adaptation and mitigation using various technologies? (RSA 2011)

Workshop participants pointed out that there was little / no convergence in South Africa on the meaning of the topic of social innovation, and that research was needed to develop the concept in the wider context of CCD. It was noted that there were a number of science-based research programmes focusing on CCD but very few that were focused on social innovation, and it was noted that this issue was under-supported and under-researched in South African CC and sustainable development research more broadly.

3.5.1.10 Research Theme 10: Social networks, social learning and education and training system research

The Global Change Grand Challenge National Research Plan (DST 2010) includes a theme on 'SOCIAL LEARNING FOR SUSTAINABILITY, ADAPTATION, INNOVATION AND RESILIENCE'. It suggests that Learning, and social learning in particular, is at the centre of the successful translation of research results in society. The scientific programmes proposed for climate change adaptation and mitigation, and for social innovation may not achieve what is needed unless the knowledge developed within them can be appropriately translated and taken up in society, hence the significance of an underpinning research theme on social learning for sustainability, adaptation, innovation and resilience. Environment and climate change education trajectories are found both inside, and outside of formal education boundaries, and learning systems for global change responses are being developed in schools, colleges, universities, workplaces, communities, faith based and other community based organisations, and through new media technologies. This indicates that global change learning systems are broad based, and affect all sectors of society. The GCGC NRP suggests that this theme should be 'cross cutting' and should be researched in relation to all other research themes. The GCGC NRP frames the following cross-cutting research question:

> *"What kinds of social learning processes and systems would be most effective for creating or enabling appropriate and effective responses to various societal problems brought about by, or contributing to, global change?"*

The Second National Communication (RSA 2011) notes that this is a relatively under-researched area in South Africa. It points to the following research needs:

- The role of social change support processes such as social networks, education, and adaptation with reference to climate change need to be researched, as does the use and relevance of social networks and social learning for heightened capacity to face climate stresses are of great potential value.
- There is increasing evidence that social networks and social learning within and across such 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 are, however, operating, but remain under-

researched for their capacity to enhance human agency, especially forms of collective agency for change and transformation.

- Research possibilities exist to develop a range of case studies of local social networks and their social learning processes and outcomes, especially for enhancing adaptive capacity at local level, but also at interacting levels, and between different social networks and activity systems.
- Inclusion of various forms of knowledge systems in climate change adaptation and social learning, especially in and for development of early warning systems, where local knowledge indicators could be incorporated in the design and composition of current scientific early warning systems. The links to using such knowledge together with other traditional knowledge sources (e.g. local medicines). Detailed research on this key element has been sporadic and not well co-ordinated.

The NCCRWP (RSA, 2011), and national human capital development planning research conducted by the DEA (2010), SANBI (2010), the DST (2010) and others all point to the fact that there is also a need to strengthen and support:

- **Environmental education and training system research**, focusing on innovation and efficacy of the education and training system and its mechanisms for enabling climate compatible development (e.g. skills planning, supporting graduate transitioning, effective and participatory approaches to teaching and learning, critical thinking etc., content and curriculum coherence, experiential learning approaches). Such research is needed to shift from a *re-active* to a *pro-active and futures oriented* education and training system that aligns with the National Climate Change Response White Paper.
- The **NCCRWP specifically suggests** the establishment of a robust research agenda that, amongst others, focuses on quantitative research on the labour requirements for the green transition as well as on other societal adaptation strategies and needs.
- Other research needs associated with the **mainstreaming of CCD into education policy and practice**, as outlined in the NCCRWP (RSA 2011) includes: research on how to best integrate climate change into all national curricula, including Higher Education, how to strengthen extension training for climate change; how to integrate climate change elements into the National Skills Development Strategy (NSDS IV) and into the Human Resources Development Strategy for the country and into other education and training system policies and practices (e.g. Quality Council for Trade and Occupations (QCTO) occupational qualifications; national systems of assessment etc.).

Workshop participants noted that there was a strong need for environmental education and training research that dealt with the following issues:

- CCD methodologies and content i.e. a ‘new’ field, and how it should be ‘integrated’ and be dealt with on top of existing packed curricula;
- Conceptualisation of the ‘layers of learning’ involved in CCD needs to be researched, and outlined in a coherent manner – starting at school level all the way through to university, ensuring coherence and progression of concepts, knowledge and systems thinking throughout the education and training system;
- Mainstreaming community engagement and input into what is being taught in university curricula in ways that strengthen CCD knowledge and practice;
- How to bridge the gap between knowledge and practice;

- Educational policy research that deals with the need to mainstream CCD into education policy and practice at all levels of the education and training system;
- Research on the conceptual 'legacies' of existing development trajectories, and how these should be changed / re-oriented for CCD (social, economic, environmental); and
- There is a need for research that integrates social and natural sciences and that transgresses the boundaries that have been historically structured and embedded in education and training institutions.

3.5.1.11 Research Theme 11: Complex social-ecological systems research

In addition to the research themes 1-10 that could be distilled from existing documentation, workshop participants also noted:

- A **strong 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 CCD* in Southern Africa. This was also related to a call for a stronger framework to guide **system-based transitioning** from one development paradigm to another.
- A need to focus on **stronger synchronisation between indigenous knowledge and climate science**, as this lack of synergy "*makes climate science very unfamiliar to local communities".*

Research themes 1-11 above offers some indication of where the major needs are, all of which are of relevance to the implementation of the 2011 National Climate Change Response White Paper. Many of the CCD needs for adaptation and mitigation, as well as the associated knowledge needs are highly reliant on research and knowledge (co) production processes, and it would be important that the diversity of these knowledge needs should be well articulated in policy, national research planning and practice at a suitable level of detail and consistency, and that appropriate research questions and approaches are applied in response to these knowledge needs. The analysis above also offers an 'update' on some of the research themes of the Global Change Grand Challenge National Research Plan (released by the DST in 2010), and shows how within the CCD arena, new research themes, nuanced perspectives and issues are being identified as knowledge of CC and CCD related concerns emerge and become more sophisticated.

A further part of addressing the process question related to CCD policy implementation is an analysis of individual and institutional capacity gaps, which are addressed in the following two sections.

3.5.2 Needs analysis: Individual capacity gaps

One of the key individual capacity gaps that was repeatedly emphasised – in documents, as well as in workshops, and in questionnaire data is the need for **integrative, complex systems thinking** and **cross-scale thinking in between and across all disciplines and sectors.** The DEA (2010) study on scarce and critical skills in the environmental sector also listed **leadership skills,** and **sustainable development planning skills** as being cross-cutting skills that were required in all sub-sectors, including CCD.

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**. It identifies the following individual 'core disciplinary skills' that are needed to address fundamental Earth System

questions, including the analysis of the human subsystems coupled to the biosphere as follows (in alphabetical order):

- Biogeography and evolution;
- Climatology and climate modelling;
- Development studies;
- Disturbance, population and dispersal ecology;
- Ecophysiology, both terrestrial and marine, and of both plants and animals;
- Environmental history, particularly over the past 300 years;
- Human demography;
- Geomorphology;
- Hydrology;
- Palaeoecology and paleoclimatology, including palynology;
- Physical and biological oceanography;
- Resource and environmental economics;
- Social anthropology and sociology; and
- Systems ecology and biogeochemistry.

Additionally various human capital development studies in the environmental sector (DEA, 2010; DST 2010; SANBI/Lewis 2010; DWA 2010) have identified **leadership skills, sustainable development planning skills, hydrological, engineering** and **technical skills, a variety of specialist scientific skills,** and **environmental education and training skills as being 'scarce'**. The following individual skills gaps / scarce skills, most of which are related to CCD in some way or other are also identified in these skills planning initiatives:

- Environmental Engineers;
- Environmental Scientists;
- Environmental Educators and Trainers (especially with SD/CCD knowledge and expertise);
- Resource Economists;
- Waste researchers and scientists;
- Toxicologists;
- Soil Geochemists;
- Remediation specialists and Landfill designers;
- Environmental science technicians;
- Waste recyclers;
- Air quality and air pollution specialists;
- Engineers (water; environmental; renewable energy);
- Nanotechnologists;
- Space Scientists;
- Climatologists;
- Astronomers;
- Long term modellers;
- Climate change risk assessors;
- Inspectors;
- Hydrologists;
- Entomologists;
- Clean technology development specialists;
- Green building specialists and building control officers;

- Sustainable development planners;
- Control and compliance officers;
- Social scientists;
- Taxonomists;
- Soil Scientists; and
- Curators.

In general there was agreement that all of these scarce skill areas need to be more accurately quantified with more accurate labour market analysis tools. Labour market analysis is notoriously weak in South Africa, and accurate analysis of scarce skills has been on the DHET agenda for some time. Recently a Labour Market Intelligence Research Project has been set up by the DHET to establish methodologies for more accurately conducting labour market studies (DHET 2013). However, environmental sector skills studies have shown that environment, CCD and sustainable development knowledge skills and labour market analysis involves a complex mix of: identifying scarcity in specific occupations, integration of sustainable development knowledge and skills into a range of existing occupations, as well as construction and emergence of new occupations. This makes labour market analysis for new areas such as sustainable development or climate compatible development extremely difficult, as data extracted from the 2012-2013 Scarce Skills List (compiled from composite SETA Sector Skills Plans; see Appendix F) shows.

The list above (together with the rough quantifications shown in Appendix F shows an overall scarcity of key occupations that are related to climate compatible development in South Africa. The list is not comprehensive, but is rather indicative of an overall shortage of skills for sustainable development / climate compatible development in South Africa. The DEA, in the workshop, emphasised the need for a strong skills development programme for CCD as there is a "change of scale of innovation needed" that requires "new technologies, new finance flows, **a new skills base** which is both multi-disciplinary and sector based".

Besides the individual capacity gaps identified above, workshop and questionnaire data repeatedly emphasised the need for capacity development in government (especially also at local government level) for:

- CCD and sustainable development **planning;**
- **Informed decision making;**
- Capacity development for **policy implementation;**
- Capacity development for **risk and vulnerability assessment and analysis**; and
- Capacity development for using **climate models and climate data** for decision making.

Workshop participants made some suggestions on how some of the individual capacity gaps at local government level could be dealt with, for example, through:

- Continued promotion of the development of Risk and Vulnerability Service Centres at universities, which will, in turn, support resource-constrained municipalities;
- Design of training programmes that could facilitate increased use of seasonal climate forecasts among key stakeholders such as those in the water and agricultural sectors; and
- Collaboration with social networks such as community organisations, non-governmental organisations (NGOs), women and farmers' organisations, and the Adaptation Network to help raise awareness and to transfer technology and build capacity.

3.5.3 Needs analysis: Institutional capacity gaps

In the course of this analysis, the following major institutional capacity gaps were identified that influence climate compatible development in South Africa.

Key to these, is the recognition in the National Climate Change Response White Paper that the institutional infrastructure for science and technology, and for Education Development in South Africa is currently inadequate for building a climate resilient future.

The NCCRWP makes the following commitment to Science and Technology Development (RSA 2011):

An analysis of the state of climate change science and technology reveals that **the current scientific output, technology development, intellectual property and the pool of high level skills** are **inadequate** to support a robust climate change response. Because the response to climate change is so complex, Government and the scientific community will conduct a climate change foresight exercise. Such an exercise will deliver the following:

- A **human capital development plan for climate science and technology** informed by the country's climate change response requirements and the outcomes of the National Employment Vulnerability Baseline and Assessments as well as the Sector Jobs Resilience Plan;
- A complementary **science and technology plan for climate change** in partnership with the Department of Science and Technology (DST); and
- A **climate change technology roadmap**.

To address the **funding** needed to support climate change research and development, the DST will conduct a feasibility study into the development of **a specialised funding agency: the Climate Change Science Council**. In parallel to this study, the DEA will engage the relevant partners in the DST, National Research Foundation (NRF), the Technology Innovation Agency and the DTI to develop the following R&D funding instruments:

- Climate Change Research Chairs in the family of the DST/NRF South African Research Chairs Initiative;
- 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 to develop much higher levels of climate change science and produce more PhDs and postdoctoral fellows in this area and to develop intellectual property and technologies that will make South Africa a global leader in climate change science; and
- Research and innovation partnerships in the area of climate change resilience.

Technology transfer

- Technology transfer continues to be very prominent in the multilateral environmental agreements in general, and in climate change-related agreements in particular. A national capacity to optimally engage climate change-related technology for South Africa, both as a recipient as well as donor to other developing countries, will be developed (RSA 2011).

The National Climate Change Response White Paper South Africa (RSA 2011) also sets out a strategy for Education, and for Science and Technology Development, noting 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. This will require* ***systematic interventions to empower and capacitate people****. We need to mainstream climate change knowledge into education and training curricula. Climate change education should be part of the broader framework of education for sustainable development, and should equip South African citizens to re-orient society towards social, economic and ecological sustainability. "*

To meet this challenge, South Africa will:

- Ensure that a holistic understanding of climate change and related issues (specifically the required response to climate change) is **included in all relevant aspects of formal education curricula**. This will prepare future generations for a rapidly changing planet and the transition to a lower-carbon society and economy.
- Include climate change elements in the **review of the National Skills Development Strategy** 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**. This will be accompanied by requisite resource reallocation.
- Establish **incentives for research and training** such as bursaries to encourage students and scholars to research and study climate change.
- Ensure that the building of knowledge and expertise in new and emerging economic sectors is considered in all **tertiary education curricula and relevant formal and informal training**.
- Establish a **robust research agenda that**, amongst others, focuses on quantitative research on the labour requirements for the green transition as well as on other societal adaptation strategies and needs.
- **Encourage tertiary and research institutions to develop national monitoring, reporting and verification guidelines for a climate-resilient South Africa**. These guidelines would focus on mitigation and adaptation actions such as land-use practices and change. (RSA 2011)

Additional to the above key institutional foci on **SCIENCE AND TECHNOLOGY DEVELOPMENT** and **EDUCATION SYSTEM DEVELOPMENT**, the following institutional capacity gaps were identified in the Second National Communication (RSA 2011a) and other relevant documentation. In some cases they relate to the priorities for Science and Technology Development and Education System Development as outlined above, but also include institutional capacity gaps related to POLICY SYSTEM INTEGRATION AND EFFICACY.

3.5.3.1 *Science and technology development:*

- **Scientific infrastructure:** In order for SA to succeed in meeting its scientific objectives there are a number of prerequisites which are state-of-the-art infrastructure, modern laboratories and research institutes and an NSI that is linked to the global scientific community and appropriate funding agencies. This also requires maximisation of existing international collaborations. Agriculture researchers attending the workshop for example indicated that they lack equipment and facilities to study the impact of CC on crops, grasses (feedstock), and for researching methane production by animals for modelling. They also lacked the necessary micro-climate weather data for crop management, and lamented the fact that there were few weather stations in the country.
- **Research funding and research system fragmentation:** It was noted in the workshop that there were serious problems with research funding fragmentation in the research funding system. It was noted that funding normally came in "small amounts, with short time frames, no carry-over, and no links to academic cycles". The tendency is to fund a number of small, independent projects with budgets of about ZAR 3 million, which is not an adequate mechanism for funding integrated, social-ecological systems research programmes that require multi-disciplinarily, and longer term research engagement. There was also little money for physical experiments (e.g. technology and pilot projects for human settlement research requires tens of millions). This has the perverse effect of research fragmentation and a lack of critical mass; substantive research outputs and coherent, longer term research trajectories and knowledge production. There was an additional problem in that most research funding is limited to South African students; which reduces opportunities for southern African knowledge integration and co-production. Bursary funding for South African students is also inadequate at all levels (honours, masters, PhD and postdoctoral), and research supervisors and/or students are forced to 'double fundraise' to keep good students involved in research programmes; this wastes time that could be spent on research supervision, and/or research / knowledge production. It was noted in the workshop that

  > *"Compromising the ability of researchers to respond to CCD challenges is also the fragmentation and disconnection of the basic research infrastructure in the described fields of study in South Africa's research councils, universities and research-orientated NGOs".*

  The Global Change Grand Challenge National Research Plan indicates that "Knowledge-bridging institutions and a centre of focus are required to foster collaboration among leading researchers working in energy, water, sanitation, waste, soils/food, ecosystem services, industrial design and construction in the following broad research sectors: applied engineering, economics, social sciences, ecology, life sciences, institutional development (public and private sector management) and development studies". Such knowledge-bridging institutions for these aspects of CCD are yet to materialise.

- **Observation capacity needs:** The SNC (2011) reports that in South Africa, a key challenge is the lack of permanent observation and monitoring sites, and the sub-optimal size of sites that are used. Furthermore, arid and semi-arid areas, forest and woodlands, mountains, agro-ecosystems, and rural areas are under-represented in the monitoring network, despite the fact that they are likely to be affected earliest and most severely by climate change. There is a clear need for an integrated system of adequately sized and equipped permanent

observation and monitoring sites that cover all biomes and ecoregions throughout the country. It was noted too that the data currently obtained tends to be one-dimensional, or monitored at limited spatial scales, preventing the formulation of a complete picture. Additionally, some programmes lack laboratory infrastructure and modern equipment. Furthermore, information management is weak in most programmes, and non-existent in some. The needs in terms of infrastructure include suites of *in situ* sampling, observation and monitoring systems, and remote sensing imagery and imaging devices. Other needs include state-of-the-art data processing and analysis hardware and software, relevant laboratory space and equipment, as well as robust and accessible information management systems. Systematic observation and monitoring programmes also experience funding challenges. Human capacity is also a related need, and there is need for suitably qualified personnel to collect data, operate the relevant instrumentations, process and analyse data, and communicate results (SNC 2011).

- **System integration for early warning systems:** The SNC (RSA 2011) notes that climate change and DRR activities could be better aligned through early warning systems and planning.
- **Climate change technology needs of South Africa:** In terms of climate change, technology transfer includes the 'hard issues' of accessing technology and the skills and capabilities necessary to use it, and the 'soft issues' that are associated with its adoption or non-adoption. The LTMS identifies institutional capacity needs in the following four areas (SBT 2007: 21–23):
  - Support for South Africa's efforts to make a just transition to a low-carbon economy;
  - Positive incentives for people-oriented measures;
  - Assistance in searching for lower-carbon resources; and
  - New technology through joint development and transfer.

The extent to which these actions will be implemented depends on the provision of financial resources, the transfer of technology, and capacity building support by developed countries (RSA 2010).

3.5.3.2 *Education system development*

- **Supervision capacity:** Human capital development planning and strategy development in the environment and global change sectors all point to a lack of adequate and expanding supervision capacity in South Africa. This was repeatedly mentioned in the workshop by different groups; and has also been noted in national and programme documents, such as the ACCESS programme documents. This has the adverse effect of leading to stasis of graduates at postgraduate level. Supervisors are expected to 'absorb more students' without adequate support for enhanced and expanded supervision roles and/or capacity building for new research supervisors. Workshop participants particularly emphasised the need for supervision capacity building in multi, inter- and transdisciplinary approaches to research. It was also noted that this issue was exacerbated by inequalities that persist in the South African Higher Education system. The SARCHI Chairs initiative aims to address this, but according to ACCESS (in their project document), this system of creating 'self organising discipline specific specialist entities' may not address the fundamental challenges in the 'hetrogeneous academic system'.

- **Weak education foundations and teacher knowledge:** The weak education foundations laid in the formal schooling sector have a knock-on effect into higher education, especially in the Science, Maths and Technology disciplines, but also in other areas such as career guidance, life skills and general writing and reporting capacity amongst students. Added to this is a finding in the UNESCO South Africa case study on climate change education[13] that the environmental foundations of learning as currently represented in the national Curriculum and Assessment Policy Statement (DBE 2012), are fragmented, and lack conceptual and progression of learning coherence. It was noted in the workshop that "Educators (school, college and university educators) are not skilled/trained in climate change 'teaching/training"' and there was need for teacher education and professional development of academics in this area. There was also a need to bridge the gap between theory and practice in educational programmes.
- **Poor career guidance:** Inadequate attention is given to career guidance of students in universities, and transitioning of students from especially first degree, to honours degree, to masters degree levels, and bursaries are inadequate to attract full time South African postgraduate scholars. The SANBI/Lewis (2010) and DEA (2010) studies both found that almost no environment related career guidance was on offer in South African universities.
- **Attraction of postgraduates and postdoctoral scholars**: The human capital development strategies produced by DEA, SANBI/Lewis all show that there is difficulty to attract postgraduates and postdoctoral scholars to the global change research field due to a mix of factors: inadequate scholarships and bursaries, poor quality maths and science backgrounds, and lack of co-ordination of postdoctoral scholarly opportunities in the sector. It was also noted in the workshop that there was need to give attention to the 'pipeline' for capacity development and attraction of students and research staff, from undergraduate, through postgraduate and into research careers.

3.5.3.3 *Policy integration and efficacy*

- **Cross-sectoral collaboration:** There is need to develop collaboration across formal, 'state' driven institutions, and more informal, or 'community-linked' institutions. Climate change is a multi-dimensional issue and will require adaptation inputs from both the state and non-state actors, and would benefit from integration across various government departments and between actors at various levels of governance. Current institutional patterns show a lack of adequate co-operation between mitigation and adaptation programmes, and between different types of stakeholders in the system (SNC 2011).
- **Policy complexity and policy synergy:** The SNC (2011) states that multiple policies and other requirements (e.g. disaster risk reduction and various disaster management plans; integrated water resource management; Integrated Development Planning (IDP)) as well as outcomes and plans related to the National Development Plan (Vision 2030), may overload formal administrative capacity and compromise active policy implementation. Finding ways to 'mainstream' climate change and such activities may result in some reduction of such burdens (SNC 2011). Workshop participants also emphasised the need to streamline policy

[13] Lotz-Sisitka, H. And C. Mandikonza. 2013. *Climate Change Education in South Africa. A national case study*. Paris: UNESCO.

and research policy coherence, and reduce duplication while encouraging multi-sectoral engagements. The DEA noted during the workshop that a **key issue** was to organise and seek to achieve coherence amongst the many different projects and programmes that were underway. The DEA is in the process of creating the framework around which existing programmes can start cohering. Adaptation should cohere around a single set of adaptation scenarios whilst mitigation should cohere around a single set of emissions outcomes. It was noted in the workshop too that education policies are not mainstreaming climate change, even though it is a policy intention in the National Climate Change Response White Paper (RSA 2013). Closer engagement between government sectors on this issue is urgently needed, as was also found in the 2013 UNESCO case study on climate change education in South Africa.

- **Practical mandates, understandings and outcomes:** The SNC (2011) reports that one of the persistent challenges emerging from much of the adaptation work to date is assigning practical responsibilities and mandates for mobilising and shaping adaptation and mitigation efforts. Greater understanding of climate change and climate compatible development pathways and practical responses are needed at all levels of government and amongst stakeholders to ensure that CCD is seen as part of mainstream development solutions at the national and local levels (SNC 2011). The workshop presentation by the DEA also noted that there is a need for more systematic approaches to monitoring and evaluation. It was noted that South Africa was generally good at putting pilot projects in place, but that we were NOT good at building basic systems of Monitoring and Evaluation related to outcomes and impacts. This was noted as a critical area for research and development. The DEA presented the following framework for Monitoring and Evaluation at the workshop.

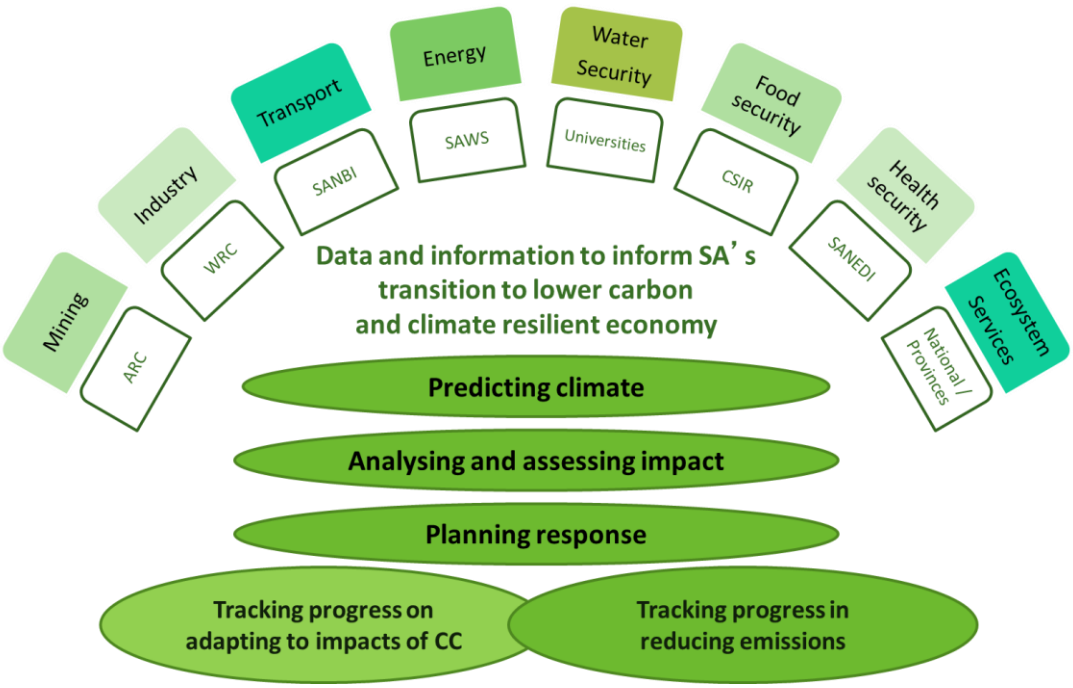


Figure 9: Climate Change Response Monitoring and Evaluation System

Source: Beaumont, SARUA workshop presentation, 21 August 2013.

- **Sustainable development, integrative and adaptive planning capacity**: Current approaches to sustainable, integrative and adaptive approaches to planning are generally weak across institutional levels, and between institutions. This issue has been repeatedly noted, and was also mentioned a few times in the workshop. In particular, the workshop raised issues about urban planning which only happens at scales where early intervention is not possible and that there is little planning capacity in small towns and secondary cities to deal with adaptation, an issue that was exacerbated by ineffectiveness in service delivery.
- **Dynamic organisations and leadership:** Climate compatible development will require dynamic, integrative organisations. Currently many of South Africa's major institutions are characterised by skills shortages, inadequate skills and capacity development planning, poor mentoring systems, general inertia and a lack of dynamism. The SNC (RSA 2011) states that research in the water sector shows that climate change adaptation planning requires dynamic organisations that are well-informed and offer leadership that can create effective strategies when adjusting to changing circumstances and that successful uptake of new information must usually be internally coherent (across sectors and between government levels), as well as externally coherent (stakeholders using and impacting water directly and indirectly. The DEA ESSP (2010) noted that there was a need to strengthen leadership for environment and sustainable development, including climate change and climate compatible development in South Africa.
- **Transition thinking and practice:** The workshop raised the issue of transition thinking and practice. The DEA presentation at the workshop indicated that transition from existing high carbon emissions development path to a low carbon development path would require the following institutional capacity development processes: policy instruments to ensure coherence and synergy; strengthened institutional arrangements; a new generation of funding instruments; an evolving set of skills to support emerging green sectors; a strong science and technology platform (that does not ignore social science aspects but rather integrates them); strong conceptualisations of a southern African response to CC; effective information and knowledge management for decision making at all levels (e.g. farmers, health workers, policy makers); cross sectoral and multidisciplinary research. It was noted that the work of SARUA was 'spot on' in this respect. In this regard Dr Beaumont noted that:

> *"A transition generates vast research needs; it is difficult to present them in the cross cutting manner that is needed."*

Workshop data also showed that transition thinking is hampered by current knowledge 'silos' and a lack of attention to systems thinking in climate teaching.

