science
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Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

SOUTH AFRICA'S CLIMATE CHANGE TECHNOLOGY NEEDS ASSESSMENT

SYNTHESIS REPORT

SEPTEMBER 2007

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FOREWORD

This report is the outcome of a stakeholder-driven Technology Needs Assessment (TNA) to identify and assess environmentally sound technologies that will, within national development objectives, reduce the impact of climate change and the rate of greenhouse gas emissions in South Africa. The process of conducting the TNA was initiated by the National Committee on Climate Change, which mandated the Department of Science and Technology to manage the process.

Within the United Nations Framework Convention on Climate Change (UNFCCC), developed country parties are required to cooperate with developing country parties in the area of technology transfer to address climate change. Technology transfer in this context refers to a broad set of processes covering the flows of know-how, experience and equipment for mitigating or adapting to climate change among different stakeholders such as governments, private sector entities, financial institutions, non-governmental organisations, and research/education institutions.

South Africa, as a developing country party to the UNFCCC, is required to undertake a TNA with respect to climate change and to submit the report of this assessment to the secretariat of the UNFCCC as a National Communication to the Convention. Once these technologies have been prioritised and the TNA Synthesis Report has been submitted to the UNFCCC secretariat, developed country parties can use the Report as a means to cooperate with developing countries in order to meet their obligations in terms of technology transfer with respect to climate change.

This report indicates to our developed country partners what South Africa's priorities are in terms of technologies to address climate change. It is hoped that this initial submission will facilitate the next, critical step, which is the development of specific implementation plans for the prioritised technologies. It is envisaged that this process will open up access to funds, create an enabling environment for the transfer and uptake of technologies, and highlight opportunities for research and development cooperation in this area.

1. BACKGROUND AND INTRODUCTION

1.1 South Africa's institutional response to climate change

South Africa ratified the United Nations Framework Convention on Climate Change (UNFCCC) in August 1997. The primary objective of this multilateral agreement is to achieve the stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic activities from interfering with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable development to proceed in a sustainable manner.

In terms of Articles 4.1(c), (j) and 12 of the Convention, countries are periodically required to submit reports to the Conference of Parties on various topics regarding their attempts to address climate change. In order to fulfil these requirements, South Africa prepared an Initial National Communication in 2000. In July 2002, the South African Government acceded to the Kyoto Protocol. This was deemed necessary as the international community recognised that the commitments set out in the UNFCCC were inadequate for achieving its ultimate objectives. Over this period South Africa compiled a detailed Country Study on a sectoral basis. This study, with information obtained from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Reports, made a significant contribution to the national Department of Environmental Affairs and Tourism (DEAT) launching South Africa's National Climate Change Response Strategy in 2004. In further pursuit of fulfilling its obligations under the UNFCCC to furnish information, DEAT undertook a stocktaking exercise in 2005 in preparation for South Africa's Second National Communication in terms of the UNFCCC.

Article 4.5 of that Convention identifies technology transfer as a key mechanism for addressing climate change, and requires developed countries to support technology development and utilisation in developing countries. In order to operationalise Article 4.5, parties agreed to introduce a mechanism known as a technology needs assessment (TNA). This document reports on South Africa's TNA.

1.2 Sustainable development, climate change and national priorities

South Africa, like other developing countries, faces the dual challenge of protecting the environment while pursuing economic growth in a sustainable manner. A key concern is that climate change has the potential to undermine progress in this domain.

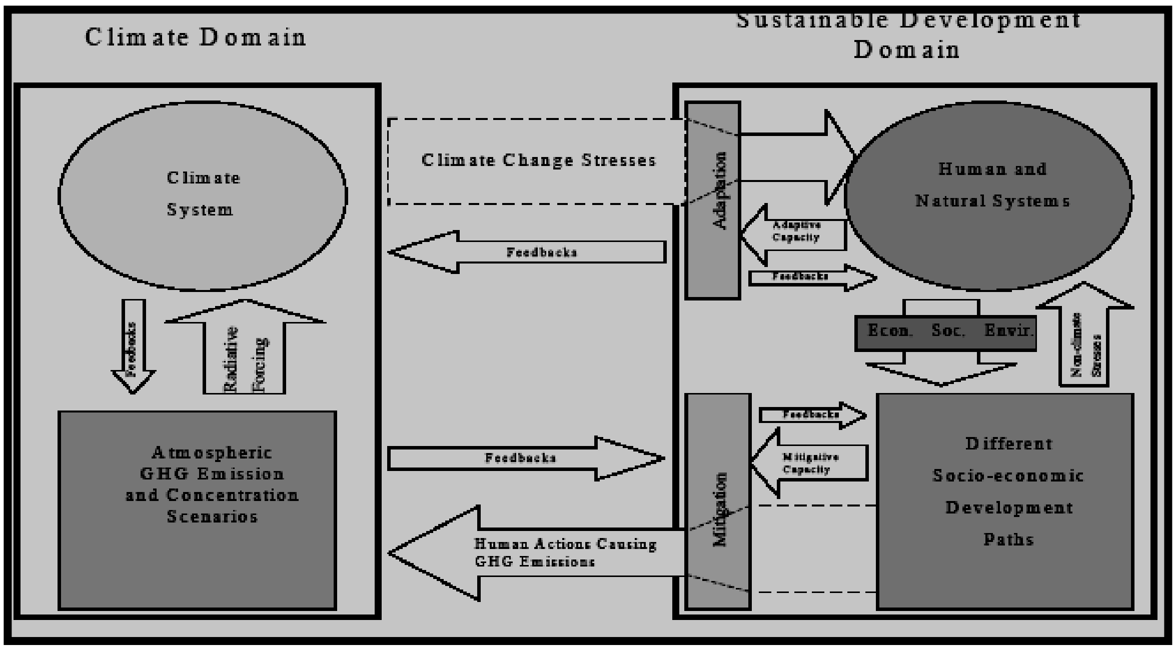

Fig. 1. Integrated assessment modelling for analysing climate change and sustainable development linkages (Source: Adapted from IPCC 2001)

The full cycle of cause and effect between climate change and sustainable development is summarised in Figure 2 (IPCC 2001). Each socio-economic development path (driven by the forces of population, economy, technology and governance) gives rise to different levels of GHG emissions, which impose stresses on the human and natural systems. In this way adaptation and mitigation strategies are dynamically connected with changes in the climate system and the prospects for ecosystem adaptation, food production, and long-term economic development.

South Africa clearly needs to place climate change at the centre of its economic policies and development projects, as it is evident that climate change and development interact in a circular fashion (Swart 2003). Sustainable development that is appropriate and specific to the South African context will entail shared and accelerated growth, targeted interventions and community mobilisation to eradicate poverty, and ensure the ecologically sustainable use of our natural resources and ecosystem services (DEAT 2007).

The Millennium Development Goals warrant the integration of sustainable development principles into country policies and programmes. The South African government has initiated responses to the Millennium Development Goal targets of reversing the loss of environmental resources, increasing the numbers of its citizens who have access to safe drinking water, improving the quality of life of people living in informal settlements, addressing health issues pertaining to the eradication of major diseases, reducing infant mortality and improving maternal health. The environmental rights provided for in the Constitution of the Republic of South Africa, 1996, and progressive environmental legislation have made it possible to incorporate sustainable development principles into various sector policies and programmes. Key strategies have been developed and adopted to address biodiversity loss and development pressures on ecosystems and natural resources, combat the effects of increasing desertification, and respond to the effects of an increasingly warmer and drier climate on the natural environment, communities and the economy. These include the National Biodiversity Strategy and Action Plan, the National Climate Change Response Strategy, the Energy Efficiency Strategy, the White Paper on Renewable Energy, the National Water Resources Strategy, the National Disaster Management Framework, the Cleaner Production Strategy, the National Land Care Programme, the National Action Programme for Desertification and the National Action Programme for Combating Land Degradation to Alleviate Rural Poverty. Provincial and local governments are also proactively involved in addressing sustainable development issues (DEAT 2007).