- **Knowledge management and knowledge sharing**: The DEA presentation at the SARUA workshop also raised the issue of knowledge management. Dr Beaumont's presentation indicated that there are a number of questions that need to be addressed in ensuring coherent knowledge and information management for CCD in South Africa which include:
  - What are the data and information needs … by different stakeholders, in different sectors, in spheres and tiers?
  - What data is being generated?
  - Who are the users?
  - Where is the data / information located?
  - Are there gaps?

- What are the information channels … how it gets to the users?
- What partnerships are needed to most effectively convert data into information……and to inform decision-making?
- What is the definition of "climate services" in the South African context?

Workshop participants also commented on knowledge management and information sharing issues, and noted that "the tertiary education sector needs to assist in the design of climate change knowledge transfer at different levels and in different contexts" and that "scientific knowledge needs to be translated to practical implementation, communicating research message from scientists to government officials and citizens". There was also a sense that researchers should carry some responsibility for generating and disseminating knowledge in a way that suitably captures real societal issues, and that research should be "translated" into digestible messages.

4 INSTITUTIONAL ANALYSIS

4.1 Introducing the institutional analysis

This section describes the current responses of different institutions (higher education, government, NGO/CBO, private sector) to addressing climate change and promoting CCD, within the broad context of the above-mentioned research, knowledge and capacity gaps. Core emphasis is placed on higher education institutions, as it is widely recognised that they have an important role to play in research, education and training, and in providing policy and strategy support and leadership for development.

The institutional review begins by mentioning wider institutional arrangements for addressing climate change and moving towards CCD, and any relevant research and development frameworks. It then goes on to discuss some of the current climate change and CCD initiatives and programmes that are taking place in South Africa, and identifies some of key stakeholders that could form part of South Africa's CCD knowledge co-production framework.

Following that, it examines understandings of CCD amongst stakeholders and university staff, and then begins to probe research practice and capacity, as well as curriculum, teaching and learning programmes and capacity in the higher education sector, although in the South African this aspect is not strongly developed due to the scope of the CCD research currently being undertaken. It was not possible to conduct an in-depth assessment of curriculum and CCD related issues in the South African context (see limitations of the study); the emphasis is therefore mainly on information related to Masters degrees, and a broad understanding that CCD programmes are also required in undergraduate programmes. From there, it also considers other aspects of higher education interaction with climate change and CCD, namely community engagement, student involvement, policy engagement and campus sustainability initiatives, where such information was available. A full analysis of the scope of activities associated with these areas lay outside of the scope of this mapping study.

4.2 Policy and institutional arrangements

4.2.1 Policy and institutional arrangements governing Higher Education in South Africa[14]

The South African higher education sector falls under the Department of Higher Education and Training (DHET). The DHET was formed when the then National Department of Education (DoE) was split into the Department of Basic Education (DBE) and the DHET. South Africa has a plethora of policies and legislation governing higher education. In the period immediately following the 1994 elections there was an extensive, participatory drive to formulate new policies that explicitly broke

[14] This text is a summary of drawn from SARUA Country Profiles (Fongwa, www.sarua.org/files/country reports) and aspects of the section on Higher Education in the most recent Department of Higher Education and Training Policy (2013) entitled the 'White Paper for Post-Schooling Education and Training' (PSE&T).

with the apartheid past. Key policy governing Higher Education includes the 1997 White Paper 3 (A Programme for Higher Education Transformation) which was legally formalised in the Higher Education Act No. 101 of 1997. The 2001 National Plan for Higher Education (NPHE) took the legislative process one step further by outlining the framework and mechanisms through which the policy goals and transformation imperatives of the White Paper and the Higher Education Act could be implemented.

More recently, the DHET has released the White Paper Post-School Education and Training which sets out to provide a vision for the post-schooling system in the country (DHET 2013). Besides the DHET as the body responsible for higher education in South Africa, there are other statutory institutions with various responsibilities, all of which aim to improve the higher education system and report in one way or another to the DHET. These include:

- The Council on Higher Education (CHE): As already mentioned, the CHE advises the minister on the state of higher education policy formulation, and enhances the development of higher education through scholarly engagement at various levels. The Higher Education Quality Committee (HEQC) of the CHE conducts audits of universities against a range of institutional criteria and external peer review. The HEQC also governs the process of course accreditation with the help of the national qualifications framework (SAQA).
- Higher Education South Africa (HESA): HESA is the leadership body that represents the 23 public higher education institutions. Led by the vice-chancellors of the universities, HESA acts to support and advance the higher education sector in South Africa.
- The South Africa Qualification Authority (SAQA): SAQA was established via SAQA Act No. 58 of 1995. Under this act, SAQA seeks to uphold the underlying regulations ensuring access, quality and redress for all learners as stipulated in the National Qualifications Framework, through an integrated national framework responsible for credit accumulation and transfer.

The South African National Development Plan Vision 2030 (RSA 2011) outlines three main functions of universities in South Africa: education of the person, and education for the labour market; knowledge production; and provision of opportunities for social mobility, social justice and democracy. Policy changes introduced by the White Paper on PSE&T (DHET 2013) include indications of how growth, quality improvement, equity and better articulation will be addressed. In this policy, universities are seen as 'crucial institutions' with an important role to play in achieving national development objectives, a role which "includes supporting the rest of the post-school system and aligning curricula and research agendas to helping to meet national objectives, including tackling the challenges of poverty, unemployment and inequality".

There have been many changes to the South African university landscape since 1994. Via a series of mergers and incorporations, South Africa now has 23 public universities. These comprise eleven "traditional" universities, six universities of technology (what used to be known as technikons) and six comprehensive universities (that combine the functions of traditional universities and universities of technology). There are also two institutes of higher education in Northern Cape and Mpumalanga; they serve as administrative hubs, co-ordinating higher education provision in these provinces through partnerships with universities elsewhere. Two new universities, in Kimberley and Mbombela, will start offering programmes from 2014 (DHET 2013).

The DHET (2013) report that the 2011 student head-count for the 23 universities was 937 455, which includes full-time and part-time enrolments. This represents nearly a doubling from 1994, when the head-count was 495 356. Almost 60 percent of students were engaged in contact-based study, with the remainder enrolled in distance education, mainly at the University of South Africa (Unisa). In 2011, 82 percent of the total head-count enrolment was at undergraduate level, 5 percent at Masters level and just over 1 percent at PhD level; the remainder were engaged in Honours and postgraduate diploma studies or were occasional students. Head-count enrolments for Science, Engineering and Technology (SET) have grown substantially, from 160 802 students in 2000 to 263 721 in 2011, as have annual graduation rates. The number of SET graduates as a percentage of total graduates has risen marginally, from 27 percent in 2000 to 29 percent in 2011. The DHET (2013) reports that "Despite these achievements, South Africa is still not producing enough SET graduates to meet its economic development objectives". It also reports that recent studies have reported a loss of status of the humanities and social sciences and the White Paper on PSE&T (DHET) recommends establishment of a National Institute of Social Sciences to address the loss of strength in the social sciences.

The South African university sector is also diverse, with differentiation being linked to both historical legacies and recent policy that differentiated between traditional universities, universities of technology and comprehensive universities. Differences in university missions and curriculum offerings have been partly the result of government policy and partly the result of the individual decisions of institutions and the resources they have been able to acquire from government or elsewhere.

The DHET (2013) reports that expansion will not be a major policy driver in the next term, but rather efforts will go into improving quality and building appropriate diversity within the sector. It also sees a closer link between universities and other post-schooling institutions. It also proposes better co-ordination and alignment between DHET and the Department of Science and Technology (DST) in the area of research funding and development, and states that priorities will be addressing South Africa's scarce and critical skills. It furthermore suggests that curriculum development initiatives are needed to strengthen improved success and graduation rates, distance education modalities, and that teaching skills of academic staff need to be supported by appropriate professional development. Community engagement is also a recognised feature of Higher Education Practice.

4.2.2 Policy context for climate change

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 as the basis for a global multilateral response to the threat of human caused (anthropogenic) climate change. The government of the Republic of South Africa signed the convention in June 1993, and ratified it in August 1997. In 2004, South Africa submitted its Initial National Communication in accordance with Article 12 of the convention, and in 2011 it submitted the Second National Communication. Although the National Climate Change Response Strategy (NCCRS) for South Africa, published in September 2004, was the government's first formal provision of policy direction for national climate change responses, this strategy was developed in the context of the policies in place at the time and not within the context of a specific climate change policy. From 2006, government also undertook two significant studies to address climate change in South Africa: the Long-Term Mitigation Scenarios (LTMS) (ERC 2007, RSA 2007, SBT 2007, ERC 2007) and a Technology Needs

Assessment (TNA) (DST 2007). Cabinet considered the LTMS outcomes in 2008, and agreed on a strategic direction: the country's GHG emissions must peak, at the latest by 2020–2025, stabilise for up to ten years, and then decline in absolute terms. The LTMS is one of the key documents on which national climate policy and strategies are based.

In October 2011, the National Climate Change Response White Paper (RSA 2011) was released. South Africa's response to climate change has two objectives:

- Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity; and
- Make a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner. (RSA 2011)

In terms of **adaptation,** the policy identifies the following sectors as priorities for the immediate future: water, agriculture and forestry, health, biodiversity and human settlements. Resilience to climate variability and climate change-related extreme weather events will be the basis for South Africa's future approach to disaster management and we will use region-wide approaches where appropriate. South Africa's approach to **mitigation** balances the country's efforts to curb global emissions with economic and social opportunities presented by the transition to a lower-carbon economy as well as with the requirement that the country successfully tackles the development challenges facing it.

The White Paper sets out the following strategic priorities:

- **Risk reduction and management** – prioritise near-term adaptation interventions that address immediate and observed threats to the economy, ecosystem services and the health and well-being of South Africans while researching and developing short-, medium- and longer-term climate resilience, risk and vulnerability management policies and measures.
- **Mitigation actions with significant outcomes** – prioritise cost effective and beneficial mitigation policies, measures and interventions that significantly contribute to the country's deviation from the GHG emission "business as usual trajectory" as measured against a benchmark "peak, plateau and decline" GHG emission trajectory where GHG emissions peak between 2020 and 2025, plateau for approximately a decade and begin declining in absolute terms thereafter.
- **Sectoral responses** – prioritise, in accordance with the provisions of this policy, the requirement for all key actors, organisations or participants in relevant sectors or sub-sectors to prepare, submit, implement, monitor and report the implementation of detailed climate change response strategies and action plans that clearly articulate their roles, responsibilities, policies, measures, and interventions or actions to contribute to the achievement of the National Climate Change Response Objective in a measurable way.
- **Policy and regulatory alignment** – firstly, 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. Secondly, review existing national policies, legislation or strategies, with a view to optimising and maximising the climate change co-

benefits of their interventions. Thirdly, integrate into the relevant existing or new policies, legislation or strategies those climate change response interventions that stimulate new economic activities as well as those that improve the efficiency and competitive advantage of existing activities.

- **Integrated planning** – prioritise the mainstreaming of climate change considerations and responses into all relevant sector, national, provincial and local planning regimes such as, but not limited to, the Industrial Policy Action Plan, Integrated Resource Plan for Electricity Generation, Provincial Growth and Development Plans, and Integrated Development Plans.
- **Informed decision-making and planning** – prioritise research, systemic 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 the environment.
- **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 sub-sectors.
- **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.
- **Behaviour change through choice** – prioritise education, training and public awareness programmes to build the general public's awareness of climate change so as to empower all South Africans to make informed choices that contribute to an economy and society that is resilient to climate change.
- **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, including, but not limited to, public and private financial resources, incentives, non-market and market-based instruments, technical cooperation and partnership agreements, and technology transfers at domestic, sub-regional, regional, and international levels. (RSA 2011: 13-14)

Policy is supported by ongoing research. Most recently, the Long Term Adaptation Adaptation Scenarios (LTAS) Programme, a research programme under the Adaptation Flagship of the National Climate Change Response Policy White Paper has produced a draft of the first phase technical report (June 2013).

4.2.3 Institutional arrangements for climate change

South Africa has a multi-stakeholder National Committee on Climate Change (NCCC) which is responsible for climate change policy development. The committee is chaired by the Department of Environmental Affairs (DEA) and has representation from seven other government departments as well as from provincial government representatives, research institutes, private sector, labour and NGOs. The next layer is that of the Intergovernmental Committee on Climate Change (IGCCC), which is inter-ministerial involving ten government departments. It exists to facilitate policy development and implementation. DEA is the lead department for directing and coordinating the national climate change response programme and hosts the NCCC and the IGCCC. The Department of Science and Technology provides leadership on global change and energy science and technology innovation while the South African National Biodiversity Institute is responsible for coordinating measures that

respond to the science and technology needs of various climate change interventions in South Africa according to the Climate Change Adaptation and Preparedness in South Africa report (2010). Other relevant multi-stakeholder groups identified by the Environment Sector Research, Development and Evidence Framework (2012) are: Thematic Forums; and the Multi-sectoral Forum. DEA has an Internal Coordinating Forum.

The development of the NCCRWP, GHG mitigation, and climate change adaptation related actions are specifically included in the President's list of service delivery agreements with Cabinet Ministers. This facilitates the process of regular reporting and monitoring of progress against the agreed climate change outputs. In order to facilitate co-operative governance in the area of climate change, the Intergovernmental Committee on Climate Change (IGCCC) fosters the exchange of information, consultation, agreement, assistance, and support among the spheres of government with respect to climate change, and facilitates the policy development process and its implementation. The IGCCC serves as the 'delivery forum' for the President's climate change outputs.

The National Climate Change Response White Paper (RSA 2011) proposes an institutional arrangement that will mainstream climate resilient development into all planning and policy systems and structures. It sets out a strategy for:

1. Policy and planning and regulatory audits (to align policies and actions with climate resilience);
2. Establishing roles and institutional arrangements for climate resilient development for parliament; an Inter-Ministerial Committee on Climate Change (IMCCC); the Forum of South African Directors General clusters; the Intergovernmental Committee on Climate Change (IGCCC); the National Disaster Management Council; Provincial and local government;
3. Partnering with stakeholders including business and industry; civil society; academia and scientists;
4. Co-ordination Mechanisms involving the National Committee on Climate Change (NCCC); the National Economic Development and Labour Council (NEDLAC);
5. Communication and behaviour change;
6. Regulatory measures; and
7. Market-based instruments including carbon pricing, accessing and using carbon markets; providing incentives (RSA, 2011).

4.3 Research and development frameworks and institutions

The Department of Science and Technology (DST) is responsible for implementing the National Research and Development Strategy (2002) and the 10-Year Innovation Plan for South Africa (2007), which identifies five grand challenges for the National System of Innovation for the period 2008-2018. This provides the basis of national research policy in South Africa. 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 transform the economy to create decent work and sustainable livelihoods. The establishment of a Technology Innovation Agency is expected to address the 'innovation chasm' – the gap that exists between the knowledge generators and the market (RSA 2011a).

As indicated above, the Global Change Grand Challenge National Research Plan, and the Energy Grand Challenge National Research Plan provide the core research frameworks for CCD research. As indicated above, South Africa has a well-defined research framework for CCD research already in place, with clearly defined research areas and research plans. The Department of Science and Technology and the National Research Foundation provide public funds for research in the country.

Observation, monitoring and research programmes are undertaken by 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 host active researchers (with most having at least some climate change or CCD related research expertise as can be seen in Table 5 below), operate research and development budgets, and supervise PhDs, although this capacity is unevenly spread across the 23 institutions (see Appendix F and Table 4 below for an indication of the spread of research capacity across the South African 23 universities).

There are also nine research councils in South Africa, with the following having a role to play in climate change research (they also support university research, work in partnerships with universities, and can also host and co-supervise postgraduate scholars):

- Agricultural Research Council (ARC): www.arc.agric.za;
- Council for Scientific and Industrial Research (CSIR): www.csir.co.za;
- Council for Geoscience (CGS): www.geoscience.org.za;
- Human Sciences Research Council (HSRC): www.hsrc.ac.za;
- Medical Research Council (MRC): www.mrc.ac.za;
- Council for Mineral Technology (Mintek): www.mintek.co.za;
- National Research Foundation (NRF): www.nrf.ac.za; and
- Water Research Commission (WRC): www.wrc.org.za (WRC is included as a 'research council' as their mandate is basically to facilitate, coordinate, and fund water research as well as build capacity within the water sector).

The DST/ NRF also has an established SA Research Chairs Programme, which currently supports 92 research chairs, each with a 15-year research programme framework; and postgraduate scholarships and research partnerships. A number of these research chairs are also conducting climate change or CCD related research – see Table 4 below.

4.4 Some current CCD initiatives and programmes

There are a number of CCD initiatives and programmes active in South Africa. This institutional analysis was only able to identify *some* of these. They are reported in more detail elsewhere (e.g. RSA 2011a) so will simply be listed in short here:

4.4.1.1 Systematic observation and monitoring:

- South Africa hosts some of the more extensive monitoring networks in Africa, and has established its own Earth Observation Strategy (SAEOS) in 2007. It contributes to earth observation of the integrated global system.
- The South African Risk and Vulnerability Atlas and SARVA Science Centres Initiative are programmes in the Global Change National Research Plan. The SARVA provides scientifically sound information regarding local risks and vulnerability in accessible formats for decision making. The SARVA Science Centres are currently located at three universities: University of Venda, University of Limpopo and University of Fort Hare.
- Future Projections and CORDEX: The Co-ordinated Regional Downscaling Experiment (CORDEX) programme is located at the University of Cape Town and is providing comprehensive multi-model dynamical downscaling of Global Climate Models for southern African contexts.
- Early Warning Systems Development programmes exist including efforts of the SARVA and the South African Weather Services Severe Weather System programme. The National Forecasting Centre in Pretoria interacts closely with the National Disaster Management Centre in Pretoria, and the flood forecasting programme of the DWA. Regional forecasting offices interact with Provincial and Municipal Disaster Management Centres to improve early warning systems.
- The South African Environmental Observation Network (SAEON) was established in 2002, and also forms part of the wider Global Change Grand Challenge National Research Programme supported by the NRF. It co-ordinates long-term *in situ* environmental observation systems that are established via a set of 'observation nodes' located in different ecological contexts (e.g. marine, fynbos, grassland etc.).
- Department of Environmental Affairs South African Air Quality Information System (SAAQIS) programme, used by local and provincial government and industries to ensure compliance with national and international requirements and commitments.
- Other monitoring and observation projects and initiatives are run by the Agricultural Research Council (ARC), the Council for Scientific and Industrial Research (CSIR), the South African National Biodiversity Institute (SANBI), the South African National Parks (SANParks), the South African Institute of Aquatic Biodiversity (SAIAB), and the Water Research Commission (WRC), the South African National Space Agency (SANSA); the South African National Antarctic Programme (SANAP), and the Climate and Environmental Research and Monitoring Unit at the South African Weather Services.
- Oceanographic research programmes that contribute to climate observation knowledge of the Southern and Indian Oceans include: the Ocean Dynamics and Climate programme at the CSIR; the SAEON marine research programme at its Egagagasini marine offshore node; and the SAIAB offshore and marine research programme.

4.4.1.2 Adaptation and Mitigation programmes and projects:

- Various national and provincial government department projects and programmes focusing especially on water and agriculture, and urban adaptation have been established. Some municipalities have integrated CC adaptation projects and objectives into their Integrated Development Plans.
- The South African National Biodiversity Institute (SANBI) are developing climate change adaptation programmes and strategy (they led the development of the LTAS). They are, with

the support of the DEA, the accredited **National Implementing Entity (NIE) for the Adaptation Fund**, and are currently working with partners to develop adaptation fund proposals. Two examples of such adaptation fund proposals are: "Building resilience in the Greater uMngeni Catchment, South Africa" and "Taking Adaptation to the Ground: A Small Grants Facility for enabling local level responses to climate change." The full proposal for the largest project, "Building Resilience in the Greater uMngeni Catchment," is currently being developed under the lead of the executing entity of the project, the uMgungundlovu District Municipality (UMDM) in KwaZulu-Natal, in collaboration with the NIE and local stakeholders. The project works to address three main components, namely early warning systems; climate-proof settlements; and climate resilient agriculture, through an integrated approach. The plan is for the full proposal to be submitted to the Adaptation Fund in March 2014. The full proposal for the second project, "Taking adaptation to the ground: A Small Grants Facility (SGF) for enabling local level responses to climate change," is currently being developed by the NIE together with the two facilitating agencies: Conservation South Africa and GenderCC. The project development process will also include stakeholder engagement processes, thus ensuring that the voices of the people at the grassroots level are included in the project development phase. The plan is for the full proposal to be submitted to the Adaptation Fund in June 2014. (www.sanbi.org)

- A variety of science councils, universities, NGOs and businesses are increasingly initiating and implementing adaptation and mitigation projects across a range of sectors. As indicated in the workshop, however, the challenge with these initiatives is to scale them up and sustain them "beyond the pilot project".
- The **South African National Energy Development Institute** (SANEDI; see below) runs a number of programmes including: Advanced Fossil Fuels; Clean Energy Solutions; Energy Efficiency; Green Transport Programme; Smart Grids Energy Data and Knowledge; and the Working for Energy Programme The DST has also played a significant role in supporting key programmes housed within SANEDI. These include Carbon Capture and Storage, the Energy Efficiency Hub at the University of Pretoria and lastly, the Centre for Energy Systems Analysis and Research (CESAR). CESAR is a virtual centre involving cooperation between the Data and Knowledge Management Component of SANEDI and the Universities of Cape Town (through the Energy Research Centre) and Pretoria (through its Institute for Technological Innovation) (www.sanedi.org.za).
- The South African Smart Grids Initiative (SASGI) has gained traction during the year and the Smart Grid Vision for South Africa is now well under development. It is largely due to this initiative that the Department of Energy and National Treasury have seen fit to appoint SANEDI as the implementing agent for the **piloting of smart meters in South African cities**. The proposed pilot involves the installation of between 10 000 to 15 000 smart meters in either one or two metropolitan areas. This project has been made possible by a grant from the European Union, totalling some R180 million over three years. The first allocation, of R71 million has already been received by SANEDI (SANEDI 2012/13 annual report).
- SANEDI is also implementing the second phase of the **Wind Atlas of South Africa** (WASA II). The Danish government confirmed further support for the expansion of WASA and SANEDI has been chosen to manage the project, WASA II. All the information contained in all the WASA projects is invaluable to project developers, financiers, government and the utility. The WASA project is funded by the Danish Government and the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP) and is implemented by a consortium of local and international institutions (SANEDI 2012/13 annual report).

- Under the **Clean Coal programme** of SANEDI, the 2012/13 year saw the completion of four multi-year clean coal technology projects, namely: Direct extraction of liquid fuels from coal; the adsorption of carbon dioxide onto coal as a carbon sequestration mechanism; the speciation of heavy metals in coal; and the finalisation of the high pressure spray injector project that tests the characteristics of new liquid fuels. These projects were undertaken at the University of Witwatersrand and the North-West University in partnership with SANEDI (SANEDI Annual Report 2012/13).[15]
- The Department of Energy (www.energy.gov.za) reports that to date (2013), there are **347 Clean Development Mechanism** projects submitted to the Designated National Authority (DNA) – 209 Project Idea Notes (PINs) and 138 Project Design Documents (PDDs). Out of 138 PDDs, 80 have been registered by the CDM Executive Board as CDM projects (12 issued with CERs), and 58 are at different stages of the project cycle – DNA approval, validation stage and/or request for review. The projects submitted to the DNA for initial review and approval cover the following types, bio-fuels, energy efficiency, waste management, cogeneration, fuel switching and hydro-power, and cover sectors like manufacturing, mining, agriculture, energy, waste management, housing, transport and residential. In 2011 there were only 125 projects submitted; showing a ***doubling*** in the last two years of project proposals. This shows an active engagement with project development under the Clean Development Mechanism.
- **The Carbon Disclosure Project** which South Africa has participated in since 2007 requests business and industry and other institutions to participate in auditing and reporting on carbon emissions. In 2013 the CDP requested climate change information from the 100 largest South African companies by market capitalisation, based on the FTSE JSE All Share Index. The 2012 report to the JSE 100 companies on behalf of 655 institutional investors (CDP signatories) representing $78 trillion in assets showed that the number of companies with GHG emissions reduction targets continues to increase with 43 companies reporting having emissions reduction targets; this compares with 40 in 2011. Fifty-seven (75 percent) companies reported implementing energy efficiency initiatives related to processes, building services and building fabrics (www.cdp.net).

4.4.1.3 Climate Change / CCD Education

- There are a number of climate change education projects and programmes in South Africa. A recent national case study of climate change education produced for UNESCO[16] shows that climate change education has been included in the National Curriculum and Assessment Policy Statement of the Department of Basic Education (even though its representation is somewhat fragmented and lacks coherence and progression across the grades and across subjects).

[15] Note: There are other projects and programmes co-ordinated by SANEDI, not all are reported here, only a small selection to demonstrate the kinds of projects and programmes that are in process. Of interest to this mapping study is the manner in which universities are involved in these projects and programmes.

[16] Lotz-Sisitka, H.B., C. Mandikonza, V. Malema, R. Ellman and J. Mpungose. 2013. *Climate Change Education in South Africa. A case study.* Paris: UNESCO.

- A national teacher education project supported by the Department of Environmental Affairs, the Department of Basic Education, Department of Water Affairs, the South African National Biodiversity Institute, the South African National Parks, and all major national environmental NGOs as well as a number of South African universities is **Fundisa for Change** that focuses on transformative environmental learning through teacher education. It has produced materials on climate change for teacher education to support teachers to engage with the new content that is required in the various subjects at all levels of the schooling systems (www.fundisaforchange.co.za)
- ACCESS runs an innovative career guidance and inter-disciplinary scientific orientation / 'summer school' programme for university students (second to fourth years) to attract them into the climate and earth system sciences called the **Habitable Planet Programme**. This programme is taught in partnership with a range of South African universities, and is largely student-led.
- The Wildlife and Environment Society of South Africa has a number of education programmes that involve the public, a key one focusing on CCD is the **Stepping up to Sustainability Project** that involves the public in learning how to use green technologies in everyday life and practice. It works via a series of ten 'Sustainability Commons' projects located at WESSA' centres, and at the Rhodes University Environmental Learning Research Centre providing small scale demonstrations for sustainable living and CCD practice.

4.5 Existing status of CCD research, education, outreach and networking in South Africa

4.5.1 Understandings of CCD: National policy, stakeholders and university staff

Discussion on the meaning of Climate Compatible Development in the workshops in South Africa centred around the core definition provided by the facilitators:

- Climate Compatible Development (CCD) is low carbon, climate resilient development – in other words, development that integrates current and future climate risks, adaptation to climate change, and mitigation (or reduction) of greenhouse gas emissions.
- Given uncertainties in climate projections, and the complex manner in which climate change and other drivers such as environmental degradation, globalisation and economic development processes interact, CCD necessitates an iterative, learning-by-doing approach, which involves on going adaptation.

Workshop presentations demonstrated a strong understanding of Climate Compatible Development in the South African climate change community. For example Dr Beaumont from the DEA noted that "*responding to climate change must be a developmental response, there is a need to balance job creation and poverty eradication with imperatives to address climate change and build a climate resilient society*". There were also questions about the inherent tensions that exist in the notion of climate compatible development, especially when it is being conceptualised within the existing economic paradigm, of which it was said "*the development system paradigm was not working well anyway*"; to which Dr Beaumont responded that CCD is not about 'trade-offs' i.e. how one does one thing without the other, but rather how to conceptualise new solutions that address the tensions. This must be an ongoing process of re-orientation as "*development is ongoing; it is happening now".*

Amongst the stakeholders involved in CCD related policy and knowledge mediation activities, different understandings of CCD exist, as shown by these extracts from the questionnaire data:

- "Development which has the lowest possible climate impact, provides resilience to climate changes and opportunities to adapt."
- "Transformation of existing social, economic and environmental relationships towards greater equity in ways that acknowledge climate-induced change, but also do not contribute to increased global warming."
- "Climate compatible development is development strategy that minimises the adverse impact caused by climate impacts, while maximising the many human development opportunities presented by a low emissions, more resilient, future. Climate change and responses to it are changing patterns of innovation that create a new development landscape for policy makers, who need to nurture and sustain economic growth and social development in the face of multiple threats and uncertainties while also cutting emissions or keeping them low. This strategy moves beyond the traditional separation of adaptation, mitigation and development strategies. Instead it emphasises climate strategies that embrace development goals and development strategies that integrate the threats and opportunities of a changing climate. It heralds a new generation of development processes that safeguard development from climate impacts (climate resilient development) and reduce or keep emissions low without compromising development goals (low emissions development). Climate compatible development goes one step further by asking policy makers to consider 'triple win' strategies that result in low emissions, build resilience and promote development simultaneously."
- "Finding compatible solutions that will enable sustainable development in line with challenges brought by climate change."
- "Development that builds resilience to climate variability and change."
- "In the context of conservation, it is critical that biological corridors are established to enable the movement or change in species distributions on a landscape level. Without such biological corridors and sufficiently large conservation areas, a great loss of biodiversity is predicted to occur."
- "Development that conforms to sustainable development principles, with an especially long term planning horizon, and one which is implicitly low-carbon, non-energy intensive, and supports local economic."
- "A broadly integrated, cross-sectoral, transdisciplinary approach to development which factors in the increasing reality of extreme weather events, and gradual onset of climate change. Development which is climate resilient and which is also appropriately considerate of protecting the environment from further degradation -and which is aimed at protecting the most vulnerable members of society."

Within the universities across South Africa, there were also diverse understandings of CCD, as shown by these extracts from the questionnaire data obtained from nine university respondents:

- "Development that is sensitive to environmental disturbances e.g. sustainable housing (energy, water, efficiency)."
- "Development or way of life that is much less dependent on fossil fuel than has been the case up to now."
- "Adaptation to changes in climate, e.g. change in planting dates."

- "In Agriculture this most probably means agricultural practices/systems that are in harmony with the environment. Producing crops/cultivars/breeds best suited to the climate of a region and management practices (e.g. plant density, row spacing etc.) best suited to the climatic conditions."
- "Alternative models of creating the built environment that both mitigate and adapt to climate change, moving towards a net positive footprint."
- "Understanding the causes and effects of climate change and respond by way of appropriate physical environment planning that will ensure a resilient built environment."
- "The development of a country in regards to the overall social-ecological system in a sustainable manner, that sees water and climate as a key resource and hence, a catalyst to learn about vulnerabilities and implementable, innovative solutions."
- "The capacity to adapt to current climatic conditions, as well anticipated changes in climate, or engaging in activities that will minimise contribution to climate change, such as reducing emissions of gases that contribute to the greenhouse effect."
- "Because so many environmental and economic systems are tied to climate, a change in climate can affect many related aspects of where and how people, plants and animals live, such as food production, availability and use of water, and health risks."
- "Climate change has an adverse effect on Agricultural production, both crop and animal. Climate compatible development in my context would mean developing programmes on animal production that would make either animals or farmers adapt to effects of climate change."
- "Building resilience to climate variability (which includes change) into policy and development actions, in a way that is cost effective, appropriate to time scale of projected impact, and includes full consideration of non-climate factors."
- "Do not know what it means."
- "Delivering goods and services in such a way that greenhouse gas emissions are avoided (so that includes pollution avoidance and mitigation)."
- "I am not convinced that this is a feasible concept, to begin with."
- "Development directed to decoupling carbon (and other) emissions from economic growth, in other words to mitigate against climate change, and that improves the resilience of the economy, and society at large, in other words to adapt to climate change."
- "Development that takes into account future, context specific changes in climate and associated impacts. Merges climate change adaptation, mitigation and poverty alleviation and development."
- "Development that allows resilience and sustainability for communities from current resources without impacting on the sustainability of future generations."
- "Socio-economic development that shows respect for ecological factors, that is based on a low-carbon trajectory and development that is able to adapt to a changing climate."

From this it is possible to see that although understandings of CCD differ amongst and between stakeholders and university staff involved in CCD related work, there is generally a close conceptual association between climate compatible development and **adaptation and mitigation**, and climate compatible development and **sustainable development**. **Context and disciplinary specialism** also has an influence on how CCD is understood, and influences meaning making and understanding of the concept. This has important implications for knowledge co-production processes, and will require careful engagement in development of mutual understanding in such processes. The data above also shows that in one case the person did not know what CCD meant, and in another the

person was sceptical about the relevance and meaning of the concept. This shows that understandings of CCD should not be taken for granted in any knowledge co-production process or programme.

4.5.2 Current research related to Climate Compatible Development

4.5.2.1 General view

As indicated above, major research initiatives are government supported via the national research systems that fall under the 10 Year Innovation Plan. Major institutions such as the CSIR are heavily involved in climate change research and a DST Centre of Excellence for Applied Climate Change and Earth System Sciences (ACCESS) has been established by the DST and the NRF (see below for further discussion on this Centre of Excellence). This CoE works closely with most of the South African Universities through a partnership agreement, and with other affiliated research institutions and programmes such as SAEON, AEON and others that form part of the Global Change Grand Challenge National Research Plan's implementation system (see Figure 9 below).

A Global Change Society and Sustainability research programme was launched by the DST and NRF in 2011, and a number of projects have been funded under this programme to service the Global Change National Research Plan objectives. Of interest is that this research plan specifically sought to support transdisciplinary approaches to research. The Global Change National Research Plan has an 'implementation architecture' that involves a range of inter-related programmes that are all linked together via the GCGC NRP, and all of whom are DST and NRF funded.

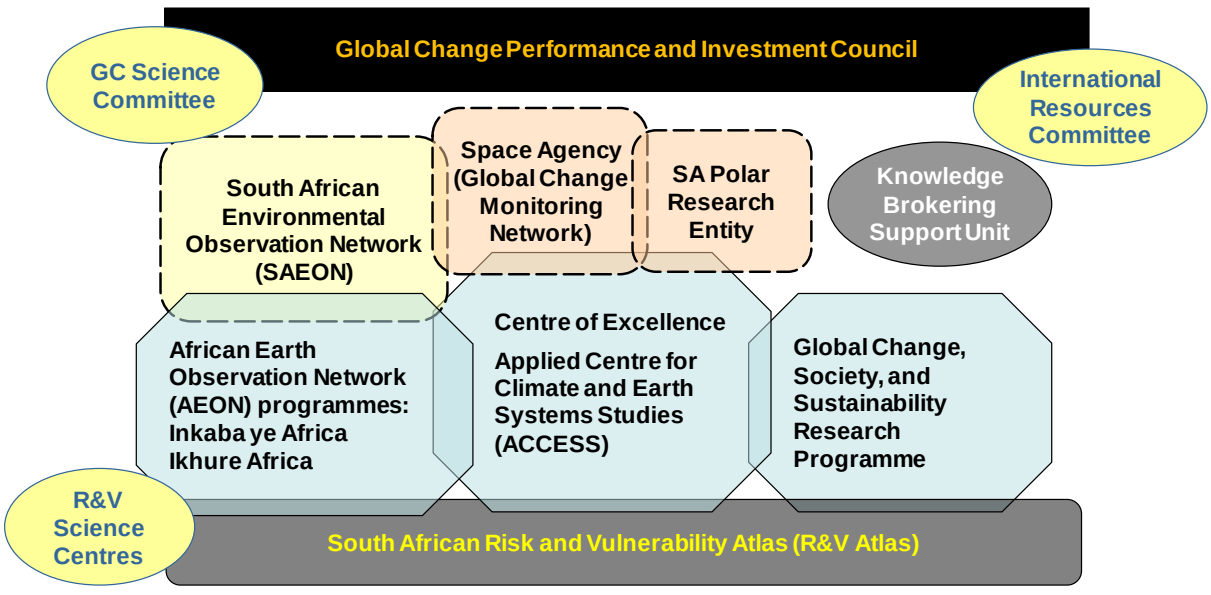


Figure 10: Global Change Grand Challenge National Research Programme 'Architecture'

These programmes, and associated Human Capital Development (investment in student scholarships and research) are obtaining increasing levels of funding from the National Research Foundation.

From a mitigation / CCD perspective, a public research entity for energy research, named the South African National Energy Research Institute (SANERI), was established in October 2004. It recently (in 2012) amalgamated with the National Energy Efficiency Agency to form the **South African National Energy Development Institute** (SANEDI). SANEDI is a Schedule 3A state owned entity that was established as a successor to the previously created South African National Energy Research Institute (SANERI) and the National Energy Efficiency Agency (NEEA). The main function of SANEDI is to direct, monitor and conduct applied energy research and development, demonstration and deployment as well to undertake specific measures to promote the uptake of Green Energy and Energy Efficiency in South Africa. SANEDI has an overarching executive structure working and works with six Research Centres with defined research and development programmes namely: the Renewable Energy Centre of Research and Development (RECORD); the Centre of Energy Systems Analysis and Research (CESAR); the South African Centre for Carbon Capture and Storage (SACCCS); the Working for Energy (WfE); the National Energy Efficiency Agency (NEEA); and the Green Transport Centre. The establishment of SANEDI has concentrated and focused clean and renewable (low carbon) energy research capacity in South Africa. SANERI (predecessor to SANEDI) helped to produce the LTMS, which has informed the climate change mitigation pathway of South Africa (RSA 2011); and SANEDI is leading a number of research programmes on CCD related energy research. The SANEDI works closely with universities as can be seen in the descriptors above of some of the energy research and development programmes and projects listed above in section 4.4 above.

Science production on the African continent is dominated by South African research, with paper publications rising from 3 617 in 2000 to 7 468 in 2010. During this period South Africa also more than doubled its publication numbers, improved its international publications ranking by two positions, and was ranked 33rd in the world (Pouris 2012[17]). Pouris (2012) attributes this to DST science and technology policy, and increased commitment to research and development at a national level. Pouris (2012) reports that during 2008/2009 (the most recent year for which figures exist), the country spent R21 billion or 0.92 percent of GDP on research and development. South Africa had a world share of publications of 0.65 percent in 2010. As a share of world publications the highest for South Africa is in the field of 'Multidisciplinary' (1.6 percent); followed by 'Plant and Ecology Science' (1.57 percent) and 'Environment/Ecology' (1.39 percent) (Pouris 2012). From this it can be seen that while South Africa's publications are still low compared to other countries [*Pouris (2012) reports that BRIC (Brazil, Russia, India and China) countries are all scientifically stronger than South Africa in terms of scientific knowledge produced. In 2010 China produced 124 822 publications, India 40 711, Brazil 31 274 and Russia 26 374. During that year, South Africa produced only 7 468 publications*], research outputs have grown exponentially. Pouris (2012) reports further that the single most critical factor in influencing the upswing of publications since 2003/4 is the new funding framework for higher education institutions that was published in terms of the Higher Education Act, 1997 (Act No. 101 of 1997), in the Government Gazette (No. 1791) on 9 December 2003. The new funding framework was implemented in the 2004/2005 financial year. Under this framework universities are funded according to their research outputs (number of publications and number of

[17] Pouris, A. 2012. "Science in South Africa: The dawn of a renaissance?" *South African Journal of Science* 108 (7/8) http://dx.doi.org/10.4102/sajs. v108i7/8.1018

postgraduates). Universities receive approximately R120 000 (US$17 000) for each article a staff member produces, and most (not all) universities in turn provide incentives to their members of staff to improve their publication profile. Pouris (2012) also reports that international collaboration in research increased from 7.9 percent of the total number of South African articles in 1980 to 47.2 percent during 2010. When compared to countries like Brazil, South Africa has a low rate of research practitioners per 1000 population (0.61 percent). According to the 2010 ASAAF PhD study, South Africa has a total of 1 274 doctoral graduates or 26 doctoral graduates per million of the country's population, which is seen to be low compared to other countries, and is one of the major challenges in the South African research system.

At a broader level, from a research outputs perspective, the National Development Plan Vision 2030 acknowledges that, while South Africa's publication output is the highest on the continent, its innovation system is small by international standards. In particular, the National Development Plan and the DHET White Paper on Post-Schooling Education and Training recognises that doctoral graduate numbers are significantly lower than in equivalent developing countries (DHET 2013). The DHET 2013 White Paper therefore suggests policy responses that grow research and innovation, and that improve the quality of research. The DHET indicates that further investment will be made in research capacity development (various strategies); promotion of internationalisation; and providing support for ongoing efforts to achieve transformation targets.

4.5.2.2 University-based research

A Google scholar search on 'Climate Change South Africa' (a rapid review of the first 50 entries) revealed that a number of South African scholars are publishing work on climate change related concerns in internationally peer reviewed publications; that they are from diverse institutions; and also include international partnerships in the research. The brief rapid review also showed that research publications on climate change modelling, biodiversity related changes, water related CC concerns, and agricultural adaptation were quite prevalent. However, there were also publications on urban related CCD concerns such as urban resilience, social justice and climate change. There were also publications on the economics of climate change, the politics of climate change, food security and climate change, marine and oceanographic aspects of CC, and climate change and health risks (especially malaria) and social change aspects related to climate change. This shows that South African researchers are engaged with climate change and CCD related concerns from a variety of disciplinary perspectives, and are actively producing CCD related knowledge, as is also shown in the comprehensive research-based analysis presented in the Second National Communication (RSA, 2011). From this it is clear to see that CCD is in fact a rapidly emerging area of multidisciplinary scholarship in South Africa.

Given the size of the South African university and research system, it was not possible within the limitations of this study to establish the details of all active climate change researchers in the South African higher education system. However, it was possible to establish where potential 'nodes of expertise' for CCD related research exist, and also where Centres of Expertise that are CCD-dedicated exist (such as the UNISA Exxaro Chair of Climate Change and Business; or UCT's African Climate Change and Development Research Initiative; or Wits University's Global Change Research Institute), or that are partly dedicated to CCD related concerns (such as the Rhodes University Environmental Learning Research Centre or the Nelson Mandela Metropolitan University's Sustainability Research Unit or the Stellenbosch University Tsama Hub and Sustainability Institute).

There is a growing Global Change Sciences Research Community in South Africa, shown by attendance at the Global Change National Research Conference held towards the end of 2012 which attracted in the region of 300 academics and researchers (the NRF holds the database for this research community); and various CCD related research networks centring around multi-institutional Centres of Excellence such as ACCESS located at the CSIR; and/or the Centre of Excellence in Invasive Biology located at the University of Stellenbosch all of which are networked nationally and regionally and who work with multiple universities, government, research councils and other research partners. The Energy research community is also extensive, and is linked into the SANEDI structure (see above), and these structures work closely with energy research centres in universities, listed in the table in Appendix E. Each of these centres hosts their own networked database of active researchers. It was therefore not necessary to duplicate these databases, but rather to provide an overview of the 'landscape of expertise' via which various databases of active researchers could then be accessed; i.e. via the centres of expertise, Centres of Excellence and major research institutions listed in Appendix E. What stands out in the South African context is a strongly networked research community that is linked into and supported by state supported research councils and institutes.

The only university that has a comprehensive overview of its multidisciplinary climate change research programmes *at a university-wide level* on its website is the University of Cape Town, which has defined CCD as a strategic thrust of the university's collective, cross-faculty research. It also has a DVC dedicated to working on this research theme to address it strategically, and to engage a range of faculties across the university in CCD research. Wits University has defined Global Change as a '21st century research theme' and this is also positioning the university as a research hub for global change research.

The best available strategy to ensure full coverage of all universities from a research capacity perspective was therefore via the 2013 NRF Rated Researchers Database; and via university websites to identify Centres of Expertise in CC or CCD *related*[18] research areas. Questionnaire data was not comprehensive enough, although it was useful to identify some of the key areas of expertise in the universities that responded. Insights from the questionnaires and workshop data have been integrated into the table in Appendix E.

Thus, for constructing the table in Appendix E, the NRF rating system was taken as a proxy for nationally recognised researchers that operate as 'nodes of expertise' as most established researchers would be supervising a number of students, be co-ordinating research programmes, and be nationally and/or internationally linked as these are the criteria used for rating an 'established researcher'. Within the NRF rating system scientists are rated via a formal peer review system involving national and international reviewers within a five-year cycle according to the following categories: Promising young researcher; Established researcher (C rating); Internationally acclaimed

[18] Note: It was not possible in all instances to establish the extent to which university academics are engaged in CCD research at present. Thus, CCD related research areas were also included in the table in Appendix E, as researchers in these areas of research may, in future, wish to become more involved in CCD related concerns, as the historical pattern shows that engagement in CCD issues does not necessarily come via a particular specialisation in CC related concerns only, but also via integration of CCD concerns into existing specialisations that lend themselves to CCD research and knowledge co-production.

researcher (B rating); and Leading international researcher (A rating; the highest category). Every five years researchers have to re-apply for their rating, which may stay the same, decline or improve. The majority of researchers in South Africa are within the category 'established researcher', but there are an increasing number of internationally acclaimed and leading international researchers. A search of this database showed that there are a number of researchers, in all categories noted above, that are involved in climate change research, and research fields that are closely associated with, or that are necessary for CCD research. Not all researchers involved in climate change are, however, listing it as an area of specialisation in the NRF rating system, although other evidence shows that many of the researchers are beginning to include aspects of climate change in their research (e.g. questionnaire data, website data, publications). It was interesting to note too that it was the younger, promising researchers who were more explicit about claiming climate change research as an area of academic expertise. This may be linked to the fact that CCD is a relatively *new* area of specialisation for many researchers, as shown in Appendix B where, in general, it can be seen that years of experience were not matched by years of experience in CC / CCD related research.

South Africa has **2 637 rated scientists** most of whom are located in universities (see Table 4 below). South Africa currently has **92 NRF funded research SARCHI Chairs (as of 2012**) all located at universities; and a number of **Department of Science and Technology Centres of Expertise**, some of which are relevant to CCD research (as shown in the table in Appendix E). For the construction of the table in Appendix E, only those research areas which had researchers classified as *established, leading international, and internationally acclaimed* associated with them were considered in the construction of Table 4 below. SARCHI Chairs that are involved in CCD research are also listed below (based on best available information).

The table in Appendix E should ideally also be more fully verified at individual university level, a process that would need to take place in the follow up phase of the SARUA mapping study. **This information is therefore *indicative, rather than fully comprehensive or fully accurate.*** Brief descriptions on the Centres and Institutes (Centres of Expertise) are provided where these were available.

Questionnaire data also revealed that researchers in South Africa were able to raise funding to support their research, and that they were accessing national and international research funding. The CSAG at the University of Cape Town for example has "over 25 funded projects". The mapping study also revealed that it was easier for research groups to raise funding where 'critical mass' existed, and that fundraising was also increasingly requiring multi-sectoral and multidisciplinary partnerships. Universities were responding by developing cross-cutting thematic research groups and institutions at a strategic level (e.g. the Wits University Institute of Global Change Research or the Stellenbosch University Centre of Water Research) which better positioned their research communities to make best use of the changing funding landscape, and also to address new cross-cutting research challenges such as CCD.

4.5.3 Curriculum innovations and teaching for CCD

The institutional assessment was not able to probe into the full range of courses being offered in CCD related fields in South African universities due to the scope of the task. However, the Department of Environmental Affairs Environmental Sector Skills Plan for South Africa (DEA 2010)

showed a 'groundswell' of new environmental courses being developed in and across all of South Africa's universities with almost every university having a Department of Environmental Sciences (which would not have been the case 20 years ago). Interesting however, is that CCD related courses are not only confined to the Departments of Environmental Sciences, and are instead emerging across a range of disciplinary contexts. There are also examples of courses that are explicitly multi- and transdisciplinary in their construction, especially at Masters level.

Questionnaire data, although limited to 40 respondents, showed that there were some interesting curriculum innovations occurring in response to sustainability and CCD related issues most notable amongst these are the University of Stellenbosch's Tsama Hub Transdisciplinary PhD programme, the University of Stellenbosch MPhil in Sustainable Development (which is multidisciplinary); the University of Cape Town's MSc/MPhil specialising in Climate Change and Sustainable Development, the Rhodes University Environmental Learning Research Centre's MEd and PhD programmes that specialises in Environment and Sustainability Education and Social Learning (which includes a CCD focus); UNISA's Exxarco Chair's teaching programmes in climate change, business and the green economy; the University of Free State Masters Degree in Integrated Water Resources Management (focus on groundwater); and Disaster Risk Management; and the University of KwaZulu-Natal's MSc programmes in conservation, agriculture and water resources management (amongst others). The University of Fort Hare's Agricultural degrees, and the University of Limpopo also have programmes on offer that address CCD related concerns notably in the Agricultural, Environmental and Geographical Sciences. The University of the North West has strong environmental law and governance programmes in place with a focus on climate law, while the University of Pretoria has conservation, environmental management and sustainable development and built environment degree and post-degree programmes (amongst others). The data shows that there is increasing specialisation in CCD related areas, especially at postgraduate level, and that CCD issues are being integrated into undergraduate programmes although the full data on this was not accessed in this mapping study due to the scope of the task.

Corroborating this finding is reporting in the Second National Communication (RSA 2011) which states that South Africa's tertiary education institutions offer varying levels of training in climate change-related topics. It states that these opportunities usually reside in geography, environmental, or physics departments, and are either early-level compulsory or higher-level options. The subject material of modules offered reflects the research interests of faculty members, and also their availability. This results in the focus being varied between institutions.

A key finding of this mapping study, and as also reported in the SNC (RSA 2011), is that where climate change science and human dimensions research interests and expertise exist, opportunities are available for both undergraduate teaching and postgraduate research supervision, contributing to the growth of specific 'hubs' of knowledge and capacity, as shown in the table in Appendix E. Examples include the Climate Systems Analysis Group at the University of Cape Town (UCT), the Energy Research Centres at various universities, and the Global Change Research Institute at the University of Witwatersrand (amongst others). The recently established Risk and Vulnerability Science Centres at the Universities of Fort Hare, Limpopo and Venda are establishing CCD focused research programmes in these universities, with teaching and learning programmes attached.

The SNC (RSA 2011) notes that these hubs may also draw from experienced professionals from outside academia to add diversity to the material offered, such as the climate change module of the conservation biology Masters course at UCT, which includes co-ordination and lectures by professional scientists from the SANBI.

The ACCESS programme has as one of its objectives to support curriculum innovations at Masters degree level across the ACCESS linked universities, and a process has been underway to support courses for some of the 'critical shortage' areas such as modelling. There have been discussions to develop a national Masters degree but due to cost and accreditation specifications that favour individual institution programmes, this initiative has not taken off the ground as yet.

An MSc. in climate and development has been approved for inclusion at the University of the Witwatersrand, and a strong MSc/MPhil in climate change and development already exists at the University of Cape Town. Energy and renewable energy courses; and CC and urbanisation are also on the rise across the South African university landscape and many Engineering faculties and Faculties of Architecture and Design are taking up these foci within their courses and programmes. Examples can be found at the University of the Witwatersrand, the University of Stellenbosch, the University of Pretoria, the University of the North West, the University of Fort Hare, the Tshwane University of Technology and others.

Questionnaire data did not reveal much detail on the actual courses taught, and in some cases respondents said 'none' which indicates that CCD is not integrated into courses.

Table 4: Some examples of CCD courses in a diversity of faculties and universities

University	Lecturer	Faculty	Department	CCD courses being taught or courses with CCD content
University of the Witwatersrand	Jasper Knight	Science	Geography	Earth sciences, sustainable architecture, climate studies - PhD research
University of the Free State	Linda de Wet	Natural and Agricultural Sciences	Soil, Crop and Climate Sciences	AGR424 - Crop development (4th year / Postgrad-Hons) DIM608 - Management of natural and human-made disasters (Postgrad-Hons) DIM706 - Environmental risk and impact assessment (Postgrad-Masters) GEO114 - Introduction to general geosciences (first year) GEO224 - Environmental studies (second year) GIS224/324 - Geographic Information Systems (second/third year) GKG124 - Introduction to soil, crop and climate sciences (first year) GKD708 - Land evaluation (Postgrad-Masters) LWR214 - Fundamentals of agrometeorology (second year) LWR224 - Agrometeorology for farming systems (second year)

University	Lecturer	Faculty	Department	CCD courses being taught or courses with CCD content
				LWR314 - Climate data analysis for agrometeorological services (third year) LWR324 - Climate change and variability (third year) LWR414 - Micrometeorology and specialised instrumentation (fourth year / Postgrad-Hons) LWR424 - Simulating biophysical interactions (fourth year / Postgrad-Hons) MOB707 - Resources and processes (Postgrad-Masters) MVL722 - Natural agricultural resources and the environment (Postgrad-Masters) MVL723 - Sustainable utilisation of natural agricultural resources (Postgrad-Masters)
University of South Africa	Prof Godwell Nhamo	College of Economic and Management Sciences	Institute for Corporate Citizenship	Only third year, 6-credit course on Sustainable Construction.
University of KwaZulu-Natal	Trevor Hill	Agricultural, Earth and Environmental	Geography	Hydr220 Hydr330 Hydr720 (Honours)
University of Johannesburg	Jaenine Marais	Faculty of Management		Agro-meteorology (first year) Introduction to crop science (first year) Elements of crop production (second year) Plant breeding (final year) Crop ecology and crop physiology (honours)
University of Fort Hare	Charles Mutengwa	Science and Agriculture	Agronomy	Geography offers a course on climate change to second years. Honours, Masters and PhD conduct research on climate change related issues. The RVSC recruited Masters and PhD students focusing on assessing impact of climate change on food security
University of Fort Hare	Viola Maphosa	Science and Agriculture	Department of Livestock and Pasture Science	Many courses. I am involved with one undergraduate course (third year) and two honours level courses.
Tshwane University of Technology	C J Lideque du Toit	Science	Animal Science	Just one undergraduate course, but in GG course, reference to climate change impacts; in pollution control mitigation of greenhouse cases. (Little bits everywhere in diploma)
Tshwane University of Technology	Catherine Coni	Science	Environmental, Water, Earth Sciences	No

University	Lecturer	Faculty	Department	CCD courses being taught or courses with CCD content
Tshwane University of Technology	Koos Engelbrecht	Science	Environmental Health	None
Tshwane University of Technology	R Kruger	Arts	Fine and Applied Arts	None
Tshwane University of Technology	J P Maree	Science	Environment, Water and Earth	Honours and Masters courses (23 in total); for example: sustainable development, complexity theory, renewable energy systems, ecodesign for community building, etc.
Stellenbosch University	Alan Brent	Engineering and Economic and Management Sciences	School of Public Leadership	Second year - course of climate change as a global environmental challenge. Third year long project topic has often been climate related. Climate change adaptation course at Honours level
North-West University	Beatrix Bouwman	N/A	Community Engagement and sustainability	LLM course in Climate Law LLM course in environmental law with climate aspects LLM course in international environmental law with climate aspects Short courses in environmental law
North West University	Louis Kotze	Faculty of Law	Faculty of Law	LLM environmental law and governance (module climate change law and governance); LLB module fourth year: environmental law - including climate change law; LLB module third year: local government Climate change law in International Environmental Law - LLM level
North West University	W du Plessis	Law		Environmental law, fourth year

Note: This list is not complete and does not cover all universities and university courses. It is therefore only indicative of how CCD and related concerns are integrated into a variety of disciplinary teaching programmes.