1.3 The South African context for addressing climate change

On a global scale, South Africa's contribution to GHG emissions is small, accounting for less than 2% of total emissions. However, South Africa's highly energy-intensive economy and reliance on coal-based electricity makes the country the 14th highest carbon dioxide emitter in the world, with per capita emissions being higher than those of many European countries and more than 3,5 times higher than the average for developing countries (Winkler 2007).

South Africa, as a developing country (Non-Annex I country), does not have any binding GHG reduction commitments. Under the Kyoto Protocol, carbon constraints, or caps, were only placed on industrialised countries. South Africa and other Non-Annex 1 countries are allowed to continue to grow without carbon constraints, at least until the end of a first commitment period (2012). However, once developed nations take the lead, they expect (at least some) developing countries to follow. South Africa may be pressurised to accept future commitments to reduce emissions and possibly be required to take on a bigger burden regarding emissions if its per capita emission levels are used to determine its share of emissions burden in a post-2012 scenario (Winkler et al. 2006).

1.4 Implications of climate change for South Africa

According to the latest scientific information, key impacts predicted for Africa for the period 2020 to 2050 include (IPCC 2007) the following:

- Between 75 and 250 million people will experience greater water stress by 2020.
- Rain-fed agricultural yields could be reduced by 50% by 2020 in some countries.
- There could be a 10 to 30% reduction in average river run-off and water availability by mid-century.
- Drought-affected areas will increase in extent.
- Flood risk in high rainfall areas will increase.
- Ecosystem structures will change and there will be a loss of biodiversity if temperatures increase more than 1,5 to 2,5°C.
- Human health challenges will arise, e.g. possible changes in malaria transmission potential.

For Southern Africa, subcontinental warming is predicted to be greatest in the northern regions. Temperature increases in the range of between 10°C and 30°C can be expected by the mid-21st century, with the highest rises in the most arid parts of the country. Of greater consequence for South Africa, as a semi-arid country, is the prediction that a broad reduction of rainfall, in the range 5% to 10%, can be expected in the summer rainfall region. This will be accompanied by an increasing incidence of both droughts and floods, with prolonged dry spells being followed by intense storms. A marginal increase in early winter rainfall is predicted for the winter rainfall region of the country.

Key risks of climate change for a water-stressed country such as South Africa include threats to water supplies and changing rainfall patterns. Temperature increases could enlarge the areas prone to malaria and other vector-borne diseases. Temperature changes could also pose various challenges to crop cultivation. Higher carbon dioxide levels could reduce proteins in grasslands in livestock producing areas, in particular in poorer, drier parts of the country, and fisheries and the livelihoods of fishing communities will be affected by changes in the sea temperature. The impact of climate change is increasingly emerging as possibly the greatest threat to biodiversity loss. For example, the Cape Floral Kingdom could be significantly reduced, with negative economic impacts in the tourism sector.

While global climate change provides serious challenges to South Africa, opportunities to optimise our progress towards more sustainable development lie in a growing awareness of the need to find more sustainable production and consumption processes (in particular in the Energy Sector), to reduce our high per capita emissions, and to respond to climate impacts through mitigation and adaptation. Harnessing this awareness could drive a gradual shift towards more robust farming methods such as organic farming to build soil quality and the biological capacity of local ecosystems to respond to change. Higher energy prices need not be seen as retarding growth, but rather driving increased efficiencies across all production and consumption systems. Large-scale investments in renewable energies have proven to be significant job creators in other countries, and major opportunities are generated for technology innovation and skills development. South Africa could harness financial benefits through global funding mechanisms, including the Clean Development Mechanism, created under the Kyoto Protocol (DEAT 2007).