Teaching methods that were identified in questionnaires as being potentially effective for CCD in courses include:

- Photographs, mainly examples;
- Traditional lecturing; group discussions; distance learning (e.g. online modules/quizzes);
- Problem-based group work;
- Design projects in which students have to demonstrate their grasp of issues such as alternative technologies, passive building climate design, water management, alternative waste and sewerage management systems, optimising appropriate land use etc.;
- Role plays and open discussions;
- Using powerpoint, and showing appropriate videos on climate change; hands-on practical activities;

- Game and scenario-based exploration of decision making. Many hands-on exercises to expose the complexity of integrating climate and non-climate information. Field work with stakeholders. Internships;
- Identify greenhouse gas emissions in case studies; in subject called "industrial process", learn about renewable energy projects; do sustainable agriculture projects in the urban context;
- Tutorials, group discussions, practical;
- Video presentations;
- Problem-based (group) assignment/learning;
- Determining carbon footprints as part of assessment; self-learning in CCA Honours course and field component;
- Formal lectures and students presenting problem solving lectures;
- Combine science lecture with law to explain issues; videos; and
- PowerPoint (available technology); Movies on climate change to understand the real effect of climate change.

Questionnaire data showed low levels of engagement with service learning approaches to CCD education, but high levels of engagement with problem solving approaches; average levels of engagement with socio-technical and ethical actions linked to CCD courses; and average levels of integration of CCD concerns into examinations. Questionnaire data showed that staff willingness to get involved in CCD issues was high amongst those who responded, and also that there were enough opportunities for staff to get involved in new concerns such as CCD.

Inter- and transdisciplinary approaches to curriculum innovation are discussed in the next section (section 5).

4.5.4 Community and policy outreach

As indicated above, South Africa has an active research community that is strongly linked with government supported research institutions. There is therefore a close relationship between research outputs and inputs into policy and policy processes, as can be seen from the relationship that exists between the research used to construct the Second National Communication (RSA 2011a) and the National Climate Change Response White Paper (RSA 2011b). University researchers are therefore drawn on to provide scientific evidence and perspectives for policy making. The DEA, in turn, provide direction for policy making and research, as can be seen from the framework that the DEA are putting in place at present to ensure CCD coherence and synergy in South Africa, and in their appeals for construction of a national monitoring and evaluation system that involves all research partners and climate change research institutions. Government, via its incentive schemes and research funding frameworks is also playing a strong role in aligning research in ways that inform and contribute to policy directions, technological innovation and economic growth and sustainable development, as most recently outlined in the National Development Plan Vision 2030. Policy instruments and strategic plans such as the DST 10 Year Innovation Plan are also strong drivers of research direction, and associated research responses; all of which contributes to a strong relationship between research and policy. Questionnaire data showed a high level of engagement with policy, and researchers were generally of the view that their research was contributing to CCD policy pathways as outlined in national and international policy.

There was discussion in the workshop on the efficacy of policy and its implementation, especially at local government level; this is a pervasive issue across the South African policy landscape. In most cases, especially in applied CCD research areas, researchers were engaged in research that either contributed to, critiqued and/or informed policy and its implementation.

Amongst South African universities it is possible to identify a strong community engagement movement, which has been spearheaded by post-1994 debates about the role of universities in communities; and which is supported at a high level by the Council of Higher Education (CHE) who produced guidelines for community engagement in higher education. There is an annual conference on community engagement, and the NRF has supported community engagement research. Most universities have community engagement directorates and there are a number of community engagement initiatives that are also CCD related, as reported on in the questionnaire data. There was also work taking place on the concept of 'community engaged research' in which the relationship between research and community engagement is being probed and theorised. Additionally the CHE has also supported the development of guidelines on service learning as this is a key strategy for enhancing community engaged teaching. Questionnaire data, however, showed that few academics were using service learning approaches. Despite the national 'push' for community engagement to be the 'third' pillar of academic work, it remains outside of formal incentive frameworks for academics and universities. The post-schooling White Paper on Education and Training (released in late 2013) notes that in future service learning approaches will be more strongly supported by the DHET.

4.5.5 Student involvement

Questionnaire data generally showed low levels of student engagement in CCD related activities on campus and/or in communities. The lack of substantive engagement with service learning approaches may help to explain this. However, despite this there was some evidence that students were involved in CCD related activities and that on some campuses there were active student associations that were involved in environmental matters. There are also cross institutional networks such as a student energy network, and the 'Blue Buck' student environmental association network that was linking student organisations involved in environmental matters from different campuses. On different campuses there were also various student organisations; for example at NMMU there is a Green association, and the George Campus has a strong student action programme, and at UCT there are various student organisations engaged with environmental concerns. The mapping study was not able to fully probe this dimension of CCD engagement in South African universities again due to the scope of data and the limitations of the study.

4.5.6 University collaboration and networking

As noted above, the South African research community are well networked via various structures, especially the Global Change Grand Challenge National Research Plan interventions, and the SANERI (now SANEDI) energy research community structures. The biodiversity research communities are also well networked with such networks also being supported via the Centres of Expertise frameworks of the DST which requires such Centres to involve multiple stakeholders and a diversity of university partners. As mentioned above, the funding environment is also increasing the levels of

university collaboration and networking, especially where requirements for collaboration are built into funding calls as is increasingly the case.

4.5.6.1 Potential knowledge co-production partners

The institutional analysis also shows that numerous knowledge partners exist for CCD knowledge co-production in South Africa. Table 5 shows these 'mapped' out.

Table 5: Some CCD Knowledge co-production partners identified (potential; with many already actualised)

Research organisations	Civil society organisations	Private sector	Government	Regional organisations	International organisations
23 Universities **Water Research Commission** **Agricultural Research Council** **Human Sciences Research Council** **Centre for Scientific and Industrial Research** **Medical Research Council** **South African Environmental Observation Network (SAEON)** **South African Institute of Aquatic Biodiversity**	Labour unions (COSATU) Environmental NGOs (e.g. WESSA, Endangered Wildlife Trust, WWF GreenPeace etc.) Project 90 by 2030	Business South Africa and major industries Johannesburg Stock Exchange Companies KPMG and other auditing organisations involved in Sustainability Indicators and Climate Disclosure Monitoring National Cleaner Production Centre	Municipalities Department of Environmental Affairs Department of Science and Technology National Research Foundation (NRF) Department of Agriculture, Forestry and Fisheries Department of Water Affairs Department of Energy Parastatals: SAN Parks; SANBI; Eskom;	SADC NEPAD Africa Earth Observation Network (AEON) SASSCAL African Union ACP African Development Bank SADC REEP SADC Remote Sensing Centre	ICSU IDRC International development partners (EU, Sida, USAID, DifD, JiCA, GIZ and others) European-South African Science and Technology Advancement Programme (ESASTAP) Resillience Alliance Global Environmental Facility FAO UN-Habitat UNEP UNDP

Note: This table is incomplete. The mapping study showed that each 'sub-group' associated with CCD related research has complex partnership networks that are both national and international and involve both research institutions and other stakeholders.

4.5.7 University policy and campus management

The mapping study revealed that a number of universities had, or were establishing sustainability policies for campus management. There was also an emerging movement around the Africa Green Campus initiative. The **African Green Campus Initiative** is a strategic response to climate change challenges facing universities, colleges and communities. It is based on the notion that campuses that address climate change by reducing greenhouse gas emission and integrate sustainability into their curriculum will better benefit the students and will help create a thriving, moral and civil society. The South African Green Campus initiative was launched by the Minister of Higher Education

and Training in 2012 at UCT. The Minister noted at the launch of this initiative that colleges and universities could help provide students with the skills needed to address climate change and allow them to benefit from the economic opportunities that arose from the solutions they helped develop. He noted that the Department of Higher Education and Training will be supporting the initiative by reducing energy consumption at colleges and universities through recycling, encouraging students to use bicycles and buses, and conducting consumption audits. It would also look at structuring curricula to include more focus on sustainability, at retro-fitting and creating energy-efficient buildings, and at encouraging universities to procure more "green" products and services. The Minister conceded that initiatives such as energy-efficient buildings were more difficult to attain, but said his department was currently looking at proposals for infrastructure funding at universities for the current and coming financial years, and that "green" building was one of the key criteria in the approval of new projects.[19] The African Green Campus Initiative was created and is being funded by the Southern Africa chapter of the Association of College and University Housing Officers International (Acuho-I-Sac) in collaboration with African Compass and PD Naidoo and Associates. The Department of Higher Education and Training, as well as the Department of Environmental Affairs, are both supporting the initiative.

The Nelson Mandela Metropolitan University has hosted two Green Campus conferences, and are themselves also engaged in a number of innovative Green Campus activities, with a strong Green Campus organisation. The NMMU co-ordinates the Africa Green Campus programme. NMMU students had been running various green initiatives on waste management and had also signed a green pledge. The university had also helped Eastern Cape farmers to grow Spekboom which, once planted, could be traded for carbon credits. Rhodes University's student organisation RU Green is also playing a co-ordination role for the South East African Student Climate Change Forum, involving NMMU, University of Fort Hare and Walter Sisulu University.

In 2012 the University of the Western Cape (UWC) was awarded the national Green Campus of the Year award for 2012 at the inaugural African Green Campus Initiative conference, along with another six awards. UWC is involved in various green campus initiatives. It is home to a 30ha private nature reserve, which is rich in fynbos vegetation and located within an international biodiversity hotspot. Students are actively involved in managing the reserve through eradicating alien vegetation and maintaining firebreaks. UWC also has a recycling initiative, which has been a huge success, collecting an average of 70 tons of recyclables each month and creating employment for 120 previously unemployed people to sort the recycling materials. The University is also able to benefit financially from the recycling initiative through selling recycled materials to companies – and have estimated that they are able to reduce emissions by 840 tons of CO_2 annually. The University also promotes sustainable mobility – using solar powered golf carts instead of cars for travelling distances across the campus and promotes the use of lift clubs and public transport.

The mapping study revealed a growing number of academic institutes across South Africa have established green campus initiatives and student groups. Examples include UCT's Green

[19] ttp://www.southafrica.info/about/sustainable/green-campus-230412.htm#.UuC_Uxbg7fY#ixzz2rCebhm8t

Campus Initiative, Stellenbosch University's Eco Maties, Rhodes University RU Green Node**,** and the BlueBuck Network (started via an Eastern Cape Consortium of Rhodes University, NMMU, UFH working with UCT) which is a youth-driven, non-profit organisation that aims to connect youth in southern Africa who are interested in protecting the environment and stimulating sustainability. The University of Fort Hare established an energy efficiency hostel project in collaboration with Eskom which expanded to the entire university. From the energy savings, the university has appointed a Director of Energy.

4.6 What existing practices can be strengthened and what can be done differently?

4.6.1 Co-ordination, collaboration and improved partnership building

The mapping study revealed that funding incentives and frameworks are a key driver of co-ordination, collaboration and improved partnership building. State supported structures for collaboration and co-ordinated research initiatives such as SANERI, which has now changed to SANEDI, and the Global Change Research National Research Plan are also key to supporting collaboration and co-ordination in knowledge co production, as are policy frameworks such as the National Climate Change Response White Paper. While progress has been made in enabling and supporting co-ordination, collaboration and partnership building using these frameworks and instruments, workshop participants still felt that CCD research tended to be approached from a silo perspective and more needs to be done at the conceptual level to ensure integrated scientific production framed by social-ecological and whole systems perspectives. University structures that facilitated multi- and interdisciplinary research such as the ACDI at the University of Cape Town were noted as being significant enablers of such scientific practice. The South African context also shows that more needs to be done to enhance collaboration and partnership building across universities with unequal research capacity and capability to strengthen the whole system of knowledge production.

4.6.2 Strengthen and expand understandings of CCD

While there is an emerging consensus around the meaning of CCD and its relationship to Sustainable Development, the mapping study indicated that the concept of CCD is a) not uncontested, b) required in-depth engagement especially related to the inherent tensions and paradoxes that are contained within the concept and CCD trajectory, c) that it was not a concept 'known' by everyone, and d) that there was need for careful differentiation between the concept of climate change and climate compatible development as the two were not the same thing, and therefore had very different implications for research, teaching and community and policy outreach. There is therefore a need to continue to strengthen and expand debate on, and understandings of CCD in South Africa, as is the case elsewhere.

4.6.3 Capacity building for CCD and staffing

As indicated above there are some substantive human capital development initiatives underway to begin to strengthen and support an expanded climate change and CCD research community in South

Africa. However, as is also recognised in the National Climate Change Response White Paper, these efforts are as yet inadequate and further impetus is needed to build capacity of staff as well as new entrants / students and postgraduates in the area of CCD. The mapping study also shows that many academics are entering the area of CCD research 'mid-way' through or during their tenure tracks, which has implications for professional development and support of academics to enter new arenas of knowledge (co) production that emerge from their foundational disciplines. This is a multidisciplinary phenomenon, and such professional development / engagement should strengthen understandings of the meaning of this multidisciplinary phenomenon and its implications for inter- and transdisciplinary research. The NRF indicated that few applications were put in for their call for transdisciplinary research and discussions at the workshop revealed that this was a relatively new area for university research, and that further capacity building for this is required across the system, especially to work within social-ecological, resilience oriented and knowledge co-production orientations. At a wider level, the South African higher education system was struggling to build adequate staffing capacity, and interventions are being put in place to attract young academics into the system, as the system is characterised by an 'ageing' academic workforce. This has implications for CCD capacity building and staff attraction too.

4.6.4 Curriculum development and curriculum innovation

As indicated above there are a number of curriculum development and curriculum innovation activities occurring related to climate change teaching and CCD teaching, across faculties and universities. However, the mapping study revealed that this could be expanded in all universities. Use of service learning opportunities also present an additional curriculum innovation that does not appear to be fully utilised at present.

4.6.5 Research

Many recommendations were made on how research for CCD could be improved in South Africa's university and between other stakeholders. Key amongst these was a more substantive, longer term frame for research funding as it was felt that that short term, short cycle funding was not adequate for the type of research problems that are being addressed under CCD, and especially for knowledge co-production involving multiple stakeholders. Adequate student funding (scholarships) that could attract more black South African scholars was another area critical area that required ongoing attention. The research agenda for CCD is also complex and requires a wide range of expertise, and concerted efforts need to be made to develop a broad range of relevant expertise in ways that develop 'critical mass'.

4.6.6 The role of university leaders

The mapping study also identified a number of roles for university leaders in strengthening South African capacity for CCD research. Amongst these (as noted in questionnaire data) are:

- "Facilitate multidisciplinary research institutes and fund them.".
- "Help to mediate and establish partnerships (public-private) to fund research. Provide support for securing funding for climate change related research."

- "Lead by example in terms of business on campus (planning of new buildings, maintenance of the terrain, etc.)"
- "Provide support for including climate change modules into all earth and environmental sciences and other relevant curricula."
- "Get the internal housekeeping in order – practice what you preach. Step away from fixation on disciplinary silos. Facilitate the introduction of multi/interdisciplinary degrees; and student ability to move between disciplines."
- "Raise awareness of the need to develop resilient responses to climate change."
- "Provide an enabling environment where researchers have time to do research activities and supervise students."
- "Provide infrastructural development, availability of essential equipment, ensuring availability of adequate bursaries for postgraduate students, including research funds."
- "Facilitate the implementation of climate change programmes or research."
- "Support programmes relating to climate change and integration of climate change issues in the curricula."
- "Provide flexible metrics of research engagement in response to stakeholder needs. We need clear recognition that silo-based research is counterproductive in the context of current climate knowledge gaps, yet the career and performance metrics in universities remain discipliner specific. Second, we need greater freedom and support to rapidly grow capacity by providing longer term soft-money support for researchers, and developing career paths for such emerging capacity."
- "To facilitate the attendance at collaboration workshops and also hosting them. To practice climate change 'avoidance' in the operation of the university."
- "University managers are informed by HE policy, which is informed by broader government policies, which are formulated in the neoliberal innovation framework/model. The various parts of the overall system can't be isolated and expected to solve the systemic issue."
- "Provide for an enabling environment for new, appropriate technology development and transfer, and associated capacity development to ensure the transition to a low carbon, resilient economy - the green economy."
- "Support integrated, cross-disciplinary climate change research and training within the university, invest in this research, set an example in terms of the way the university conducts its business (not business as usual), treat climate change as a priority area within the university and not something left only to those that "believe' in it."
- "Driving the agenda as part of core business and including this as part of the institutional business strategies."
- "Make sure things can happen from the bottom up."

From this it can be seen that there is an expectation that university leaders should help to support the creation of an enabling environment for the kind of 'new' scholarship that CC resilience demands. Part of this should also be the setting of examples on campus via campus management practices, mediation of funding and infrastructure development and engaging in academic leadership with regard to curriculum development, and institutional structural changes that can facilitate multidisciplinary scholarship.

5 KNOWLEDGE CO-PRODUCTION POSSIBILITIES

5.1 Current knowledge co-production practices via multi-, inter- and transdisciplinary approaches

5.1.1 Clarifying the meanings of multi-, inter- and transdisciplinary approaches to research

The scope and scale of problems and challenges associated with climate change, and climate compatible development – as shown in the needs analysis of this mapping study Country Report - require new forms of knowledge production. Multi-, inter- and transdisciplinary approaches to research are emerging in this context, from an understanding that research modelled on a 'business as usual' approach will not drive ingenuity in resolving complex social-ecological challenges like climate change.

Historically, the dominant approach to research is based on research in the single discipline. While single discipline research remains extremely important for development of in-depth and high quality knowledge, there is also a need to expand these approaches over time towards new, institutionally more complex forms of knowledge production.[20] Figure 11 below shows that over time, research can build towards and include a wider range of research approaches that include multi-, inter- and transdisciplinary research approaches.

Note: Diagram showing research approaches and how they can emerge over time, in relation to outcomes that meet societal needs in the context of complex problems that need to be resolved such as climate resilient development.[21]

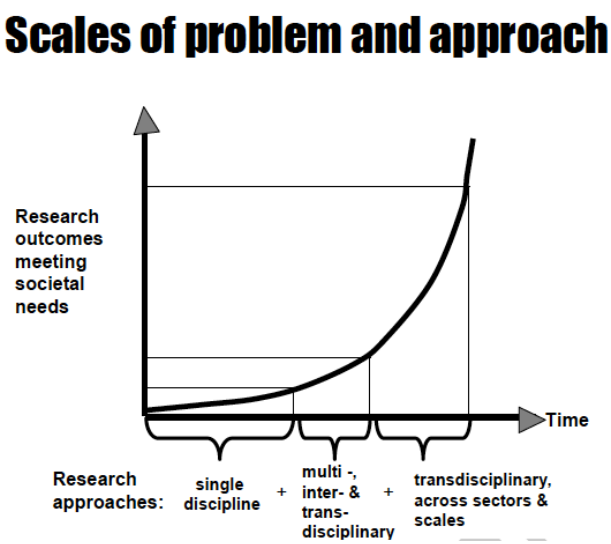


Figure 11: Research approaches

[20] This is because universities are organised and established around a disciplinary knowledge production structure.

[21] Source: Palmer, Lotz-Sisitka, Fabricius, le Roux & Mbingi, in press.

There is global evidence that more researchers are beginning to expand the single discipline approach to research, to include multi-, inter- and transdisciplinary approaches, and through this, their research is engaging across sectors and scales, and with changing social-ecological systems, complexity and integration.

Researchers working with these approaches argue that research outcomes that are generated in this manner have a greater chance of meeting societal needs[22].

These emerging approaches to research are clarified below.

Multidisciplinarity

This involves using different disciplinary studies to address a common empirical focus or problem. Existing disciplinary methods and structures are not changed in multidisciplinary research. Multidisciplinary research helps to develop different 'angles' or different understandings of a problem, from the vantage point of different disciplines.

Interdisciplinarity

This marks a position between multi- and transdisciplinarity. It involves multidisciplinary studies, but takes these further by synthesis work that takes place *across* the different disciplines. It involves the development of a common framework and perhaps the use of discipline-transcending terminology and methodologies while maintaining certain critical disciplinary distinctions. Important in inter-disciplinary research are processes of synthesis and a 'blending' or relating of knowledge from different disciplines.

Transdisciplinarity

This entails using strategies from interdisciplinary research, but it also involves taking this further into development of new theoretical understanding and new forms of praxis that are needed across sectors and at different scales. These are based on an inter-penetration of disciplinary perspectives or understandings, and a 'creative re-deployment' of these in contexts of practice[23]; often contexts that are complex.

It is possible to differentiate between 'weak transdisciplinarity', which only relates existing knowledge to practice and 'strong transdisciplinarity', which goes much deeper into developing new and more complex ways of understanding and engagement in contexts where new forms of theory and practice come together[24] across sectors and at different scales.

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[22] There is a growing body of scientific work that reflects this perspective. See for example: Hirsch Hadorn, G., H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Phol, U. Wiesmann and E. Zemp (eds). 2008. *Handbook of Transdisciplinary Research*. Springer.

[23] Bhaskar, R. 2010. "Contexts of interdisciplinarity: interdisciplinarity and climate change." In *Interdisciplinarity and Climate Change. Transforming knowledge and practice for our global future,* edited by R. Bhaskar, F. Frank, K. Hoyer, P. Naess and J. Parker. London: Routledge.

[24] Max Neef, M. A. 2005. "Commentary: Foundations of Transdisciplinarity," *Ecological Economics* 53: 5-16.

Transdisciplinarity involves different modes of reasoning: the rational, the relational and the practical. Transdisciplinarity research presents an 'unfinished scientific programme' that offers fascinating possibilities for advanced reflection and research.[25] This is increasingly being seen as a real opportunity for innovation. Transdisciplinary research, oriented towards knowledge production for societal change, can be seen as a process that can develop over time.

Knowledge co-production

Traditionally (and currently) most research partnerships and funding arrangements still focus on the single discipline. However, international research platforms are changing towards inter- and transdisciplinary knowledge production, especially in the social-ecological sciences. Engaging in inter- and transdisciplinary knowledge production (because of its interest in new synthesis and creative deployment of knowledge in contexts of practice across scales and sectors) requires new ways of relating, thinking and doing.

As a result, new partnerships are needed between researchers and a wider range of societal actors. Movement in this direction depends on: 1) society becoming widely involved in the research domain (this includes researchers, managers, practitioners and civil society); 2) time investments to develop the trust between and competence of research partners and participants; 3) a willingness to recognise that there are different forms of knowledge that need to interact for societal change to occur; and 4) learning by doing, or social learning[26]. Knowledge co-production is also referred to as knowledge co-creation. This requires working to bring together different contributions in the knowledge production process.

5.1.2 The current 'status' of multi-, inter- and transdisciplinary approaches to research and knowledge co-production

As shown above, there are a number of key drivers of multi- and interdisciplinary approaches to research in South Africa. Key amongst these is the defining of a national research agenda for Global Change and Energy research under the 10 Year Innovation Plan. As seen above the Global Change Grand Challenge National Research Plan sets out a research agenda that involves Earth System Sciences, the Biological and Natural Sciences, the Geographical sciences; Engineering and technological sciences; and the Humanities and Social Sciences including Economics, Ethics, Education, Sociology and others. The energy sector, whilst mostly focused on Engineering, Physics, and technology related study fields is also working with more multidisciplinary approaches especially related to innovation and innovations uptake. The establishment of national research institutions with associated research funding that 'drive' these agendas with funding, and strategic frameworks that work with and in support of university research is having a strong influence on university research, as can be seen by the strategic direction setting and multidisciplinary research thematic clusters that are emerging in the larger research intensive / research led universities such as the

[25] Max-Neef. 2005. "Commentary: Foundations of Transdisciplinarity".

[26] Adapted from the Akili Complexity Forum draft proposal, NRF South Africa (March 2010).

University of Cape Town, the University of Stellenbosch, the University of Pretoria and the University of the Witwatersrand. Smaller universities, universities of technology and universities that do not have as strong a research-based history (i.e. most of the historically disadvantaged universities) are less well-positioned at a strategic level, although the universities of technology are fast positioning themselves as research centres with capacity for the technological CCD related research fields. What appears to be at the centre of establishing multi- and inter-disciplinary approaches is the creation of research thematic areas/ research groups / research hubs and specialised and well-positioned research centres. In such centres a 'critical mass' for research is created that better facilitates research partnership building and multi-institutional arrangements. The NRF rating database also shows that such centres are normally established and run by established or internationally recognised researchers. Behind the institutional drivers, is the actual nature of the research problems that need to be addressed and there appears to be strong consensus that CCD related concerns cannot be addressed via the single discipline, and that multi- and interdisciplinary partnerships are needed.

There are a number of examples of inter- and transdisciplinary research emerging, although the NRF and the WRC have both reported that uptake of funding for transdisciplinary research is slow. University academics report in response that the institutional structures for such research are not well established. Problems faced by academics wanting to engage in transdisciplinary research relate to the existing incentive and promotions systems which favour disciplinary specialisation over inter- and transdisciplinary approaches; there are questions associated with the 'scientific merit' of these approaches in many circles, especially amongst the more strongly established disciplinary structures and research traditions; and there are few accredited journals that publish transdisciplinary research. It appears that while there is some movement towards such approaches at an institutional development level (particularly at a wider research policy, framing and funding level) this is not carried through into the 'nitty gritties' of institutional life in universities. Academics that are engaging with inter- and transdisciplinary approaches to teaching also report that it is not easy to overcome the structural barriers to do with how funding is allocated to various disciplines and departments for teaching loads and responsibilities. Of interest here, however, is that most of the academics that responded to the questionnaire indicated that they were engaged in some form of interdisciplinary teaching and/or research even though most were still associated with a particular Faculty and/or Department. Especially at postgraduate level it seems easier to engage in interdisciplinary teaching activities, and a number of the Masters degrees mentioned had inter-disciplinary elements. The only university with a PhD in Transdisciplinary Studies identified in the mapping study is the University of Stellenbosch.

There are a number of examples of inter- and transdisciplinary knowledge production in South African universities. However, only two are presented here for illustrative purposes (Boxes 1 and 2).

Box 1: CASE STUDY: A research-led programme of knowledge co-production

Title of research Programme: Vulnerability, coping and adaptation within the context of climate change and HIV/AIDS in South Africa: Investigating strategies to strengthen livelihoods and food security and build resilience (Shackleton, S. et. al. 2010)

This research programme, set in two sites in the rural Eastern Cape, South Africa, involved the following studies undertaken by a multi-institutional research partnership (Rhodes University and University of Alberta in Canada). Each study was co-supervised by researchers from each institution and with different disciplinary backgrounds.

Study 1 – Assessing household assets to understand vulnerability to HIV/AIDS and climate change (RU) – Environmental Science and Development Economics Researchers

Study 2 – Effects of social grants on labour supply and food security (UA) – Development Economics and Environmental Science Researchers

Study 3 – Responses to the linked stressors of climate change and HIV/AIDS amongst vulnerable rural households (RU) – Environmental Science and Economics Researchers

Study 4 – Social learning (RU) – Environmental Education, Politics and Environmental Science Researchers

Study 5 – Relative contribution of wild foods to individual and household food security in the context of increasing vulnerability due to HIV/AIDS and climate variability (RU) – Environmental Science and Agroforestry Researchers

Study 6 – Local perceptions of climate change (RU) – Environmental Science Researchers

Study 7 – A community case study of local institutional structures, culture and food security (UA) – Sociology Researchers

Study 8 – An empirical investigation into the relationship between household headship and income i(UA) – Development Economic Researchers

Study 9 - Household adaptive behaviour and climate change: A contingent behaviour approach (UA) - Economic Researchers

Study 10 – Gender and climate change adaptation (UA) - Economic Researchers

Study 11 – De-agrarianisation and forest succession in abandoned fields in a biodiversity hotspot (RU) – Environmental Science Researchers

Study 12 – Baseline and repeat survey of knowledge, attitudes and practices – All Researchers

The research team held monthly meetings as well as regular meta analysis workshops to examine how the knowledge that was being produced in the different studies was related, and what it means in relation to broader policy and scientific knowledge of climate change and HIV/AIDS vulnerability. Through this they have produced meta analysis papers that synthesise the individual research project findings.

The study also worked with the following boundary partners / stakeholders who have an interest in the studies for policy making and practice, where the meaning of the research findings has been deliberated and discussed, particularly for practical and policy related implications:

- Eastern Cape Socio Economic Consultative Council (ECSECC): Provincial policy making responsibility
- Chris Hani District Municipality: Planning and service delivery responsibility at district level
- Gatyana traditional leadership structures: Traditional authority at a local level
- Eastern Cape Environmental Network: Network of 250 sustainable development NGOs in the province
- Environmental Monitoring Group: National NGO working at provincial level on climate change issues
- Isibindi: Local NGO working on community based care for orphans and vulnerable children
- Promotion of Rural Livelihoods Programme (RuLiv): Rural development NGO linked with the Premier's office
- Agricultural extension officers, social development workers

Additionally, a social learning group was established involving community members nominated by the communities involved in the two study sites. Various activities were undertaken with this group to a) understand the meaning of vulnerability from their experience, b) understand their capabilities and c) to strengthen their capabilities and social network interactions to problem solve and further expand their resilience capabilities and agency development. This included practical problem solving actions, and training for community problem solving. This provided a practical mechanism for integrating research knowledge into community action at a local level.

Box 2: University of Cape Town's Bergrivier Transdisciplinary Research Programme (an initiative of the African Climate and Development Initiative (ACDI))

The "Bergrivier" action research project for climate responsive development: Emergence as a challenge and opportunity for transdisciplinary collaboration

The Bergrivier Project is an exploration of the UCT African Climate and Development Initiative (ACDI), seeking to develop innovative means to foster and support inter- and transdisciplinary interactions among researchers, and between researchers and practitioners. The overarching question is: "How do we create and sustain transdisciplinary action research processes that link knowledge co-generation and practice in pursuit of development that is responsive to climate variability and change?" To create a tangible platform for such a process, a geographic focus was identified in the Bergrivier municipal area, though other scales are included where appropriate, such as the Berg River catchment. Drawing on the work of Otto Scharmer and others, a 'U-process' was implemented. This was characterised by dedicated stages for collective 'sensing' of the 'system' and key issues in the region, a retreat to link these themes to personal proclivities and motivation, and smaller teams developing linked action research projects within the broader initiative. This has given rise to the tentative beginnings of a series of nested collaborative research projects involving UCT researchers and students that respond to the overarching question within the case study area.

These research projects include: (i) Support for Bergrivier Municipality in assessing climate change vulnerabilities and designing an adaptation strategy; (ii) Opportunities and barriers for making low cost housing climate resilient; (iii) Exploration of the primary organisational capabilities that are needed and missing in municipalities in support of climate responsive development; (iv) Water system governance in the Bergrivier Municipality and beyond; (v) Climate policy and behavioural change interventions at school and community level; (vi) Long-term land use/land cover change in the Groot Winterhoek Wilderness Area; (vii) Landscape and environmental education.

The project has clearly demonstrated the value of transdisciplinary approaches that engage participants from civil society, government and business in the definition of the research problem and in the actual research. However such processes have high transaction costs (time and funding), require administrative and financial support to maintain a collaborative network, and also raise tensions between research (depth and philosophy of enquiry) and practice (need for action).

Summary produced by the Pro-VC for Climate Change and the Director of the African Climate and Development Initiative (ACDI) at the University of Cape Town, Professor Mark New.

As can be seen from the above examples in Box 1 and 2 (presented here in summary only) these research programmes can provide examples of different facets of the design and development of inter- and transdisciplinary research. Some of the key points worth examining here are:

- Such research programmes tend to be larger scale and involve multiple disciplines and multiple partners, and therefore also the kind of research funding that will support multi-partner and multidisciplinary collaborations.
- Such research programmes tend to require adequate time for synthesis of the individual studies that are often undertaken by researchers in or from specialist disciplines.
- Once individual studies have been conducted and/or synthesised there is a need to carry the findings into practice. This involves engagement with other stakeholders and need not only take place at the end of the research, but these stakeholders may also inform the research problem formulation, and further assist with ongoing reflections on the meaning of the research in and for the social / technical context in and for which it is being produced.

- Such research programmes require skilled and experienced researchers with multi- and interdisciplinary research expertise.
- Social learning processes can add value to the research process, particularly if they are conceptualised as being integral to the research. This, however, requires researchers who are also willing to engage with questions of how the knowledge that they are producing can be disseminated and used in ways other than the via academic journal papers.
- There is a need in such processes to differentiate between the meanings and value of the single discipline study, its relationship to other disciplinary studies, how these differ from interdisciplinary studies and synthesis building across studies; and how interdisciplinarity differs from transdisciplinarity and knowledge co-production processes.

6 SUMMARY AND CONCLUSION

6.1 Synthesis of the needs analysis

6.1.1 Context that drives needs

South Africa already has a well-established warming trend. Even under emission scenarios that are more conservative than current international emission trends, it has been predicted that by mid-century the South African coast will warm by 1 to 2 °C and the interior by around 2 to 3 °C. By 2100 warming is projected to reach around 3 to 4 °C along the coast, and 6 to 7 °C in the interior (RSA 2011b). This will significantly affect human health, agriculture, other water-intensive economic sectors such as the mining and electricity generation sectors as well as the environment in general. Increased occurrence and severity of veld and forest fires, extreme weather events, and floods and droughts will also have significant impacts. Sea-level rise will impact the coast and coastal infrastructure. Mass extinctions of endemic plant and animal species will greatly reduce South Africa's biodiversity with consequent impacts on eco-system services (RSA 2011b).

It is against this context, described in more detail in the Second National Communication to the UNFCC (RSA 2011a), that a set of clearly defined adaptation, mitigation and cross-cutting strategies are put forward at policy level that also commit the country to making the transition to a climate-resilient and low-carbon economy and society. This is to be achieved through balancing mitigation and adaptation responses and, in the long term, redefining competitive advantage and facilitating structural transformation of the economy by shifting from an energy-intensive to a climate-friendly path, as part of a pro-growth, pro-development, and pro-jobs strategy (RSA 2011a). Across all of the policy and strategy documents, workshop inputs and questionnaire data used to inform this mapping study, there is a very clear recognition that this will have to be done **by building the knowledge base and capacity** to upscale mitigation efforts, while also adapting to the inevitable impacts of climate change in key affected sectors, and by enhancing early warning and disaster reduction systems.

6.1.2 Adaptation and mitigation priorities identified for South Africa

The National Climate Change Response White Paper (RSA 2011b) identifies a set of clearly defined adaptation measures for the following areas: water security; agriculture and commercial forestry; health; biodiversity and ecosystems adaptation; human settlements (urban, rural and coastal); disaster risk reduction and management. There are also mitigation targets identified in the National Climate Change Response White Paper (RSA 2011b) which include: setting a performance benchmark for GHG emissions, identifying desirable sectoral mitigation contributions, defining carbon budgets for significant GHG emitting sectors and/or sub-sectors, developing and implementing a wide mix of mitigation approaches, policies, measures and actions that optimise mitigation outcomes as well as job creation and other sustainable development benefits, using market instruments and monitoring and evaluation. These are important priorities, as South Africa is one of the highest emitters of GHG per capita in the world. The National Climate Change Response White Paper also sets out broader objectives for systemic change, including policy and regulatory alignment, co-ordinated sectoral response, integrated planning, facilitated behaviour change (using

incentives and disincentives) and resource mobilisation. Two priorities that are particularly important for this mapping study are the intention to prioritise research, systemic observation, knowledge generation, information management and early warning systems that increase national abilities to measure and predict climate change and the implications of its adverse effects on the economy, society and environment. Additionally, the National Climate Change Response White Paper also prioritises education, training and public awareness and recommends actions to integrate climate resilient development principles into national curricula and into higher education curricula and teaching programmes, to strengthen research capacity in universities, and to undertake labour market research to inform the emergence of a green TVET system.

6.1.3 National research themes and knowledge needs

The Global Change Grand Challenge has a well-defined National Research Plan that was produced by a broad community of Global Change researchers, including those that are associated with SAEON, AEON, the CSIR, WRC, ARC, SANBI, universities and other major research institutions. The research plan identifies research needs and research questions that cover both the earth system sciences, the ecological sciences, and the social sciences, using a framework of four 'knowledge challenges' which include: Understanding a Changing Planet (with five research themes: observation and monitoring, dynamics of the oceans around southern Africa, dynamics of the complex internal earth systems, linking the land, air and sea, improving model predictions at different scales); Reducing the Human Footprint (with four research themes: waste minimisation methods and technologies, conserving biodiversity and ecosystem services, institutional integration to manage ecosystems and ecosystem services, doing more with less); Adapting the way we live (with four research themes: preparing for rapid change and extreme events, planning for sustainable urban development in a South African context, water security for South Africa, Food and fibre security for South Africa); and Innovation for Sustainability (with five research themes: dynamics of transition at different scales, resilience and capability, options for greening the developmental state, technological innovation for sustainable social-ecological systems, and social learning for sustainability, adaptation, innovation and resilience). The Energy Grand Challenge has identified four major thrusts which are also relevant to CCD, namely: Clean coal technologies for environmentally friendlier processes; nuclear energy generation; renewable energy technologies with focus on commercialisation and coherent policy interventions; and hydrogen with the goal to place South Africa (which holds 87 percent of the known platinum reserves) in the emerging fuel cell market. The Second National Communication to the UNFCC, and the National Climate Change Response White Paper, and the Long Term Mitigation and Adaption Strategies also identify research needs. These provide important nuance, and refinement on the broader research themes identified in the Grand Challenge National Research Plans, showing reflexivity amongst research communities, which is made possible by the existence of coherent national research plans.

Workshop participants identified social learning and social innovation, integrative and systemic approaches, human settlements, climate change and health, and agriculture and water as key research priorities. Questionnaire data shows more detailed engagement and contextualisation of these broader research themes, for example priorities on adaptation and livelihoods in rural areas, how heritage shapes social learning engagements with new sustainable practices, renewable energy technology development, life cycle assessments of various construction materials, passive

ventilation and lighting methods for health care facilities, sustainable landscaping on national highway roads, landscape level adaptation practices, water security in catchment contexts, transitions to green economies and so on. This more refined engagement with national research themes is evident in this citation from a questionnaire:

> *"There is relatively little knowledge in SA regarding the impacts of CC on human health, particularly the multiplier effect of CC on large scale current public health challenges such as malnutrition; waterborne diseases; HIV and Malaria."*

Workshop and questionnaire respondents also raised other dynamics of the CCD research agenda oriented towards a broader social change agenda, not quite as visible in policy and research plans such as "*Changing social values and aspirations shift in a from 19th century political ideologies to a political ideology that is relevant to the challenges of the 21st century*", and "*Restructuring of law and economics and social change with a specific emphasis on poverty alleviation and protection of vulnerable people to increase human and environmental security and resilience*".

6.1.4 Individual capacity gaps

As can be seen above, the South African climate change vulnerability context and policy response objectives create a challenging environment for capacity development. South Africa's education system continues to suffer from poor quality basic education which affects higher education provisioning in numerous ways. There are high levels of drop out in the schooling system, and South Africa continues to come last in international benchmarking tests in literacy, mathematics and sciences. The educational quality problems are both fuelled by, and exacerbated by high levels of social inequality, which continue to persist, despite social policies that seek to transform contexts of poverty (the Gini coefficient is still between 0.66 and 0.69, one of the highest in the world). A spate of recent human capital development strategies and plans in and for the environment and sustainable development sector point to high levels of skills shortages in key occupations relevant to CCD. These skills shortages have been classified as 'absolutely' scarce, which means that there are simply no people in the country with these skills, and 'relatively' scarce, which means that there may be people with the requisite skills, but that these need to be re-oriented for specialist aspects. The national scarce skills list (see Appendix F) gives an indication of the shortage of key professions and skills required for CCD. As stated in the Second National Communication "these skills shortages are likely to constrain innovation and implementation relating to climate change adaptation and mitigation in urban [and rural] settings". Ongoing attempts to quantify skills shortages continue, and in 2010 the Department of Environmental Affairs noted shortages of over 600 environmental science professionals, and over 800 environmental technicians in the public sector alone. These include oceanographic sciences, ecologists, hydrologists, managers, environmental technicians and so on. The Department of Environmental Affairs National Environmental Sector Skills Plan for South Africa concludes that the skills development system in South Africa has been 're-active' rather than pro-actively engaged with the provisioning of environment and sustainable development skills.

The Department of Science and Technology in its human capital development plan for the Global Change National Grand Challenge identified shortages of skills in specialist areas such as Biogeography and evolution, Climatology and climate modelling, Development studies, Disturbance, population and dispersal ecology, Ecophysiology, both terrestrial and marine; Environmental history,

particularly over the past 300 years, Human demography, Geomorphology, Hydrology, Paleoecology and paleoclimatology, including palynology, Physical and biological oceanography, Resource and environmental economics, Social anthropology and sociology, Systems ecology and biogeochemistry. These, it was argued, "are the core disciplinary skills needed to address fundamental Earth System questions, including the analysis of the human subsystems coupled to the biosphere".

The South African National Biodiversity Institute, working on human capital development planning for biodiversity management in South Africa, has also identified a variety of scarce skills, including GIS specialists, bioinformatics, marine taxonomy, resource economy, leadership (amongst others). Important for this mapping study, and its intention to strengthen the education, training and research system, is the identification by both the Department of Environmental Affairs and SANBI studies that environmental education / human capital development skills are also 'scarce skills' in South Africa, and are in short supply given the scope of environmental education and training that is required across the system. [Note: the use of the term 'skills' here recognises that skills do not exist without knowledge and values, and it is all these that need attention in education, training and capacity building systems). Green Economy planning and the new national infrastructure programmes are also highlighting scarce skills. For example, plans are in place to address the national shortage of environmental engineers (estimated at 300) for the structural infrastructure programme, while efforts are underway to strengthen energy technology skills (e.g. for installation of solar water heating systems) in FET Colleges. Workshop participants commented on the need for cross-scale, integral systems thinking; capacity for dealing with complexity; capacity for engaging with indigenous knowledge in science contexts; skills for accessing and working with climate data; and systems innovation skills as being important for CCD.

6.1.5 Institutional capacity gaps

While South Africa has a relatively well developed research infrastructure and set of research institutions, there are still institutional capacity gaps, especially in the context of transitioning to a low-carbon, climate resilient society. The National Climate Change Response White Paper recognises that the institutional infrastructure for Science and Technology in South Africa is inadequate for building a climate resilient future, especially to support a 'robust' climate change response. The NCCRWP suggests the need for a climate change foresight exercise, because the response to climate change is so complex. Out of this foresight exercise, the government seeks to deliver a robust human capital development plan for climate science and technology informed by the country's climate change response requirements and the outcomes of the National Employment Vulnerability Baseline and Assessments as well as the Sector Jobs Resilience Plan (RSA 2011b). Additionally it seeks to develop a complementary science and technology development plan for climate change, and a climate change technology roadmap. The DST will also conduct a feasibility study into development of a specialised funding agency: the proposed **Climate Change Science Council**, and to further develop funding instruments for research and development (RSA 2011b). This will hopefully respond to a) the inadequacy of current research infrastructure for CCD, and b) inadequacy of research funding mechanisms. As one workshop group noted "research funding is needed that allows for robust piloting and experimental development in the region of tens of millions is needed, not three or four million". This, the group noted "would also allow for longer term – at least ten year – research cycles" which are needed for serious research into the use of urban open spaces for SES

mitigation and adaption in cities for example. Similar points were made in relation to rural livelihoods development research for adaptation and so on. The key point being that the kind of CCD research that is required for substantive impact is not short term, and requires substantive funding for real impact, especially if such research is also to operate across scales, and if it is to adopt integrative social-ecological systems approaches.

Workshop participants noted that research funding cycles were currently too short, and were linked to government budget cycles (the MTEF cycles) which were not substantive enough for enabling large scale, interdisciplinary and multi-site / multi-scale research programmes. Other institutional capacity gaps identified in the mapping study include scientific infrastructure such as modern laboratories and science institutes, supervision capacity and adequate bursary funding that could attract more black South African scholars into postgraduate studies, provisioning of funds for international scholars, cross sectoral collaboration, policy synergy. Issues associated with leadership and commitment were also noted, and it was said that for CCD goals to be achieved, as per the policy, then dynamic organisations and leadership was needed, and that there was a need for better understanding of practical mandates, responsibilities and outcomes related to adaptation and mitigation and the relationships that exist between mitigation and adaptation practices. From a technical perspective, whilst South Africa probably has some of the best observational research capacity in southern Africa, it was still noted that a key challenge is a lack of permanent observation and monitoring sites, and sites used are often of a sub-optimal size. Key areas are also under-represented in monitoring work such as arid and semi-arid areas, forests and woodlands, mountains, agro-ecosystems, and rural areas (RSA 2011a), and there is need for a more integrated system for monitoring and observation, which includes provisioning of sensing imagery and imaging devices, state-of-the art data processing and analysis hardware and software, relevant laboratory space and equipment as well as robust and accessible information management systems. Workshop participants, however, warned of a technology and science bias to the approach to the problem, and noted that the current science planning tended to disregard, and underfund the contributions of humanities and social sciences in climate change research environments. It was also suggested that more attention should be given to strengthening humanities, and social research systems and institutions for CCD research, and to the development of research institutions that can 'model systems thinking'. Another institutional capacity gap cited was a lack of adequate forums that support curriculum innovation, and lack of university management support for sustainable development related directions in universities. There was also a 'gap' between researchers and societies, and current research incentives structure perpetuated this as it did not reward multidisciplinary, transdisciplinary, or community engaged approaches to research, despite much rhetoric surrounding these 'new' approaches. It was also said that there was a fundamental tension between CCD / SD and social justice related intentions of CCD, and the intentions of the 'neo-liberal' capitalist drive, which was said to also be 'shaping Higher Education directives and the research funding environment'. It was also said that there was a lack of appropriate institutional forums for engaging with public-private partnerships that need improvement.

From the above, it is clear that South Africa has made strong commitments to a climate-resilient development pathway in response to its projected vulnerabilities. It is also clear that research and knowledge production is a key element of this. Given the complex array of skills shortages and the need for new specialisms for social-ecological sciences and systems thinking approaches, much needs to be done to strengthen the pathway for knowledge co-production approaches to flourish.

Especially important perhaps are the discussions on more sustained, longer term and substantive funding for real impact to emerge in social-ecological systems research, and a stronger commitment to social science and systems-based research.

6.2 Synthesis of institutional analysis

There are numerous, complex knowledge, research, individual and institutional capacity needs expressed in various human capital development strategies produced by the Department of Environmental Affairs, the Department of Science and Technology (for the National Global Change Science Plan), the water, waste and biodiversity sectors, as well as by those involved in Green Economy planning and energy sector planning, other national stakeholders and university staff themselves. The Second National Communication and the South African National Climate Change Response White Paper (2011) highlight a number of major institutions responsible for research concerned with climate change: the Department of Science and Technology which is responsible for implementing the National Research and Development Strategy (NRDS) and the Ten Year Innovation Plan. These two policy frameworks include a definition of a number of National Grand Challenges, including the Energy Grand Challenge, and the Global Change Grand Challenge. Two of five of the National Research Grand Challenges in South Africa are oriented towards CCD.

The DST works closely with the National Research Foundation who supports the South African Environmental Observation Network (SAEON), the African Earth Observation Network (AEON), and has a system of Centres of Excellence (which includes the Applied Centre for Climate and Earth System Sciences (ACCESS)), South African Research Chairs (SARCHI) located at universities, and other research programmes such as the Global Change Society and Sustainability National Research Programme (GCSSNRP) and the National Energy Research Centre. There are also plans to establish a Technological Innovation Agency (TIA); all of which are to address the 'innovation chasm' – the gap that exists between knowledge generators, society and the market within a knowledge economy framework. Additionally there are other research institutions that carry out research in the field of climate change, for example the Council for Scientific and Industrial research (CSIR) and the Human Sciences Research Council (HSRC), the Water Research Council (WRC) and the Agricultural Research Council (ARC). South Africa is the country with the highest R&D expenditure in the region.

South Africa has a relatively well developed institutional framework for research overall, and for CCD research. However, this system is still in development, and has only really been functioning for the past five years under the National Energy Grand Challenge and the Global Change National Grand Challenge research frameworks. As noted in the National Climate Change Response White Paper, further impetus is needed to strengthen the Science and Technology infrastructure for climate change and CCD research. The proposal for a foresight study, and the possible establishment of a Climate Change Science Council are promising in this regard, as are current funding commitments to developing Centres of Excellence (such as the Applied Centre for Climate and Earth System Sciences), the African Environmental Observation Network (AEON), the South African Environmental Observation Network (SAEON) and a number of SARCHI Chairs that focus on global change / CCD related research themes.

The South African institutional assessment also revealed that there are a number of new and emerging Centres of Expertise (normally around established and acclaimed researchers and/or

research chairs) in institutions and new Centres of Excellence emerging (normally around expansive university and other stakeholder partnerships) that can potentially provide strong platforms for CCD knowledge co-production in future.

The institutional assessment revealed that the 23 South African universities are almost all engaged with some form of research that is relevant to CCD (see the table in Appendix E). However, the institutional assessment also revealed that research capacity across the South African university system is *highly unequal,* with some universities such as the University of Cape Town, the University of Pretoria, the University of Stellenbosch, the University of Johannesburg, the University of KwaZulu Natal, the University of the Witwatersrand and Rhodes University having more capacity for CCD related research than others. This inequality mirrors historical inequalities in the South African university system. There is, however, a concerted effort at government level to support historically disadvantaged universities to become more involved in CCD research and three Risk and Vulnerability Assessment Centres have been placed at the University of Fort Hare, the University of Limpopo and the University of Venda. The University of the Western Cape is also actively developing its Life Sciences research capability and has recently opened a new Life Sciences building with state of the art facilities, and in the recent round of bidding for SARCHI research chairs UWC was awarded seven research chairs.

The institutional assessment was not able to probe into the full range of courses being offered in CCD related fields in South African universities due to the scope of the task. However, the Department of Environmental Affairs Environmental Sector Skills Plan for South Africa (DEA 2010) showed a 'groundswell' of new environmental courses being developed in and across all of South Africa's universities with almost every university having a Department of Environmental Sciences (which would not have been the case 20 years ago). Interesting however, is that CCD related courses are not only confined to the Departments of Environmental Sciences, and are instead emerging across a range of disciplinary contexts. There are also examples of courses that are explicitly multi- and transdisciplinary in their construction, especially at Masters level.

Questionnaire data, although limited to 40 respondents, showed that there were some interesting curriculum innovations occurring in response to sustainability and CCD related issues most notable amongst these are the University of Stellenbosch's Tsama Hub Transdisciplinary PhD programme, the University of Stellenbosch MPhil in Sustainable Development (which is multidisciplinary); the University of Cape Town's MSc/M Phil specialising in Climate Change and Sustainable Development, the Rhodes University Environmental Learning Research Centre's MEd and PhD programmes that specialise in Environment and Sustainability Education and Social Learning (which includes a CCD focus); UNISA's Exxarco Chair's teaching programmes in climate change, business and the green economy; the University of Free State Masters Degree in Integrated Water Resources Management (focus on groundwater); and Disaster Risk Management and the University of KwaZulu-Natal's MSc programmes in conservation, agriculture and water resources management. The University of Fort Hare's Agricultural Degrees, and the University of Limpopo also have programmes on offer that address CCD related concerns notably the Agricultural, Environmental and Geographical Sciences. The University of the North West has strong environmental law and governance programmes in place, while the University of Pretoria has conservation, environmental management and sustainable development and built environment degree and post-degree programmes.

Overall this shows that there is a vibrant context of academic innovation for sustainability and CCD 'alive and well' in South Africa. However, workshop data showed that although academics were engaged in this kind of curriculum innovation, and were obviously able to 'push through' their innovations at systemic level, there was still a tendency to privilege the 'traditional course' or 'disciplinary specialisation' route. It was said that HEI leadership institutions such as the Council of Higher Education (who performed quality assurance functions) and HESA should be encouraged to take an interest in CCD related concerns and that they should actively promote new societal directions and agendas, as they did with the HIV/AIDs issue. Addressing CCD issues in education through a concerted, systematically oriented approach, is critical for longer term social justice and well-being in South African society.

Questionnaire data also revealed that there were a number of student societies actively engaging with environment and sustainability issues in South African universities, and that they were 'networked' with each other via a network called the Green Campus Initiative which Nelson Mandela University have been supporting and via the 'BlueBuck network' (referring to the first antelope to go extinct in SA), which is a student-led initiative to link up student organisations engaged in climate and environment related concerns

Stakeholders and university professionals in South Africa showed a clear understanding that CCD was closely related to both adaptation and mitigation and sustainable development, although the meaning of CCD should not be taken for granted, nor should it be assumed that it is uncontested. The institutional analysis also showed there is an active and emerging engagement with transdisciplinarity, and a number of examples of transdisciplinary research were identified, although these were in various stages of development and the contours of transdisciplinarity in the various projects were still being worked out, theorised and monitored. The NRF's Global Change Society and Sustainability research programme funding actively encouraged transdisciplinary proposals, but they report that only two strong transdisciplinary proposals were presented and approved for funding. However other organisations such as the Water Research Commission and international funding organisations are also beginning to call for transdisciplinary research programme proposals, such as the most recent CARIA research programme call, which was awarded to UCT. This is generating interest in transdisciplinary research, also amongst university management involved in the promotion of research. South African researchers, especially at the research intensive and research led universities are also 'well networked' into international research environments, and are partnering with both regional universities in southern Africa and elsewhere on the African continent, and with international research partners.

The institutional assessment has also highlighted that while an active research community and a relatively strong research infrastructure for CCD research exists in South Africa, it is still inadequate for the scope of demand. The research environment also continues to be affected by ongoing inequalities that exist between institutions, and one of the key priorities in research infrastructure development is to develop a more equitable research environment that benefits all students in all South African universities, and to upscale the research infrastructure for climate change. As shown in the institutional assessment, there is capacity for curriculum innovation, but this is also unevenly spread, and institutions like the CHE and HESA need to take a stronger leadership role in enabling all universities to engage with new societal priorities such as climate change. Research funding, while available, was also said to be inadequate for the *type* of interdisciplinary, multi-sector and multi-

scale research that is required for CCD problems. Technical skills shortages, and lack of adequate supervision capacity (as pointed out in the needs analysis) also hampers knowledge co-production possibilities for CCD.