1.5 South Africa's response options to climate change - adaptation and mitigation

Traditionally, a twin-track approach to address climate change (UNFCCC, Article 2) has been adopted, comprising mitigation and adaptation measures. Both seek to avoid the potential damages of global climate change, as well as to support the development of present and future generations in a sustainable manner. For a long time, adaptation has been treated as a marginal option in comparison to mitigation by scientists and decision-makers worldwide (Kane and Shogren 2000; IPCC 2001). In recent years, however, it has become apparent that regardless of how effectively precautionary measures are taken by the global community to mitigate anthropogenic GHG emissions, a non-negligible degree of global climate change is unavoidable due to the long lifespan of GHGs in the atmosphere and the inertia of the climate system (IPCC, 2001). Therefore, despite even the most strenuous efforts to move to a low carbon economy, the effects of climate change due to past activity will continue to be felt, and so it is imperative that society plan to adapt to them (Munasinghe and Swart 2005). For developing countries like South Africa, the way this is done will have a considerable effect on our quality of life over the long term.

1.6 The purpose and objective of a technology needs assessment

This Climate Change Technology Needs Assessment project has been undertaken to introduce technologies that could improve South Africa's developmental and environmental integrity. The main objective here is to identify and assess environmentally sound technologies that have synergy between reducing the impact of climate change and the rate of GHG emissions in South Africa within national development objectives.

Technology transfer in this context has been defined as a broad set of processes covering the flow of know-how, experience and equipment for mitigating or adapting to climate change among different stakeholders such as government, private sector entities, financial institutions, non governmental organisations and research/education institutions.

A TNA represents a set of country-driven activities that identify and determine the most appropriate mitigation and adaptation technology priorities of a country. Adopting a consultative process, it identifies the barriers to technology transfer and measures to address these barriers through sectoral analyses. The primary goals of this TNA are to –

- contribute to global efforts towards sustainable development, in particular the protection of the climate system;
- communicate South Africa's climate change technology requirements to the Conference of Parties under UNFCCC and the global community; and
- identify a portfolio of technology development and transfer programmes that have the potential to reduce GHG emissions and contribute to South Africa's sustainable development.

The broad of objectives of a TNA include –

- identifying, analysing and prioritising technologies that could form the basis for a portfolio of environmentally sound technologies, projects and programmes;
- identifying human, institutional and systemic capacity needs to ensure the smooth development, transfer and acquisition of environmentally sound technologies; and
- enlisting interest and commitment from key stakeholders, and forging partnerships to support investment or remove barriers in order to enhance the commercialisation and/or the diffusion of high priority technologies.

1.7 The Role of the Department of Science and Technology

The National Committee on Climate Change (NCCC) has mandated the South African Department of Science and Technology (DST) to manage a TNA in relation to climate change. The DST promotes the mastery of technological change in the economy and society in terms of the South

African National Research and Development Strategy (DST 2002). It is envisaged that this will be achieved through the implementation of the government's 10-year plan (2008 to 2018) for South Africa, Innovation towards a Knowledge-Based Economy. Without the establishment of new technology missions aligned to quality-of-life goals and economic and industrial strategies, South Africa will not be able to progress towards a knowledge-based economy (DST 2007). The preparation and implementation of the TNA, and the policy that will be developed, are functions of the DST.

2 PROCESS METHODOLOGY

The process used for South Africa's TNA has been set out under three main activities, which were adapted from various United Nations guidelines on conducting TNAs.

Activity 1: Project initiation

The aim of this task was to provide sufficient information to the project team to guide the direction of the project.