6.3 Enhancing knowledge co-production possibilities for CCD in South Africa and SADC

6.3.1 Possibilities for linking into a networked system of knowledge co-production in the SADC region

Climate Change and CCD research and teaching in South Africa seems to be characterised by strong Observation and modelling; Earth System / Global Change; Biological and Geographic sciences; as well as Energy and clean technology (e.g. clean coal) engineering and technology research expertise and programmes. However, there are also other 'pockets' of research emerging in the CCD area such as urbanisation and sustainability concerns; poverty and livelihoods and CCD; conservation and CC linked adaptive management; CC and Agriculture; and CC, water and social-ecological systems research that stand out. Climate change research appears to be weakest in the Social Sciences and Humanities, but emerging new areas of expertise in Green Economy and Transitioning, and Climate Law, Resilience and Social learning research is also emerging. South Africa also has a number of researchers that are working on business and climate change as a focus area. There are also a number of institutions that are beginning to focus strongly on multi- and interdisciplinary studies involving scientists from a range of disciplines. These are all areas of strength that can contribute to regional knowledge co-production.

APPENDIX A: WORKSHOP ATTENDANCE LIST

List of participants at the South Africa workshop, 21 September 2013

GROENKLOOF CAMPUS, UNIVERSITY OF PRETORIA

FULL NAME	ORGANISATION	DESIGNATION	CONTACT NUMBER/S	EMAIL ADDRESS
Brian Delcarme	Cape Peninsula University of Technology (CPUT) / Applied Science		0822020774	Delcarmeb@hotmail.com
B Nzokizwa	St. College / Private		0742173707	Nzobmail@webmail.co.za
Achuo Enow	National Research Foundation (NRF)	Programme Director	0739120573	a.enow@nrf.ac.za
Prime Ngobeni	Tshwane University of Technology (TUT) / Science	Assistant Dean	0820943507	ngobenip@tut.ac.za
Puffy Soundy	Tshwane University of Technology (TUT) / Crop Sciences	Professor & HOD	0827730484	SoundyP@tut.ac.za
Linda du Toit	Tshwane University of Technology / Animal Science	Lecturer	0837413375	dutoitcjl@tut.ac.za
Zelda Uwah	Central University of Technology (CUT)	Manager	0725591400	zuwah@cut.ac.za
Harry Kotze	University of Free State (UFS)	Director: Research	0823093597	kotzehf@ufs.ac.za
Hazel Nampanya	National Research Foundation (NRF)	Corporate Governance	0842277791	Sindy.nampanya@nrf.ac.za
Charles Mutengura	University of Forth Hare (UFH)	Lecturer	0727062495	cmutengura@ufh.ac.za

FULL NAME	ORGANISATION	DESIGNATION	CONTACT NUMBER/S	EMAIL ADDRESS
S Manzini	Green Matter	Executive Director	0814390957	sibusiso@greenmatter.co.za
LD Beukes	University of Pretoria (UP), Faculty of Education	Lecturer	0824259521	ld.beukes@up.ac.za
JC Engelbrecht	Tshwane University of Technology (TUT), Environmental Health	Associate Professor	0837786557	engelbrechtja@tut.ac.za
PF Vosloo	University of Pretoria (UP), Department Architecture	Professor	0823744497	piet.vosloo@up.ac.za
Mucha Togo	South African Qualifications Authority (SAQA)	DD Research	0727791350	muchatogo@gmail.com
Hennie Stofberg	UNISA	Professor	0827916084	stoffh@unisa.ac.za
Chantelle van Wyk	Tshwane University of Technology (TUT)	Lecturer	0798920628	VanWykC2@tut.ac.za
Lydia Mogano	Southern African Faith Communities' Environment Institute (SAFCEI)	Regional Coordinator	0722987857	Lydia@safcei.org.za
Lulama Makhubela	Tshwane University of Technology (TUT)	DVC: Post Graduate Studies, Research and Innovation	0827282951	makhubelal@tut.ac.za
Stephanie Burton	University of Pretoria (UP)	DVC: Research and Postgraduate Education	0825558663	Stephanie.burton@up.ac.za
GE Swan	University of Pretoria (UP)	Dean: Faculty of Veterinary Science	0836366157	Gerry.swan@up.ac.za
R Kruger	Tshwane University of Technology (TUT)	Acting HOD	0836247159	krugerr@tut.ac.za

FULL NAME	ORGANISATION	DESIGNATION	CONTACT NUMBER/S	EMAIL ADDRESS
J Snyman	Tshwane University of Technology (TUT)	Lecturer	0828051852	snymanj@tut.ac.za
Zini Manana	National Research Foundation (NRF)	Professional Officer	0835564210	Ntombizini.manana@nrf.ac.za
Lientjie Mogano	National Research Foundation (NRF)	Officer	0796939274	Lientjie.mogano@nrf.ac.za
Pandeleni Dzhugudzha	Dept of Environmental Affairs	Deputy Director	0123103080	Pdzhugudzha@environment.gov.za
Louis Kotze	North West University, Law	Professor	0182991974	Louis.kotze@nwu.ac.za
Anel du Plessis	North West University, Law	Professor	0182991969	Anel.duplessis@nwu.ac.za
Willemien du Plessis	North West University, Law	Dean	0182991969	Willemien.duplessis@nwu.ac.za
Beatrix Bouwman	North West University	Mrs	0182994955	Bibi.bouwman@nwu.ac.za
Catherine Coni	Tshwane University of Technology	Mrs	0834428498	conic@tut.ac.za
Judy Beaumont	Dept of Environmental Affairs	Director	0826530625	jbeaumont@environment.gov.za
Rehana Dadu	Nelson Mandela Metropolitan University (NMMU), Geo Sciences		0828296933	Rehana@greenit.co.za
Rosemary Naidoo	Tshwane University of Technology	Lecturer	0837935331	NaidooRM@tut.ac.za
Dineo Ngobeni	Department of Environmental Affairs (DEA)	Director	0825019677	dngobeni@environment.co.za
Chrisna du Plessis	University of Pretoria, Cons. Econ.	Professor	0828987877	Chrisna.duplessis@up.ac.za

FULL NAME	ORGANISATION	DESIGNATION	CONTACT NUMBER/S	EMAIL ADDRESS
Frank Mazibuko	National Research Foundation (NRF)	Mr	0725914836	fmazibuko@nrf.ac.za
Xolani Funda	Tshwane University of Technology (TUT)	HOD	0824695551	fundaxn@tut.ac.za
Jannie Maree	Tshwane University of Technology (TUT)	Rand Water Chair	0824653547	mareej@tut.ac.za
James van Hasselt	WHO Africa – CC & Health Committee	Dr	0823308484	jamesvh@global.co.za
Lorenzo Fioramonti	University of Pretoria, Centre of Governance & Innovation	Director, Professor	0760781776	Lorenzo.fioramonti@up.ac.za
G Mugovhani	Tshwane University of Technology, Arts	Professor	0828703475	mugovhanig@tut.ac.za
Neville Sweijd	ACCESS	Director	0829689660	nsweijd@access.ac.za
Edison Muzenda	UJ	Professor	0764582317	emuzenda@uj.ac.za
A Aboyade	UJ	Energy Specialist	0787477331	aaboyade@uj.ac.za
L Zhou	University of Fort Hare	UFH	0827301106	lzhou@ufh.ac.za
KO Odeku	University of Limpopo	Associate Professor	0764793816	kooacademics@gmail.com
D Nyanganyana	ICSU RSA	Manager	0764152009	d.nyanganyana@icsu-africa.org
P Witbooi	University of the Western Cape (UWC), Mathematics	Professor	0219593027	pwitbooi@uwc.ac.za
M Chudy	University of Pretoria, Dept of Engineering	Dr	0781548211	Michael.chudy@up.ac.za
C Valdes-Parada	University of Pretoria, Dept of Engineering	Mr	0781234530	valdesparada@gmail.com

FULL NAME	ORGANISATION	DESIGNATION	CONTACT NUMBER/S	EMAIL ADDRESS
Melanie Murcott	University of Pretoria, Law	Lecturer	0739176255	Melanie.Murcott@up.ac.za
Koen Dekeyser	Koen Dekeyser, University of Ghent, International Politics		0826436620	Dekeyser.koen@gmail.com
Kofitsyo Cudjoe	Norwegian Veterinary Institute	Professor	0764795997	kofitsyo@gmail.com
Gillian Maralle	Wits Business School	Professor	0824923251	Gillian.marcelle@wits.ac.za
Dr Elhadi Adam	University of Limpopo, RAVAC	Dr	0726633222	Elhadi.adam@ul.ac.za
Prof Jacques Laubscher	Tshwane University of Technology, Architecture, EBE	Prof	0722264579	laubscherj@tut.ac.za

APPENDIX B: ACTIVE RESEARCHERS IDENTIFIED WHO ARE CONTRIBUTING TO CC /CCD RELATED RESEARCH ACTIVITIES

Table 5: Active researchers contributing to CC/CCD related research activities

University	Name	Job title	Years of experience	Years of CCD experience	Faculty	Department	Programme / centre / unit / institute	Email
University of Witwatersrand	Jasper Knight	Associate Professor	20	20	Science	Geography		jasper.knight@wits.ac.za
University of Witwatersrand	Ochanda Khaseute Valentine	Lecturer	3	8	Engineering and Built Environment	Architecture and Planning	Global Change and Sustainability Institute (GCSRI)	valvabanda@gmail.com
University of the Western Cape	Peter Witbooi	Professor	30	2	Science	Mathematics and Applied Mathematics	Science Faculty	pwitbooi@uwc.ac.za
University of the Free State	Linda de Wet	Lecturer	11 years	Approx. 5 years	Natural and Agricultural Sciences	Soil, Crop and Climate Sciences	Agro-meteorology (division)	dewetl@ufs.ac.za
University of the Free State	Stephan Steyn	Lecturer	10	5	Natural and Agricultural Sciences	Soil, Crop and Climate Sciences	Agro-meteorology	steynas@ufs.ac.za
University of South Africa	Godwell Nhamo	Chief Researcher and Exxaro Chair in Business and Climate Change	16	8	College of Economic and Management Sciences	Institute for Corporate Citizenship	Exxaro Chair in Business and Climate Change	nhamog@unisa.ac.za
University of Pretoria	Chrisna du Plessis	Associate Professor	15	15	EBIT	Construction Economics	Programme: Trust (Think	chrisna.duplessi@up.ac.za

University	Name	Job title	Years of experience	Years of CCD experience	Faculty	Department	Programme / centre / unit / institute	Email
							Tank on resilient Urban Systems in Transition)	
University of Pretoria	Michael Chudy	Senior Researcher	2	2	Engineering	Graduate School of Technical Management		michael.chudy@up.ac.za
University of Pretoria	Piet Vosloo	Professor	45	20	Engineering Built Environment and Information Technology	Architecture	Programme in Landscape Architecture	piet.vosloo@up.ac.za
University of Pretoria	Neels van Rooyen	Architect/ Lecturer	07/01/2013	2	EBIT	Architecture	Construction	neels.vanrooyen@up.ac.za
University of KwaZulu-Natal	Trevor Hill	Associate Professor	25 years	25 years	Agricultural, Earth and Environmental	Geography	Geography	hillt@ukzn.ac.za
University of KwaZulu-Natal	Sabine Stuart-Hill	Lecturer	6	6	N/A	School of Agricultural, Earth and Environmental Sciences	Centre for Water Resources Research	Stuart-Hills@ukzn.ac.za
University of KwaZulu-Natal	Maria Ferentinou	Lecturer	13	6	Geological Sciences	School of Agriculture Earth and environmental Science		Ferentinou@ukzn.ac.za

University	Name	Job title	Years of experience	Years of CCD experience	Faculty	Department	Programme / centre / unit / institute	Email
University of KwaZulu-Natal	Michael	Senior Lecturer	5	5	Environmental Sciences	Geography		gebreslasie@ukzn.ac.za
University of KwaZulu-Natal	Sam Kusangaya	Student	18	6	Bioresources engineering and hydrology	Centre for water resources research	Environmental Hydrology	kusangayas@yahoo.com
University of Johannesburg	Jaenine Marais	Executive Secretary	18	1year +	Faculty of Management			jaeninem@uj.ac.za
University of Fort Hare	Charles Mutengwa	Senior Lecturer	9	9	Science and Agriculture	Agronomy	Crop Science Unit	cmutengwa@ufh.ac.za
University of Fort Hare	Leocadia Zhou	Programme manager	3	3	Science and Agriculture	N/A	Risk and Vulnerability Science Centre	lzhou@ufh.ac.za
University of Fort Hare	Viola Maphosa	Senior Lecturer	18	2	Science and Agriculture	Department of Livestock and Pasture Science	Goat production improvement in a changing climate	vmaphosa@ufh.ac.za
University of Cape Town	Bruce Hewitson	Professor	24	24	Science	Environmental and Geographical Science	Climate System Analysis Group	Bruce.Hewitson@uct.ac.za
University of Cape Town	G Thompson	Postdoctoral research fellow	1	1	Science	Biological Sciences	NRF Professional Development	genevieve.tomsin@gmail.com

University	Name	Job title	Years of experience	Years of CCD experience	Faculty	Department	Programme / centre / unit / institute	Email
							Programme	
University of Cape Town	Jenny Day	Retired academic	45	15	Science	Biological Sciences		
University of Cape Town	Johannes John-Langba	Senior Lecturer	10	10	Faculty of Humanities	Department of Social Development		johannes.john-langba@uct.ac.za
University of Cape Town	Mathieu Rouault	Principal research officer	20	15	Science	Oceanography	Nansen Tutu centre for environmental research	Mathieu.Rouault@uct.ac.za
Tshwane University of Technology	C J Lideque du Toit	Lecturer	10	4	Science	Animal Science	Animal production	dutoitcjl@tut.ac.za
Tshwane University of Technology	Catherine Coni	Lecturer	13	CCD always been one of chapters at undergrad level	Science	Environmental Water, Earth Sciences	National Diploma: Environmental Sciences	conic@tut.ac.za
Tshwane University of Technology	JC Engelbrecht	Associate Professor	31	4	Science	Environmental Health	Environmental/ Public Health	engelbrechtjc@tut.ac.za
Tshwane University of Technology	Koos Engelbrecht	Associate Professor	31	5	Science	Environmental Health	Environmental health	engelbrechtjc@tut.ac.za

University	Name	Job title	Years of experience	Years of CCD experience	Faculty	Department	Programme / centre / unit / institute	Email
Tshwane University of Technology	Prince Ngobeni	Associate Dean	20	10	Science	Chemistry		ngobenip@tut.ac.za
Tshwane University of Technology	R Kruger	Acting HoD Department of Fine and Applied Arts	18	0	Arts	Fine and Applied Arts		krugerr@tut.ac.za
Tshwane University of Technology	J P Maree	Rand Water Chair in Water Utilisation	38	1	Science	Environment, Water and Earth	Water treatment	mareej@tut.ac.za
Stellenbosch University	Alan Brent	Professor and Associate Director	18	13	Engineering and Economic and Management Sciences	School of Public Leadership	Centre for Renewable and Sustainable Energy Studies	acb@sun.ac.za
Rhodes University	Sheona Shackleton	Professor	30	6	Science	Environmental Science		s.shackleton@ru.ac.za
North-West University	Beatrix Bouwman	Director Community Engagement	30	10	N/A	Community Engagement and sustainability	N/A	bibi.bouwman@nwu.ac.za
North West University	Louis Kotze	Professor	12	10	Faculty of Law	Faculty of Law	Environmental Law	louis.kotze@nwu.ac.za
North West University	W du Plessis	Professor	32	10	Law		Research Unit Development in South African	willemien.duplessis@nwu.ac.za

University	Name	Job title	Years of experience	Years of CCD experience	Faculty	Department	Programme / centre / unit / institute	Email
							Constitutional State	
North West University	Jean Chrysostome Kanamugire	Lecturer	3		Law	School of Undergraduate Studies	Mafikeng Campus	jean.kanamugire@nwu.ac.za
Nelson Mandela Metropolitan University	Maarten de Wit	Professor of Earth Stewardship	30	20	NA	NA	AEON-ESSRI (Earth stewardship science research institute)	maarten.dewit@nmmu.ac.za
Central University Of Technology	Zelda	Manager	12	2		Technology and Innovation	Sustainable Development	zuwah@cut.ac.za

Note: This list is based on information provided in the country workshop and from completed questionnaires, and is possibly incomplete.

APPENDIX C: UNIVERSITIES QUESTIONNAIRE

QUESTIONNAIRE FOR UNIVERSITY MANAGERS, TEACHING AND RESEARCH STAFF: Status of Climate Compatible Development Research, Teaching and Policy / Community Engagement

A: GENERAL INFORMATION	
A1: NAME	
A2: GENDER	
A3: HIGHEST QUALIFICATION	
A4: JOB TITLE	
A5: YEARS OF EXPERIENCE	
A6: YEARS OF EXPERIENCE WITH CLIMATE CHANGE / COMPATIBLE DEVELOPMENT RELATED ISSUES	
A7: NAME OF UNIVERSITY	
A8: COUNTRY	
A9: NAME OF FACULTY	
A10: NAME OF DEPARTMENT	
A 11: NAME OF PROGRAMME/ CENTRE / UNIT / INSTITUTE	
A12: E-MAIL CONTACT	
A13: WEBSITE ADDRESS:	

B: GENERAL VIEWS

B1: Give a short description of **how you understand** 'climate change'

B2: Give a short description of **how you understand** 'climate compatible development' in your context

B3: What, in your view, are the most **critical aspects** to deal with in your country if 'climate compatible development' is to be achieved?

B4: In your view, what is **the role of universities** in contributing to the achievement of climate compatible development?

B5: In your view, what is the **role of university managers** in contributing to achievement of climate compatible development?

C: CAPACITY, KNOWLEDGE AND RESEARCH GAPS

Please indicate if you are answering these questions on behalf of a:

University	
Faculty	
Department	
Programme / Centre / Institute	

	Rate the contributions of your university / faculty / department / programme using 1-5 with 1 being non-existent, and 5 being very active or well developed	1	2	3	4	5
C1	Involvement in research in the area of climate change and/or climate compatible development					
C2	Involvement in **local** climate change and/or climate compatible development research					
C3	Involvement in **national** climate change and/or climate compatible development research					
C4	Involvement in **international** climate change and/or climate compatible development research					
C5	Involvement in single discipline approaches to climate change and/or climate compatible development research					
C6	Involvement in **inter-disciplinary** approaches to climate change and/or climate compatible development research					
C7	Involvement in **transdisciplinary** approaches to climate change and/or climate compatible development research					
C8	Involvement of multiple stakeholders in climate change and/or climate compatible development research					
C9	Record of raising funding for climate change and/or climate compatible development research					
C10	Contributions of the research to local climate compatible development pathways					
C11	Contributions of the research to national climate compatible development pathways					

C12: Would you describe your university / faculty / department / programme's research primarily as being focused on:

Climate Change	
Climate Compatible Development	
Other (please specify)	

C13: List major research projects / programmes focusing on climate compatible development in your university / faculty / department / programme:

C 14: List the most active researchers involved in climate change and/or climate compatible development research in your university / faculty / department / programme, and their 'specialist' areas of research and if possible give an email contact address

C 15: List any major practices and research initiatives you or others regard as innovative in your university / faculty / department / programme, and their 'specialist' areas of research, and if possible provide a contact name and email of a person responsible

C16: List any major research or knowledge production networks that you may be involved in that focus on or support knowledge production and / or use that is relevant to climate compatible development in your context? If possible, provide a contact name and email address for the person responsible for the network:

D: CURRICULUM, TEACHING AND LEARNING

Rate the contributions of your university / faculty / department / programme using 1-5 with 1 being non-existent, and 5 being very active or well developed		***1***	***2***	***3***	***4***	***5***
D1	**Specialist courses** offered on climate change / climate compatible development					
D2	Climate change / climate compatible development issues and opportunities **integrated into existing courses**					
D3	**Cross faculty teaching** on climate change / climate compatible development					
D4	**Inter- and/or transdisciplinary teaching approaches** used for climate change / climate compatible development courses					
D5	**Service learning** (accreditation of community engagement as part of formal curriculum) focusing on climate change / climate compatible development concerns					
D6	Courses develop **critical thinking** and **integrated problem solving** skills					
D7	Courses clearly focus on development of **social and/or technical innovation** and **ethical actions**					
D8	Climate change / climate compatible development aspects are included in **assessment and examinations**					
D9	**Staff willingness** to get involved in new issues such as climate change and/or climate compatible development					
D10	**Staff ability** to get involved in new issues such as climate change and/or climate compatible development					

D11: List any main courses in climate change / climate compatible development in your university / faculty / department / programme and indicate if they are undergraduate (1st, 2nd, 3rd year etc.) or postgraduate (Hons, Masters, PhD)

D 12: Give an example of one or two teaching methods that you would use for teaching climate change / climate compatible development in your courses

E: POLICY / COMMUNITY ENGAGEMENT AND STUDENT INVOLVEMENT

Rate the contributions of your university / faculty / department / programme using 1-5 with 1 being non-existent, and 5 being very active or well developed		**1**	**2**	**3**	**4**	**5**
E1	Involvement in climate change / climate compatible development policy outreach / engagement activities					
E2	Involvement in climate change / climate compatible development community outreach / engagement activities					
E3	Student involvement (e.g. through societies, clubs etc.) in climate change / climate compatible development activities on campus and in the surrounding areas					

E4: List any major climate change / climate compatible development **policy** outreach / engagement activities and if possible, the person responsible for the programme:

E5: List any major climate change / climate compatible development **community** outreach / engagement activities and if possible, the person responsible for the programme:

E6: List any major student organisations / activities that are engaged with climate change / climate compatible development activities

F: UNIVERSITY COLLABORATION

What opportunities exist for collaboration towards climate compatible development knowledge co-production?

F1: Inside the university

F2: Between universities in country

F3: With partners

F4: Regionally

F5: Internationally

G: UNIVERSITY POLICY AND CAMPUS MANAGEMENT

G1: Does the university have any policies that are aligned with climate compatible development objectives? If yes, then please list them.

G2: Does the university engage in any campus management activities that are aligned with climate compatible development objectives? If yes, then please list them.

G3: Are there major networks / research groups or programmes that the university is affiliated to that focus on climate compatible development? If yes, please list them.

APPENDIX D: STAKEHOLDER QUESTIONNAIRE

SHORT QUESTIONNAIRE FOR STAKEHOLDERS on CLIMATE COMPATIBLE DEVELOPMENT KNOWLEDGE, RESEARCH AND CAPACITY NEEDS

A: GENERAL INFORMATION

A1: NAME	
A2: GENDER	
A3: HIGHEST QUALIFICATION	
A4: NAME OF ORGANISATION	
A5: NAME OF SECTION / DEPARTMENT IN ORGANISATION	
A6: JOB TITLE	
A7: YEARS OF EXPERIENCE	
A8: YEARS OF EXPERIENCE WITH CLIMATE CHANGE / COMPATIBLE DEVELOPMENT RELATED ISSUES	
A9: COUNTRY	
A10: EMAIL CONTACT DETAILS	
A11: WEBSITE ADDRESS	

B: GENERAL VIEWS

B1: Give a short description of **how you understand** 'climate change'

B2: Give a short description of **how you understand** 'climate compatible development' in your context

B3: What, in your view, are the most **critical aspects** to deal with in your country if 'climate compatible development' is to be achieved?

C: CAPACITY, KNOWLEDGE AND RESEARCH GAPS

C1: What, in your view, are the most critical **knowledge gaps** that need to be addressed for achievement of climate compatible development in your context?

C2: What are your most critical **specific research needs** for achieving climate compatible development in your context?

C3: What, in your view, are the most critical **capacity gaps** (individual skills and institutional capacity) that need to be addressed for achievement of climate compatible development in your context?

C 4: In your view, what is **the role of universities** in contributing to the achievement of climate compatible development?

C5: In your view, how could / should **your organisation** be collaborating with universities to strengthen climate compatible development in your country?

D: INTERESTS, POLICIES, NETWORKS AND CENTRES OF EXCELLENCE OR CENTRES OF EXPERTISE

D1: Briefly describe your organisation's main interest in climate change / climate compatible development

D2: List any major policies and plans that have relevance to climate change / climate compatible development in your country and/or organisational context

D3: Briefly describe any collaboration that you have had with universities and/or research, learning and innovation centres, etc. on mobilising knowledge and capacity for climate change / climate compatible development. List the specific initiative / collaboration, and if possible give details of a person responsible for this.

D4: Are there any national centres of excellence in climate change / climate compatible development research and innovation practices in your country? If yes, please list them and indicate their specialist competence areas.

D5: Is there any specialist expertise in your country / context for climate change / climate compatible development research and learning that you know of? If yes, please list who they are, and indicate their specialist competence areas.

D6: Are there any networks that are engaging with climate change / climate compatible development research and innovation practices in your country? If yes, please list them, and indicate what they focus on. If possible, list a responsible person (with contact details if possible).

APPENDIX E: IDENTIFIED SOURCES OF EXPERTISE FOR CCD FOR SOUTH AFRICA

Table 6: Nodes and Centres of Expertise identified in South Africa for CCD research (covering all 23 South African universities)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
Cape Peninsula University of Technology, Western Cape	The Cape Peninsula University of Technology has 23 NRF rated researchers with most being promising young researchers, and /or established researchers. Fields of expertise that are applicable to CCD research issues identified in this mapping study, involving **established researchers** are: ▪ Renewable energy, thermal energy systems ▪ Food product development and preservation ▪ Medicinal plants and bioactivity of natural antioxidants ▪ Nutrition and Health, bacteriology ▪ Fish farming using renewable energy (Department of Mechanical Engineering)	**Centre for Environmental Toxicity and Remediation** (Prof Odendal) The **Energy Institute** (Prof Uken) includes research on low cost high efficient solar water heating systems; off the grid aquaculture facilities and others.
Central University of Technology, Free State	The Central University of Technology, Free State has 7 NRF rated researchers, with two of the established researchers having expertise relevant to the CCD research issues identified in this mapping study: ▪ Food safety, biocatalyst and food microbiology	CUoT has a sustainable development strategy and a **Department of Built Environment** that focuses on sustainable building (Prof Ngowi)
Durban University of Technology, KwaZulu-Natal	The Durban University of Technology has ten NRF rated researchers, all in the category of established researcher. Areas of research expertise relevant to the CCD issues identified in this mapping study include: ▪ Microbiology, traditional medicine and indigenous knowledge systems	DUoT has an **Institute of Systems Science** (Prof Duffy) and an **Institute for Waste and Waste Water Technology** (Prof Bux)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	▪ Innovation in technology management, including integrated water resources management and treatment, environmental modelling ▪ Health promotion and disease prevention, ethics, health sciences ▪ Biotechnology	
Mangosutho University of Technology, KwaZulu-Natal	The Mangosutho University of Technology has two NRF rated researchers, one of which is an established researcher, focusing on environmental geology and medical geology.	MUoT has a **Research Centre for Algal Biotechnology** which focuses on the identification, optimisation and commercialisation of value added compounds from indigenous species of algae. Technology innovation to optimise the production of micro algal cellular lipids or oils, used in the synthesis of biodiesel. This is the first centre to produce high quality biodiesel from an indigenous strain of microalgae. Ongoing research with CSIR Biosciences and the Waste and Wastewater Technology (DUT) and School of Biological and Conservation Sciences at UKZN (Prof Anandraj)
Nelson Mandela Metropolitan University, Eastern Cape	The Nelson Mandela Metropolitan University has 62 NRF rated researchers, most of whom are established researchers. Leading international researchers have expertise that is relevant to CCD research issues as identified in this mapping study include: ▪ Restoration ecology, conservation science, plant diversity ▪ Natural resources and sustainable development, geodynamics, stratigraphy, earth observation (Prof De Wit; founding member of AEON); is heavily involved in leading AEON	The University has the following identified research units, where groups of researchers are working together: **African Earth Observation Network** - AEON is a centre for Earth Systems Science (ESS) that provides a research and educational environment to seek consilient knowledge amongst earth and life sciences, engineering, resource economics and the human sciences. AEON is forging Earth Stewardship into a Science that can sustain the planet and its people. AEON fosters cutting-edge, internationally connected, science and analytical learning using advanced tools and technologies in an environment that encourages interdisciplinary science to explore our Earth, and society, particularly in Africa. AEON

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	The following internationally acclaimed and established researchers have expertise relevant to CCD: ▪ **Political and historical geography** ▪ **Sustainability Science**, Adaptive Systems, Complexity theory, Human Ecology Resilience (Prof Fabricius, also heads up the Sustainability Research Unit at the George Campus, and is Scientific Co-ordinator for the International Resilience Alliance, and has recently obtained a large research grant from the Belmont forum for coastal adaptation) **Conservation Ecology, Conservation Planning and Freshwater management and conservation** ▪ Conservation Ecology, plant-animal interactions; Conservation planning, GIS; Biogeography, Population ecology, evolution; Estuarine ecology, stress ecology, plant ecology; Freshwater conservation, social learning, freshwater management and aquatic conservation; Microbial water quality, bacteriology **Renewable energy** ▪ **Photovoltaics, solar heating, solar energy**, semiconductors (Prof Van Dyk: Head of the Centre for Energy Research) **Science and environmental literacy and education**, indigenous knowledge and science education (Prof Webb) The university also has a research policy which states that one of its key thematic areas is research into environment and natural resource management, with established strengths in the areas of:	is underpinned by dedicated programme-based hubs and a central hub managed out of the Nelson Mandela Metropolitan University in Port Elizabeth and involves EarthLAB, EarthCare, EarthLIFE, EarthTECH, EarthWISE, EarthSystem (Prof de Wit) (www.aeon.org.za) **Sustainability Research Unit** (head: Prof Fabricius) hosts a number of sustainability oriented research projects focusing on learning and reflection for adaptive co-management of ecosystems, water security, social networks and social capital, ecosystem change and society, transformations towards earth stewardship in social-ecological systems. A recent project is a coastal adaptation project (funded by the Belmont Forum) **Centre for African Conservation Ecology** (head: Prof Graham Kerley) places emphasis on conservation and conservation ecology, as well as environmental education. **Ecology Coastal and Marine Research Unit** (head: Prof Janine Adams) focuses on integrated environmental and coastal marine research, focusing on the dynamic changes in marine and coastal ecosystems. **Centre for Energy Research** (head: Prof Ernest van Dyk) was established in 2006, and focuses on solar energy development. They specialise in solar energy in the form of photovoltaic (solar cells) and solar water heating, energy management and control in the field of automotive energy, wind energy, energy efficiency, energy economics, and energy materials. The Centre brings together experts in science, engineering, the built environment, information technology, economic sciences, conservation ecology and

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	▪ The environment and ecology (including environmental law) ▪ Marine and estuarine studies ▪ Architecture and the built environment Nelson Mandela Metropolitan University are also starting a new degree in Human Settlements in 2014	manufacturing technology
North West University	The North West University has 141 NRF rated researchers, most of whom are established researchers. The North West University however, have important nodes of expertise that have particular relevance for CCD. These include: ▪ **Environmental law and governance:** Constitutional law, Environmental law, International environmental law, Environmental governance; Climate law; Legal pluralism; Human rights, Water rights, International Human Rights law ▪ **Clean energy and clean coal technology development:** Gasification, coal beneficiation; Clean coal technology, Reaction Kinetics ▪ **Renewable energy:** Fuel cells, hydrogen generation, hydrogen economy, electrocatalysis, membrane technology; Energy management, energy efficiency, energy engineering ▪ **Mining and applied environmental science, clean technology:** Gold mining, environmental pollution reduction and remediation, environmental chemistry, water resources management ▪ **Plant sciences, Conservation and Rehabilitation:** Plant stress physiology, rehabilitation, ecology, plant physiology; Conservation, ecological monitoring, restoration and rehabilitation of semi-arid rangelands; Urban ecology;	The mapping study showed that the university has applied for a DAAD **Centre of Excellence in Climate Law and Governance**, but this is pending approval (Prof Kotze – NRF Prestigious award) The University also hosts the **Unit for Environmental Sciences and Management** that provides extensive training for business and government. (head: Prof Leon van Rensburg) It also houses the **Africa Unit for Trans-disciplinary Health Research (AUTHeR)**. It is not clear if this unit is engaged in CCD health related issues, but it has a strong commitment to a transdisciplinary research focus, and has a research programme that focuses on enhancing health and quality of life in various contexts on individual, community, social and systems levels.(head: Prof Annamarie Kruger)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	Biodiversity conservation, herpetology, parasitology ▪ **Agricultural entomology, entomology and biological control** ▪ **Soil sciences:** Soil management, soil microbiology, mine dump rehabilitation, soil biology/fertility; Environmental soil sciences, soil characterisation and amendments ▪ **Bacterial biotechnology**, alien invasive plants, environmental microbiology, IKS ▪ **Ecotoxicology, environmental chemistry, pollution** and **environmental management** (water, marine); Terrestrial ecotoxicology ▪ Climate change and land conflicts (Faculty of Agriculture, Science and Technology) ▪ Legal principles of climate change (Faculty of Law)	
Rhodes University	Rhodes University has 70 NRF rated researchers, most of them established researchers. Rhodes University have the following nodes of expertise relevant to CCD research: ▪ **Biological Sciences and Conservation**: Marine biodiversity, conservation biology, aquatic biology; Biosystematics, Phytogeography, Biodiversity, Population genetics, insect plant associations; Biological oceanography, zooplankton ecology; Plant Eco physiology, ecology, climate change. ▪ **Fisheries Sciences**: Life history, evolution, evolutionary genetics, fisheries management; Fish biology and bio resource modelling; aquatic ecology; Aquaculture and fish reproduction; Fisheries Management and ecology ▪ **Environmental, Climate and Ecological Sciences**: Wetland and plant ecology; community forestry, climate risk and vulnerability, adaptation and livelihoods; interdisciplinary environmental	**Southern Ocean Group:** This research group is based in the Department of Zoology and Entomology and is involved in a five-year programme on biological oceanography at the sub-Antarctic Prince Edward Islands in collaboration with a physical oceanographic research group at the University of Cape Town. Amongst other foci, the research includes a focus on interactions between the island ecosystem and frontal systems. (Prof McQuaid and Prof Froneman) **Environmental Biotechnology Research Unit:** The main focus is on biotechnology innovation and development of bioprocesses related to remedial technologies, waste water treatment, alternative energy and biofuels, technology transfer and assessment, mine water treatment, exploration of micro-algae biomass as feedstock for renewable energy production, bioremediation of coal and hydrocarbon wastes (Prof K Cowan)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	sciences; rural livelihoods; climate change adaptation ▪ **Aquatic and Oceanographic Sciences**: Applied hydrology; Hydrologic modelling (including climate modelling), surface hydrology, water resources management; Transdisciplinary water security and IWRM research ▪ **Physical geography and environmental change**: Paleooceonography, marine biochemistry, earth history; Physical geography, environmental change, geomorphology, Antarctica ▪ **Environmental Biotechnology**: Algal biotechnology; agricultural biotechnology, plant growth regulators ▪ **Environmental Education / Education for Sustainable Development / Social Learning**: Curriculum innovation, social learning, climate change education, water and biodiversity education, teacher education, environment and sustainability education in universities ▪ **Sustainability Leadership for Business:** business leadership and climate change; green economy; sustainability reporting	**Institute for Water Research:** The main focus is wise use of natural water resources in southern Africa; researchers are working on water and climate change (modelling), and water quality and its application in risk assessment as well as transdisciplinary water security studies under the GCGCSSRP (includes the Unilever Centre for Environmental Water Quality) (Prof Hughes and Prof T. Palmer) **Environmental Learning Research Centre:** Its main focus is environmental learning at the people-environment interface; social learning; curriculum innovation for sustainability in schools, TVET and higher education. Includes a focus on climate change education; houses the Makana and Rural Eastern Cape **United Nations University linked Regional Centre of Expertise** for Education for Sustainability and **Chair of Environmental Education** (Prof Lotz-Sisitka) **SARCHI Chair** in **interdisciplinary environmental sciences and rural livelihoods** – also has a link to climate change adaptation research (Prof C. Shackleton)
University of Stellenbosch	Stellenbosch University has 311 NRF rated researchers. The following areas of expertise were identified for CCD: ▪ **Ecological Sciences, Modelling and Biological Sciences**: Ecological network analysis, fisheries, ecological modelling; Fungal ecology; microbial ecology; Climate change impact and vulnerability: evolutionary ecology, physiological ecology, thermal biology, functional morphology Arid zone ecology, vegetation dynamics and restoration; Invasive alien species, conservation ecology, biodiversity conservation; Ecological modelling, macro ecology, invasion biology, conservation	Stellenbosch University has the following Centres, Programmes and Institutes that have particular relevance to CCD: **Centre for Renewable and Sustainable Energy Studies**: focuses on development of renewable energy to facilitate economic growth in the area of renewable energy. The hub of the programme is in the Faculty of Engineering. It has a strong postgraduate research programme. It has a staff of eight research engineers. It co-operates with numerous departments and faculties inside the university, and with the Universities of Cape Town, NMMU, North West University, Wits University, the Fort Hare University Institute of Technology, the

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	ecology; Plant ecology, terrestrial ecology, conservation biology; plant pathology, microbiology, biotechnology; Climate change and insects responses; see also the Centre of Excellence in Invasion Biology below ▪ **Sustainable energy development, clean technology and environmental engineering:** Sustainable energy technologies, life cycle management; Bioenergy, bioprocess engineering; electric motor drives, electric machines ▪ **Environmental nanotechnology and biotechnology**: nanotechnology and biotechnology applications in water ▪ **Conservation Sciences**, **Biodiversity:** Conservation of natural resources, phytogeography; Conservation planning – science and social aspects; Systematics, marine biodiversity, evolution; Entomology and parasitology, conservation ecology, veterinary parasitology; Marine protected areas, fisheries management, conservation genetics, phytogeography ▪ **Environmental Management, IWRM, Sustainable Development and Environmental Economics:** Integrated environmental assessment, climate change policy, water, waste and biodiversity planning, environmental and resource economics; Water demand analysis and management, water demand modelling, water distribution systems analysis; Environmental engineering, waste and water treatment, environmental management, membranes ▪ **Environmental governance, public policy and sustainable development:** Environmental governance and public management, sustainable development, environmental policy, organisational transformation; Scenario methods, strategic knowledge, strategic analysis; Sustainable development, community development, design and planning, urban	University of KwaZulu-Natal, the University of Pretoria, the Energy Research Centre at the University of Cape Town. The Centre is the **national academic hub for renewable and sustainable energy studies**. The University's track record in conducting solar energy research is 30 years, and it has undertaken research that improves the efficiency of water use in power stations. The research includes solar thermal power generation cooling. The University was the first to build a solar research roof, and the university has large solar roof labs (1000 m^2) (Director: Prof Wikus van Niekerk). It also works closely with: The **SARCHI Biofuels Research Chair** which is implemented in partnership with SANERI (now SANEDI) which co-hosts different Masters and PhD programmes with the University of Cape Town: MSc/PhD at the Department of Microbiology (US); MscEng/PhD in Chemical Engineering a the Department of Process Engineering (US) and MS(Eng) / PhD / PostDoc at the Department of Chemical Engineering at UCT **Stellenbosch University Water Institute**: combines water research groups in five US faculties under one umbrella. Current research focused on water and health, agriculture and food, a sustainable environment, nanotechnology and filtration, effluent treatment and social aspects surrounding water. It also hosts / co-ordinates the NEPAD network of water Centres of Excellence (nepadwatercoe.org) The **Centre for Corporate Governance in Africa** at the Stellenbosch Business School focuses on researching corporate responsibility and sustainable development in the business sector in order to develop criteria for best practice. The Centre for Corporate Governance in

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	development, development economics, African economy ▪ **Agriculture and Soil Sciences:** Soil chemistry, ecology, soil crusting; Agricultural entomology, conservation biology; Agriculture, Antarctic biology, plant ecophysiology; Agriculture policy analysis, land reform, rural development, agricultural development and economics ▪ **Environmental Ethics and Education:** Environmental ethics, applied ethics, business ethics and climate change ethics; Environment and Science education ▪ **Disaster Risk Reduction and public health** The University has defined Sustainability as one of its focus areas for the forthcoming years. It has an Integrated Sustainability Management Policy, and has a flagship programme called the HOPE programme which adopts a transdisciplinary approach to science-in-society, and links a number of research programmes, centres and faculties. The University has a committee for sustainable development in the Faculty of Health Sciences.	Africa at the University of Stellenbosch Business School is one of the four core project partners in a global initiative analysing Sustainability reporting policies and practices worldwide along with the Global Reporting Initiative (GRI), the United Nations Environment Programme (UNEP) and KPMG Climate Change and Sustainability Services (Director: Daniel Malan) The **Environmental Education Programme (EEPUS)** at the Faculty of Education endeavours to include environmental education into all the programmes of the Faculty of Education, and to train trainee teachers for environmental education (Prof Chris Reddy) The **Sustainability Institute** in co-operation with the University's school for Public Leadership focuses on ecological, community and mental development, and offers sustainable practices and a demonstration site for green technologies and ecological economics. It co-hosts the Masters degree in Sustainable Development (an interdisciplinary degree programme run with input from a range of different faculties) (Head: Prof Mark Swilling, also involved in Tsama Hub PhD in transdisciplinarity and sustainability) The **Tsama Hub** is a co-ordinating mechanism that utilises the transdisciplinary potential that exists among various faculties and departments of the university that have interests and expertise in sustainability, sustainable development and complexity. The focus of the programme is to do science *with* society through a process of co-learning. Researchers and stakeholders learn together how to develop a shared understanding of the real-world problems at hand, and how to translate these into theoretical problem statements and

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
		researchable questions. (Programme Manager: John van Breda; Project leader: Prof Mark Swilling) The University of Stellenbosch also houses: **The DST Centre of Excellence for Invasive Biology**, which studies the impacts of invasive species on South Africa's plants and animals. Some researchers associated with the centre are also involved in climate change related research linked to the main focus of the CoE. The CIB explores the impacts of biological invasions on biodiversity and aims to improve understandings of how interactions amongst global change drivers might further influence the impacts of invasions, and to facilitate and formulate appropriate policy interventions. (http://academic.sun.ac.za/cib/research.asp)
Tshwane University of Technology	The Tshwane University of Technology has 34 NRF rated researchers, most of which are established researchers. They have the following expertise related to CCD: **Mining, clean technology, water resources management and treatment:** Water and effluent management and treatment; Waste water re-use, bioremediation, groundwater contamination, industrial water management, waste water bioremediation; Water resources management, arid zone hydrology, groundwater, health related microbiology, environmental biotechnology **Renewable energy technology:** Power electronics, electrical motor drives energy auditing, power quality; Power systems, power engineering **Innovation acceptance and uptake**	**Centre for Energy and Electric Power** (Department of Electrical Engineering); works with the SANEDI on thermal solar systems (Dr Munda) **Postharvest technology group** (Department of Crop Sciences) – research on linking small-scale farming operations with respect to climate change and reducing post-harvest loss of produce (Prof Sivakumar)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
University of Cape Town	The University of Cape Town has 408 NRF rated researchers, with some of these working in CCD related research areas: **Climatology and Climate modelling and Climate Change Adaptation**, including impact and vulnerability assessment and analysis **Conservation, Ecology, Biodiversity, Plant Sciences, Zoology, and Environment and Global Change Science:** Conservation biology, Biodiversity conservation, Conservation ecology, Wildlife conservation, Animal ecology, Applied ecology, Foraging ecology/behaviour, Biodiversity, Phylogenetics, Terrestrial ecology, Plant-herbivore interactions, Grassland, Savanna ecology,Landscape Ecology, Ecophysiology, Fire ecology, Evolutionary ecology, Coastal ecology, Estuarine ecology, Biosystematics, Mammalogy,Restoration ecology, Functional morphology,Evolutionary biology, Biostatistics, Taxonomy of African succulents; Ornithology, Population modelling; Invertebrate physiology, Aquaculture, Invertebrates - Taxonomy, Speciation/hybridisation, Plant Ecohydrology, Terrestrial ecology, Stable light isotopes, Climate change - Impact, Drought, Animal ecology **Soil Sciences:** Soil biology/fertility, Soil bacteria, Biological nitrogen fixation, Ecology and environmental science, Agronomy, Sustainable agriculture, Plant nitrogen, Plant-soil relations, Agriculture **Oceonographic Sciences and Meteorology**: Antarctic/Southern ocean; Physical oceanography, Climate change, Climate, Climate variability, Atmospheric and ocean modelling, Meteorology; Oceanography, Ocean atmosphere interaction, Climate variability, Agulhas, Southwest Indian Ocean, Satellite oceanography; Satellite oceanography, Physical oceanography, Antarctic regions - Circumpolar current, Variability of the ACC, Primary production distribution in the Southern Ocean in relation	UCT has a 'whole system' approach to climate change research, and established the **Africa Climate and Development Initiative** (ACDI) (http: acdi.uct.ac.za). The ACDI is the leading CCD research institution on the African continent. Its focus is to improve human well-being, but within the constraints of the need for low carbon development and the mounting impacts of climate variability and change. It is an interdisciplinary research hub that brings together academics and NGOs, business and government. It has research themes that include: 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 climate change, global to local scale issues and linkages. Departments that are working with the ACDI include: ▪ **Botany Department** (Prof Hoffman): climate change monitoring through vegetation change ▪ **Graduate School of Business** (Prof Hamann): business and climate change; governance ▪ **African Centre for Cities** (Anton Cartwright, Warren Smit): development economics and climate change; CityLAB – Mistra Urban Futures Climate Change CityLab programme ▪ **Centre for Film and Media Studies** (Dr Saleh): climate crossroads: politics, media and climate ▪ **School of public health and family medicine** (Jonny Myers): climate change, health and health policy ▪ **Centre of Criminology** (Tom Herbstein): environmental security programme focussing on communities managing risks associated with climate change ▪ **Climate System Analysis Group** (CSAG) –

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	to physical forcings, Antarctic/Southern ocean, Southern Ocean frontal dynamics **Marine Climate Sciences, Fisheries Sciences and Geoscience:** Marine biodiversity, Climate change, Benthic marine algae, Biosystematics, Ecological modelling, Fishery assessment and management, Marine geoscience, Palaeoceanography, Sedimentary geochemistry; Ecosystem modelling, Fishing - Effect of ecosystem on, Fisheries, Fisheries management, Trophic webs, ecosystem indicators; Biological oceanography, Ecology of marine small pelagic fish, Structure and functioning of marine pelagic food webs, Climate change impacts on marine pelagic ecosystems, Management of fisheries for small pelagic fish, Ecosystem approach to fisheries management **Ecological modelling and Ecosystem modelling:** Population modelling, Marine biophysical modelling, Marine ecology, Plankton ecology **Integrated Water Resources Management:** Urban Water Management, Urban storm water – Engineering, Water engineering, Water-supply, Rainwater harvesting, Water demand – Management, Water management, Wastewater, Environmental hydraulics, Engineering hydrology; **Water supply and management**: Water-supply, Water leakage, Water demand - Modelling, Water distribution system - Modelling, Reliability engineering **Health Sciences:** Health policy, Antimalarial drugs, Malaria, Malaria control, Clinical pharmacology, medicinal chemistry, anti-malarial drugs (also anti-TB, anti-HIV drugs), Medicinal chemistry, Drug discovery **Development Studies and Labour Economics:** Development economics, Labour economics, Household poverty dynamics, Survey econometrics, Labour market – Economics, Policy formulation, Economics of education,	www.csag.uct.ac.za (Prof Bruce Hewitson): climate modelling, two projects – Wild Coast Living Laboratory (systems research); Healthy Futures (predicting climate risk in Africa, disease risk mapping, focus of research is on East Africa) ▪ **Environmental Evaluation Unit** (EEU) (Sandra Rippon): Touws River Solar Energy Facility environmental authorisation process research ▪ **Department of Chemical Engineering** (Prof von Blottnitz): environmental process systems engineering ▪ **Department of Social Anthropology** (Lesley Green): contested ecologies research group focussing on informational and relational ways of knowing ▪ **Department of Sociology** (Dr Frank Matose): defragmenting African Resource Management (conflict resolution) aspects of climate change and related concerns • **Gordon Institute for Performing and Creative Arts** (Jay Pather): brings scientists and artists together to probe the relationship between climate change and its representations in the creative and performing arts • **Schools Development Unit** (Andrew Petersen): teacher education on climate change / science and environmental education. **The Environmental Evaluation Unit** at UCT (Prof Merle Sowman) covers the following thematic areas: - Coastal and fisheries governance (MPAs, small scale fishers, co-management) - Biodiversity and social justice (includes projects on bio prospecting, bioscience and bio politics, seed security)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	Poverty, Research, Development economics, Poverty, Inequality, Labour economics, Policy **Palaeontology and Archaeology:** Palaeontology: Vertebrate; Palaeoenvironments, Palaeoecology; Archaeology - Iron Age, Archaeology - Cultural heritage; Biomolecular archaeology, Palaeoenvironments, Stable light isotopes, Environmental isotopes, Biological anthropology, Pre-colonial archaeology, Archaeology – African, Archaeology – Stone Age **Energy, Waste and Clean Technology**: Climate change, Waste management, Sustainable energy, Strategic planning, Multicriteria decision analysis, Clean technology **Environmental Law**, International trade law, Coastal Zone Law, Environmental law, Energy Law, Climate Change law **Renewable Energy**: Wind power, Power electrical engineering, Power systems dynamics, Power system stability, Power systems analysis, Renewable energy systems, Intelligent systems, Power systems optimisation; Environmental economics, Environmental modelling, Energy studies, Energy policy, Renewable energy, Environmental policy **Sustainable Development and Corporate Governance:** Corporate strategy, Business administration, Food security, Climate change mitigation, Climate change – Adaptation, Mining – Environment, human rights, innovation and sustainable development, Business ethics, Sustainable enterprise; Waste management, Biofuels, Life Cycle Assessment, Industrial ecology; Strategic management, Internationalisation, Cooperative governance, Innovation –Management, Innovation and entrepreneurship	- Environmental management and sustainability (includes various initiatives focusing on renewable energy development) - Business and sustainability - Environmental governance UCT also has a number of research chairs • **SARCHI Chair of Security and Justice** (Prof Clifford Shearing): focus on the governance of environmental security • **SARCHI Chair in Climate Change** (Prof Bruce Hewitson): linked to the Climate Systems Analysis Group – focus on climate modelling, variability, change and regional projections. Lead co-ordinator of the WCRP global CORDEX programme to develop regional climate projections. • **SARCHI Chair in Marine Ecology and Fisheries** (Prof Astrid Jarre: focus on interdisciplinary research into marine social-ecological systems under global change in the Benguela current • **SARCHI Chair in Modelling of the coupled ocean-land-atmosphere phenomena related to climate change** (position still being filled)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	Biotechnology: Wastewater treatment, Biohydrometallurgy, Algal biotechnology **Environmental History**: Semi-arid rangelands, Desertification, Resource management **Development Finance:** Finance, Economics, Forecasting and time series, Development finance, Development economics, Financial economics **Cultural studies, sustainable design / architecture, and urbanisation / social change studies**: African studies, Educational policy, Sociology, Young people in Africa, Spatial planning, Planning theory, City planning; Architectural design, Design innovation, Design at times of social change, Design of roof lights that can separate light and heat, Self-built rentable housing, Environmentally responsive and responsible design in architecture	
University of Fort Hare	The University of Fort Hare has 18 NRF rated researchers. Not all of the researchers listed below are NRF rated, but they are all engaged with CCD related research: ▪ **Plant and Animal Sciences and Climate Smart Agriculture:** Ethnobotany, bioprospecting, phytomedicine; Ethopharmacology, Ethnovetinary, Animal Health; Animal breeding, Animal welfare; resilient Nguni varieties. Effects of CC on cereal stress responses; Agro-meteorology, resilient pest tolerant food plant varieties – stress tolerant maize PVCs and farmer tolerance to open pollinated maize varieties; effects of CC on livestock production ▪ **Renewable Energy:** Solar energy, photovoltaics, solar physics ▪ **Climatology, Geomorphology:** Impacts of CC on smallholder	**Fort Hare Institute of Technology (FHIT)** (Director: Prof Meyer): Renewable energy technologies, energy efficiency, energy efficient building integrated photovoltaics (EEBIPV) systems and building materials. **Renewable Energy Centre of Excellence** (RECoE). Research areas: photovoltaic modules and systems, photochemical dye-sensitised solar cells and modules, gassification of biomass. **Agricultural and Rural Development Research Institute** (Director: Prof Masika): Generates social, economic and technical information relating to livelihood systems and support services with a focus on agriculture, and then disseminates this information to facilitate change The University of Fort Hare also hosts a **DST Risk and Vulnerability**

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	farming and productivity ▪ **Water Resources Management, Water Quality, Agricultural Water:** Physico-chemical, bacteriological and virological qualities of water; Research on agricultural water, reduce the water footprint of crops; Hydrological cycle; Water harvesting for small scale farming ▪ **Agricultural economics; climate vulnerability and adaptation** options for smallholder farmers, barriers and incentives to adoption of biofuel crops ▪ **Conservation agriculture, vermicomposting, climate mitigation; small-scale irrigation cropping productivity** ▪ **Social Science Studies on CC risk perception**	**Science Centre** (RVSC) linked to the Global Change National Research Plan (Director: Dr Zhou): Generates and disseminates knowledge on risk and vulnerability on global change challenges focusing on food and water security, waste management, and environmental management in the face of climate change It also has a **Centre for Transdisciplinary Studies** (Director: Dr Mahlangu) that teaches an undergraduate transdisciplinary module on 'Life, Knowledge and Action' to all first-year undergraduate students using an innovative campus-wide model. It includes aspects of environment and climate change. SARCHI Chair in **Social Change** (Prof Minkley)
University of Johannesburg	The University of Johannesburg has 112 NRF rated researchers, with the following overall areas of expertise related to CCD (details of all the researchers are included in Volume 2): ▪ **Ethno botany, medical plant chemistry, taxonomy, indigenous knowledge** ▪ **Biodiversity: Plant and Fish Sciences; Aquatic Health:** Fish parasitology, aquatic health ▪ **Renewable Energy Production, Energy Systems, Life Cycle Engineering:** Environmental management, atmospheric environment ▪ **Biotechnology, Nanotechnology and Environmental and Water Analysis** ▪ **Water demand side modelling** ▪ **Environmental / analytical chemistry, wood, soil and water sciences** ▪ **Sustainable Construction and Construction Management** with a	It has the following research centres: ▪ **Sustainable energy Technology and Research Centre** (SeTAR) focusing on **Sustainable Energy and Geo-Informatics** (Prof Annegarn): flagship programme ENERKEY, which is an international mega-cities research programme focusing on sustainable energy for cities. Also includes residential thermal energy research, schools energy efficiency project retrofitting schools, solar water heating project focusing on roll out of solar water heaters for the domestic sector. ▪ **The Centre for Nanomaterials Research** undertakes research on nanomaterials for sensors and photovoltaic applications, and water analysis and treatment ▪ **The Centre for Social Development in Africa** (Prof Leila Patel) (in the Faculty of Humanities) conducts research into corporate social and environmental responsibility as a

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	focus on gender concerns ▪ **Land Use, Forests and Forestry Management,** including vegetation mapping, applied environmental science ▪ **International Environmental Law** ▪ **Rural Livelihoods and Vulnerability**	sustainable development strategy ▪ SARCHI Chair in **Indigenous Plant Use** (Prof BE van Wyk) ▪ It also hosts a **Centre for Aquatic research** (Prof Avenant-Oldewage): **freshwater biology –** focusing on Fish health, molecular and systematics, phylogeography, landscape genetics and population genetics; Comparative respiratory functional morphology and developmental biology (in extreme environmental conditions); Ecotoxicology and impacts of pollutants on fish species; Fish parastology
University of KwaZulu-Natal	The University of KwaZulu-Natal has 209 rated researchers, most in the category of established researcher, with the following areas of expertise related to CCD ▪ **Renewable Energy, Smart materials and Structures** ▪ **Biodiversity Conservation, Ecology:** Plant based biodiversity management and ecological studies; Marine and coral reproductive ecology, coral reef health and anthropogenic stressors, coral reef biology; Ecological modelling; Plankton and phytoplankton ecology; Zooplankton ecology; Pollination ecology; Estuarine and mangrove ecology; Spatial planning, ecosystem services; Conservation planning; Ecosystem ecology ▪ **Plant and Animal Sciences:** including plant breeding, crop diversification, natural products processing, biological evaluation, ethnobotany, seed physiology, forest science ▪ **Soil Sciences, system change**: Climate modelling, climate change impacts, crop modelling ▪ **Water Sciences**: Stochastic modelling, hydrometeorology, environmental engineering; Water engineering, IWRM, engineering hydrology, floods	Key research themes that have been defined as university-based areas of excellence of relevance to CCD at UKZN include: ▪ **Agriculture and Food Security** ▪ **Energy and Technology for Sustainable Development** ▪ **Indigenous African Knowledge Systems** ▪ **Maritime Studies** ▪ **Water, Environment and Biodiversity** (UKZN has a strong research programme on water, environment and biodiversity)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	▪ **Sustainability Science and Environmental Governance**: Sociocultural space and time, spatial planning, environmental governance; **International environmental law** ▪ **Gender Economics**, poverty, household well-being, labour economics, economic demography ▪ **Environmental Biotechnology and Rehabilitation,** agriculture, applied mineralogy; Environmental Biotechnology and bioremediation; Agricultural biotechnology, water and effluent management ▪ **Environmental History** ▪ **African Ethics** ▪ **Biochemistry, Molecular Biology; Biomedical Sciences**, including focus on malaria; Environmental epidemiology; Health promotion; Child health; Health communication ▪ **Food Processing, Food Engineering; Agricultural Engineering,** post-harvest systems, drying of foodstuffs, renewable energy use in Agriculture, energy efficiency in the food industry ▪ **Science Communication** ▪ **Development Studies, Development Economics, Social Movements, Labour**	
University of Limpopo	The University of Limpopo has eight NRF rated researchers with expertise in the following areas related to CCD: ▪ **Agricultural Sciences:** Animal sciences, animal breeding and management; Animal nutrition; Crop production, horticulture, plant pathology, phytochemistry ▪ **Biodiversity:** Taxonomy, biodiversity, biosystematics ▪ **Social change:** Psychopathology, psychology, indigenous	The SAES Geography and Environmental Studies department has a focus on water and sanitation, water resources management, public health, and hosts a **Centre for Rural Community Empowerment** (Head: Prof Mollei) The University of Limpopo also hosts a DST **Risk and Vulnerability Assessment Centre (RVAC),** which is linked to the Global Change National Research Plan (Director: Ms Geldenhuys)

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	knowledge systems, public health	
University of Pretoria	The University of Pretoria has 334 NRF rated researchers, most of whom are in the established researcher category, with the following areas of expertise and research centres that are engaged in CCD research: ▪ **Veterinary Sciences**, including veterinary epidemiology, wildlife veterinary research; Wildlife population dynamics and monitoring; Veterinary toxicology; animal nutrition; Veterinary parasitology; Mycobacterial diseases, zoonosis, zoonotic diseases (on the increase due to CC); Veterinary epidemiology, veterinary public health, agricultural development ▪ **Sustainable Agriculture, Soil, Forestry and Water sciences:** Modelling, crop water use, irrigation management, irrigation water, smallholder sustainable agriculture, plant disease control, indigenous plant beneficiation, Agroforestry, community forestry, social aspects of forests and forestry, soil fertility, soil-water relations; pasture sciences, animal nutrition; post-harvest pathology, food safety, Microbial ecology; Ethnobotany; Forest pathology; Fungal population biology; Cereal sciences; Engineering geology, hydrogeology; Seed science ▪ **Environmental Law and Governance:** IWRM, water policy, water resources governance; Governance of rural livelihoods, climate change governance; linked to Technology and food security policy; Climate change and insurance law ▪ **Human Settlements and Energy Studies:** Conservation and restoration architecture, urban conservation architecture; Appropriate technology, building science, heritage, affordable housing, sustainable development policy and housing systems, human security, housing development	UP has the following centres / departments that are involved in CCD: ▪ **Centre for Environmental Studies:** extensive climate change research including mapping, livelihoods, adaptation and health (Dr Olwoch – holds a Global Change Grand Challenge Award) ▪ **Construction Economics** (Prof Chrisna du Plessis): holds a Global Change Grand Challenge Award for research on climate resilient and sustainable human settlements ▪ **Geo-informatics and Meteorology** (Prof Engelbrecht, Prof Vogel) ▪ **Agricultural Economics, Extension and Rural Development** (Prof Hassan): climate change and agricultural adaptation

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	▪ **Innovation Studies and Business**: Innovation and technological change; Technology management; Mitigation investment and financing; Corporate involvement in mitigation ▪ **Renewable energy and energy efficiency:** Thermal energy systems efficiency, energy modelling; energy management and energy technology management; carbon materials; Energy modelling, energy efficiency, energy management ▪ **Biodiversity, Conservation and Wildlife Management**: Marine and coastal ecology, population ecology; Veld management, wildlife management, vegetation science; Apoidea (bees) behavioural ecology; Evolutionary ecology; Pollination biology ▪ **Health Sciences:** Antimalarial drug discovery, antimalarial compounds etc.; Public health, malaria control; Nutrition and health, nutritional epidemiology, micronutrients, children's nutrition; Air quality monitoring networks, exposure assessment, environmental epidemiology ▪ **Environmental Resource Economics**, development economics; Climate change economics; Macroeconomics; Transdisciplinary approaches to research in accounting and finance; Critical perspectives on accounting and finance; Ecological economics, agricultural economics ▪ **Biotechnology:** Environmental / water biotechnology, plant biotechnology – fungal-plant interactions; ▪ **Humanities:** Utopian studies, African modernism, New media and art, public art practice. ▪ **Climate Change Meteorology; CC Adaptation, impact and mitigation:** Climate variability modelling; geo-informatics	
University of South	The University has 263 470 students enrolled and is the largest distance learning institution on the African continent. The University of South	**Exxaro Chair in Business and Climate Change Institute for Corporate Citizenship:** Research on green economy transitions, climate

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
Africa	Africa has 130 NRF rated researchers, mostly in the established researcher category, with the following areas of expertise related to CCD as identified in this mapping study. ▪ **Renewable Energy:** Fuel cells, composite materials, environmental engineering and science; Carbon nanomaterial ▪ **Environmental Science and Environmental Management:** Ecotoxicology, bioremediation, environmental microbiology ▪ **Environmental History, Heritage** ▪ **Human Settlements:** Urban geography, social transformation, land reform, spatial planning and environmental management ▪ **African Studies:** African development, power and politics, social theory, Agrarian land questions, global movements ▪ **Indigenous Knowledge Systems:** IKS and Environmental Education / Education for Sustainable Development ▪ **Environmental Education**	mitigation, climate change in Africa (Prof Nhamo) **SARCHI Chair in Development Education**, includes a focus on sustainable development (Prof Hoppers) **Research Niche Area (NRF approved) on Ecotoxicology** (Prof Mphahlele) **Institute for Social and Health Studies**, includes epidemiology research (Prof Seedat) **Institute for Science and Technology Education** (Prof Atagana) **Institute for African Rennaissance Studies** (IARS), focusing on the comprehensive development of Africa(ns) in the 21st century; includes a focus on ESD and sustainable development issues, including climate change (Prof Gutto) Research Flagship Projects relevant to CCD: ▪ **Fog Harvesting Project** in the College of Agricultural and Environmental Sciences (harvesting of clean water for rural water security) ▪ **College of Science, Engineering and Technology** has several research projects focusing on climate change, poverty and pollution of soil and water, as well as a flagship project 'fuel cell and nanotechnology'
University of the Free State	The University of the Free State has 106 NRF rated researchers, mostly in the established research category, with the following areas of expertise related to CCD as identified in this mapping study	Faculty of Natural and Agricultural Sciences hosts the following Centres: **Disaster Management Training Centre for Africa** (Prof A Jordaan):

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
	▪ **Microbial Biotechnology and Microbiology,** mycology, forest pathology, microbiology and plant pathology ▪ **Agriculture, Soil, Animal and Plant Sciences;** soil degradation, soil fertility, soil chemistry, plant nutrition, animal disease control, veterinary biotechnology; plant breeding; soil assessment for land suitability; soil hydrology; soil survey; soil classification; hydropedology; animal production and breeding; soil hydraulic properties; veterinary parasitology; genetic engineering; biotransformation; agricultural biotechnology; crop modelling, cropping systems; sustainable agriculture, agricultural extension, irrigation scheduling, agricultural information systems ▪ **Ecology and Biodiversity (aquatic and terrestrial), including conservation and wildlife management:** Taxonomy, fish diseases, fish parasitology; Wildlife forensics, conservation biology, wildlife management, evolutionary ecology, systematics (biology), entomology; Integrated pest management, biogeography, soil ecology; Bioinformatics, epigenetics; Conservation ecology; Savanna ecology; Grassland science; Restoration ecology; Wetlands ▪ **Solar Energy:** photovoltaic ▪ **Water:** Water conservation, constrained optimisation, irrigation farming, risk analysis ▪ **Food sciences:** Food microbiology, food safety, bacterial taxonomy, food chemistry; Food safety; Food processing ▪ **Health sciences:** Indigenous healing systems, social aspects of health care, health systems research, medical sociology ▪ **History and Global Change:** Palynology, global change, African prehistory ▪ Department of Anthropology is focusing on **social adoption of rain water harvesting technologies**	DDR, disaster risk assessment, disaster management planning, agricultural development planning, business planning, drought risk assessments, disaster risk analyses, also at municipal levels **Centre for Sustainable Agriculture** (Prof Groenewald): Semi-arid sustainable agriculture systems, farming systems research and extension research, natural resources management in agriculture **Centre for Environmental Management** (Prof Seaman): Focus on water conservation and water management (especially groundwater), and water management in water scarce areas Research areas include: management of water aquatic ecosystems in water scarce areas, managing water scarcity in agriculture, optimal water-use for development in water-scarce areas **Department of Agricultural Economics** is focusing on the economics of climate change adaptation research in agricultural commodity contexts

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
University of the Western Cape	The University of the Western Cape has 94 NRF rated researchers, most in the established research category. It conducts research into: ▪ **Renewable Energy, Solar Energy (photovoltaic) and Hydrogen Production and Utilisation**, nanostructures, nanophysics; Solar cells; Applied chemistry, hydrogen economy, fuel cells, hydrogen production and utilisation; Hydrogen storage, hydrogen economy, electro catalysis, electrochemistry ▪ **Land and Agrarian Studies** ▪ **Marine Biology and Marine Sciences**: Biogeography and marine microbiology, biological evaluation of natural products; Biological oceanography, taxonomy ▪ **Rural Development, Coastal and Fisheries Co-management**, fisheries management, integrated coastal management, small-scale fisheries development, gender and development ▪ **Biodiversity Conservation, Plant Molecular Biology**, plant biotechnology, plant genetic transformation; Animal biology ▪ **Science Education and Indigenous Knowledge Systems** ▪ **Nutrition and Public Health**, including health policy, including epidemiology; Environmental health; Health systems, health systems strengthening, health policy ▪ **Environmental Law and Governance**: AU law, environmental law, SADC law, international law (especially international environmental law); Intergovernmental relations ▪ **Biotechnology**, bacterial biotechnology, bio mining micro-organisms, marine biotechnology ▪ **Agricultural Economics**: Research on change in agricultural seasons due to climate change, with focus on food security for smallholder farmers	It has the following Centres that are engaging with aspects of CCD: **PLAAS: The Institute of Poverty and Land Agrarian Studies** (Prof Cousins): SARCHI Chair in Poverty, Land and Agrarian Studies – it was not clear to what extent PLAAS is engaging with CCD issues, but many of the core issues that PLAAS deals with are core to CCD in southern Africa, as pointed out in this mapping study **Institute of Water Studies in the Department of Earth Sciences** (Prof Mazvimavi): involved in climate change, water availability and supply research at regional level

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
University of the Witwatersrand	The University of the Witwatersrand has 248 NRF rated researchers. Relevant areas / nodes of expertise identified: - **Forestry:** Forest hydrology, forest growth modelling, land use hydrology, plant water use efficiency - **Water and Hydrology**: Hydrological modelling, water resources management, stochastic hydrology, water risk and uncertainty; Groundwater hydrology, water engineering; Hydrogeology - **Migration Studies**: Human mobility, governance, migration - **Health:** Bio inorganics and antimalarial - **Geo-physical Changes**: Climate change, sedimentology, geomorphology and landscape; Geo and environmental sciences - **Environmental Engineering** and clean technology development; Clean coal technology - **Biological and Plant Sciences**, entomology, plant biochemistry, biological control; population ecology; Pollination ecology, bird migration, behavioural ecology, ornithology - **Biotechnology** - **Health Sociology and Public Health**: Health promotion; Urban health; Popular culture and new media - **Innovation and entrepreneurship;** Social innovation; Human ecology resilience - **Complexity sciences**, **conservation**, adaptive management, river and wetland sciences; Natural resources management; Sustainable development; Restoration ecology; Savanna ecology - **Environmental biogeochemistry** - **Human Settlements:** Urban development, regional development, environmental design	It has the following Centres involved in CCD research: **Global Change and Sustainability Research Institute** (GCSRI) (Prof Hans-Peter Plag): A multidisciplinary research centre focusing on global change adaptation and mitigation; Biodiversity, human health and nutritional status of rural communities, sustainable urban living through improved water, waste and energy management; Pollution, extraction and ecosystem health; Action research on environmental policies to improve collaboration between environmental, science and technological agencies. The GCSRI also hosts a climate leadership programme. **School of Architecture and Planning** (Prof Irurah): focuses on the built environmental and climate change in South Africa, and strategic implications for architecture; as well as the implications of CC on information settlements in urban areas (Dr Nenweli) **School of Animal, Plant and Environmental Science** is also doing CC research related to CC and changes in tick-borne diseases (East coast fever); adapting conservation strategies to climate change (Prof Erasmus); and research on urban ecology and climate change focusing on social-ecological theory; multiple strategies for resilient livelihoods in communal areas; rural outmigration and livelihoods (Dr Twine) The **School of Electrical and Information Engineering** conducts **renewable energy research** focusing on renewable energy sources such as solar and wave energy, and they are exploring development of linear synchronous generators for ocean wave-energy harvesting; photovoltaic systems conversion and cost efficacy; wind energy generation; intelligent energy systems involving micro-grids for sub-

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
		urban and rural application with renewable sources, which includes a focus on control and metering systems; load identification, and energy use monitoring The **Centre for Applied Legal Studies** also has an environmental law programme (Prof Meyersfeld)
University of Venda	The university of Venda has 15 NRF rated researchers, with some of these researchers particularly associated with the following areas of expertise relevant to CCD: ▪ **Soil Sciences and Environmental Health;** applied clay mineralogy, environmental geology, soil pollution ▪ **Health Promotion and Disease Prevention;** nutrition and health, cross-cultural studies in health care, child malnutrition, epidemiology ▪ **Health related Water Microbiology Research;** environmental health impact assessment ▪ **Biodiversity Conservation,** small mammal ecology; Invertebrate diversity, spider systematics ▪ **Plant breeding** (genetics)	The university has a core research focus on **poverty alleviation and sustainable rural developmen**t. It has the following key research themes that are relevant to CCD: ▪ Food Security: sustainable farming and agro-forestry farming systems for improved livelihoods and food security ▪ Integrated environmental management, settlement and energy for sustainable development ▪ Indigenous knowledge systems ▪ Water research for improved quality of life ▪ Enterprise development, micro-finance and innovation ▪ Public health, youth development and women's health, including gender issues It has an **Institute for Rural Development** (Dr Francis) which is involved in research for developing a household vulnerability index in southern Africa, which is implemented in partnership with the Food, Agriculture and Natural Resources Policy Analysis Network and World Vision (FANRPAN) The **School of Environmental Sciences** (Prof Odiyo) conducts research into ecology and resource management. It also has an **Institute for semi-arid environment and disaster management.**

University	Nodes of Expertise	Centres of Expertise and Centres of Excellence (where these were identified)
University of Zululand	University of Zululand has 11 NRF rated researchers, with the following areas of expertise: ▪ Fish biology, environmental impacts assessment, aquatic ecology ▪ Indigenous Knowledge Systems ▪ Savanna ecology, plant-herbivore interactions, rangeland systems, plant ecology ▪ Nano toxicology, focusing on malarial research	UniZul has a **Centre for Integrated Rural Development**, and a **Department of Geography and Environmental Studies** but it is not clear if and how they are involved in CCD research.
Vaal University of Technology	Vaal University of Technology has six NRF rated researchers with expertise in the following areas relevant to CCD: ▪ **Waste water treatment and integrated water resources management**: Physical water treatment, adsorption ▪ **Renewable energy and fuels:** composite materials, alternative fuels, renewable energy resources, casting technology, polymer nanocomposites ▪ **Community health and food security**, including nutrition/ malnutrition	The University has: A **Centre for Sustainable Livelihoods (CSL)** (Prof Oldwage-Theron) An **Institute of Applied Electronics** that is currently developing a sustainable solar-driven hydrogen plant, using fuel cells – to supply power to rural communities and off grid telecommunication sites (Prof Pienaar) **Water and Wastewater research group** (Prof Aoyi) **Environmental Pollution Group** (focusing on biological contaminants, and have investigated the use of biomass for removal of heavy metals from industrial effluent; complements membrane technology and can remove both high and low metal concentrations from water (Ms Christa van Wyk; Biotechnology Department)
Walter Sisulu University	▪ Walter Sisulu University has seven NRF rated researchers with expertise in the following areas relevant to CCD: ▪ **Plant biology** – linked to livelihoods generation: natural products from plants	Walter Sisulu University has a **Centre for Rural Development** (Head: Prof Luswazi); and a **School of Applied Environmental Science** (Dr Jumbam) but it is not clear to what extent they are engaged in CCD issues. Walter Sisulu University has a SARCHI research chair in **Indigenous Knowledge Systems**.

Other large South African research organisations / centres with CCD research expertise, that provide important research networks for the university-based researchers are:	
The Agricultural Research Council	The ARC conducts the following research related to CCD: remote sensing, geographic information systems research, conservation research, rural geography, agricultural biotechnology, applied animal breeding, and climate change mitigation and adaptation research. They conduct research on renewable energy, biological control, agro-processing, and animal and plant genetics. The ARC has 31 NRF rated researchers, four being internationally acclaimed researchers, one of which specialises in plant genetics and plant breeding.
The Centre for Scientific and Industrial research	The CSIR has 31 NRF rated researchers. It is involved in global change and Earth Systems Science / observation research in its Natural Resources Directorate (where the ACCESS Centre of Excellence is housed – see below); and is also involved in energy, water, waste and clean technology research. It co-operates with university researchers, the DST and the NRF. The CSIR assisted the DST to develop the Global Change Grand Challenge National Research Plan for South Africa.
The Human Sciences Research Council	The HSRC has 11 NRF rated researchers. Research areas relevant to CCD include: Health: health care, health sciences, health services, health systems research, child health, environmental factors impacting on nutritional status, health promotion and disease prevention. Sociology and Urban geography: Regional development, urbanisation, migration, sociology of youth, youth development etc. These are not currently engaged with CCD, but could be important research partners for CCD in future. The HSRC area is also undertaking some studies on the Green Economy, and labour market intelligence, which is important for building the national system of skills development for green economies.
The National Institute for Water and Atmospheric Research	NIWAR has one NRF rated researcher in the category of 'promising young researcher' specialising in climatology.
South African Environmental Observation Network	SAEON has two NRF rated researchers, but works with a wide range of researchers situated in different nodes. All their research is focused on environmental observation and monitoring, including oceanographic modelling and observation; wildlife monitoring; monitoring of aquatic biodiversity; monitoring of biomes etc.

Other large South African research organisations / centres with CCD research expertise, that provide important research networks for the university-based researchers are:	
South African Institute for Aquatic Biodiversity	SAIAB has six NRF rated researchers; it collaborates with a wide range of established researchers. Its key focus areas are fish behaviour, fish monitoring and tracking, taxonomy, population genetics, systematics, estuarine biology, coastal ecology, biodiversity conservation, ichthyology, fisheries management, invasion biology. It is involved in ACCESS and contributes to global change research.
South African National Biodiversity Institute	SANBI has seven NRF rated researchers with expertise in climate change, biodiversity, modelling, earth system sciences, molecular biology, biogeography, invasion biology, conservation and conservation management, ornithology, environmental observation, population ecology. SANBI co-ordinates the Long Term Adaptation Strategy Research and works with national climate change researchers on climate change research. The CEO of SANBI serves on the Future Earth Board / Steering Committee.
Applied Centre for Climate and Earth System Sciences (Centre of Excellence)	**ACCESS Centre of Excellence** (has been established for a while now and works across a number of universities), uses a number of research themes, each of which is led by leading research/ers from the participating institutions in ACCESS. ACCESS also runs an innovative student summer school programme named the 'Habitable Planet' which crosses universities and involves students offering training to other students, supported by core staff at ACCESS, and using a curriculum that has been developing over time to be more inclusive of different disciplines, making the programme more interdisciplinary. The ACCESS CoE has the following research themes which bring together researchers from the CSIR, and universities across the country: Biogeochemistry and Earth System Modelling; Seasonal / inter-annual climate predictability; Long term climate and impacts; Water Resources; Marine and Coastal Estuarine Systems; Urban and Rural Land cover and Land use; Ecosystem Services and Livelihoods (Dr Sweijd, Director ACCESS)

NOTE: Names of researchers have only been included as contact persons for Centres / Institutes identified in universities where these were available. The NRF rated researchers database includes names of researchers associated with the different areas of expertise listed for the universities – these are not all included here given the changing nature of the database (updated annually). Data on specific researchers linked to the research thematic areas listed in this table can best be accessed via the NRF website (www.nrf.co.za).

APPENDIX F: 2012 – 2013 SCARCE SKILLS LIST

The South African 2012-2013 Scarce Skills list is produced from composite data provided by all Sector Education and Training Authorities. This list indicates where South Africa has skills shortages; although it is also recognised that the methodologies used for labour market analysis are generally poor, and data associated with such 'lists' may not always be reliable. Such a list should therefore be seen as **broadly indicative,** rather than definitive.

Additionally, the skills shortages are listed against the Organisational Framework for Occupations (OFO) system. While this list of occupations is enormous and there are a great diversity of occupations, not all environment / sustainable development / climate compatible development occupations are listed (as yet) **since many of these occupations are new**, and some are quite specialised. The following list of scarce skills is therefore only *broadly indicative* of the fact that South Africa may have a skills shortage when it comes to climate compatible development, as the categories indicated below are all related to, but not necessarily directly specific to climate compatible development roles and functions. The assumption here is that if the broader set of skills are not available, the more specific and increasingly specialised skills necessary for CCD are not likely to be available either. Skills listed below are from those SETAs that have the most responsibility for various aspects of environment and sustainable development.

Table 7: 2012–2013 Scarce Skills List

Occupation	SETA listing the scarce skill	Quantification of scarce skills
Physical, Mathematics and Engineering related skills	Energy SETA AgriSETA LG SETA CATTHSETA	1001 1056 631 2260
Life Science Professionals	AgriSETA LG SETA CATTHSETA	879 100 2110
Biologists	CATTHSETA	60
Environmental Protection Professionals Conservation Scientists	AgriSETA LG SETA CATTHSETA	18 50 1000
Meteorologists		24
Electrotechnology Engineers	ESETA	1513
Urban and Regional Planners	LG SETA	111
Safety, Health and Environmental Officers	AgriSETA LGSETA	304 40
Environmental Health Officers	LGSETA	230
Training and Development Officers	AgriSETA LGSETA	300 300
Environmental Technicians	Overall	2250
Water Plant Operators	LG SETA	600
Environmental Practices Inspectors	CATTHSETA	200

APPENDIX G: SOUTH AFRICAN UNIVERSITIES AND ASSOCIATED RESEARCH CAPACITY (INDICATED BY R&D FUNDING AND NUMBERS OF DOCTORAL STUDENTS

The 23 South African universities host a number of South Africa's researchers as well as large numbers of doctoral researchers (see details below):

UNIVERSITIES R&D EXPENDITURE, RESEARCHERS AND DOCTORAL STUDENTS, 2007/08

	% of total Universities R&D expenditure	Researchers (headcount)	Doctoral students (headcount)
Universities			
University of Cape Town	15,79%	2321	1203
University of the Witwatersrand	15,50%	1630	1105
University of KwaZulu-Natal	12,85%	1910	1162
University of Pretoria	11,48%	1996	1585
University of Stellenbosch	9,99%	1034	1001
North-West University	6,17%	1328	866
University of Johannesburg	4,12%	683	565
University of the Free State	3,93%	193	632
University of South Africa	3,47%	1106	771
Nelson Mandela Metropolitan University	2,69%	444	346
Rhodes University	2,62%	291	256
University of the Western Cape	2,47%	516	353
Tshwane University of Technology	1,93%	509	146
University of Limpopo	1,29%	745	154
Universities of Science and Technology			
Cape Peninsula University of Technology	1,17%	171	90
Durban University of Technology	0,93%	299	53
Walter Sisulu University for Technology and Science	0,83%	526	13
Central University of Technology	0,74%	134	59
University of Zululand	0,59%	231	151
Vaal University of Technology	0,52%	287	29
University of Fort Hare	0,31%	292	155
University of Venda	0,24%	278	49
Mangosuthu University of Technology	0,11%	37	0
Private universities			
Monash University	0,27%	47	0

Source, SAccess report, 2013. *[note that statistics in this table require updating, but they provide a good indication of the R&D capacity of South African universities and their capacity for PhD research supervision and support, and show that the university sector play an important role in research and research capacity development in South Africa; it also shows inequality in university capacity for R&D]*

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