Preliminary assessment of climate change activities in key sectors
In January 2005, the Council for Scientific and Industrial Research (CSIR) was commissioned to undertake the groundwork necessary to initiate the TNA. A critical first step entailed a scoping exercise to collate the latest information on the mitigation and adaptation potential of key sectors in South Africa, which resulted in a TNA discussion document. As part of this process, a preliminary list of stakeholders was also developed.
Project initiation workshop to obtain stakeholder input
The TNA discussion document was reviewed by the NCCC, which consists of representatives of national, provincial and local government, civil society, academia and research institutions. Their comments and suggestions were incorporated into the discussion document. The discussion document was revised and used to initiate the development of a detailed TNA resource document.

Activity 1 outcomes:

- TNA discussion document, *A Discussion Document for the Process of Developing a Technology Needs Assessment for South Africa with respect to Climate Change* (Scholes 2005). This was prepared by CSIR Environmentek on behalf of the NCCC.
- A preliminary list of stakeholders.

- The proceedings of the workshop with NCCC stakeholders.

Activity 2: Identification of criteria to assess and prioritise technologies

The aim of this task was to develop the analytical framework required for the compilation of the TNA, to conduct an expert prioritisation exercise, and to collate the information from the expert prioritisation exercise in order to rank the technologies for the final TNA resource document.

Development of an initial TNA resource document
Following the NCCC workshop to discuss the TNA discussion document (Activity 1 outcome), the CSIR was awarded a contract to develop the TNA further.
Establishment of a project steering committee (PSC)
To ensure the ongoing and active involvement of representatives of various national government departments, a PSC was established (Appendix 1). The approach, methodology and work plan for the TNA project was agreed to at the first meeting of the PSC and the CSIR project team.
Identification of criteria for the assessment of technologies
An extensive list of technologies with mitigation and/or adaptation potential was developed for a range of sectors. Criteria for the prioritisation of technologies were developed by the CSIR project team. A complete list of technologies for all sectors and the proposed criteria to be used in the process of prioritisation was highlighted in the first draft of the TNA resource document.
Stakeholder input: sector workshops
The first draft of the TNA resource document was discussed with stakeholders in August 2006, with a view to achieving consensus on the criteria for prioritisation and the technologies to be assessed for each sector. It was agreed that the list of criteria compiled would be applied to all technologies listed in the first draft of the TNA resource document.
Development of a prioritisation matrix
The TNA resource document was refined to include the list of technologies and proposed criteria to be used in the process of prioritisation.
Stakeholder input: NCCC Meeting
In September 2006 the proposed technologies and criteria were presented at a meeting of the NCCC to obtain further input on the criteria to be used to assess the technologies.
Application of criteria
A number of key experts (Appendix 2) used the criteria to assess the technologies for their sector. This resulted in the second draft of the TNA resource document.
Stakeholder input on prioritised technologies
The second draft of the TNA resource document was reviewed by the PSC and NCCC, and their input was used to finalise the document.

Activity 2 outcomes:

- The establishment of a PSC.
- Proceedings from the sector and NCCC workshops.
- The criteria for prioritisation.
- The final TNA resource document, with a complete list of prioritised technology options.

Activity 3: Preparation of a synthesis report

The overall aim of this activity was to prepare and finalise the TNA for submission to the South African Cabinet and then to the UNFCCC secretariat. While the TNA resource document is a very lengthy document, it did not fully cover all the issues suggested by the UNFCCC. In addition, stakeholders and the PSC recognised the need to capture the information from the TNA resource document in a format that would be relevant to sector stakeholders and the international community. It was therefore decided that a shortened, strategic TNA Synthesis Report should be compiled.

Development of a framework for the TNA Synthesis Report
A literature review was undertaken to determine the key information that needed to be incorporated into the TNA Synthesis Report, specifically in respect of the key prioritised technologies in the TNA resource document. A framework for the TNA was developed on the basis of this review. A template was developed for the prioritised sectors and circulated among the relevant national departments to obtain high-level strategic input regarding the relevance of the proposed technologies for the South African context.
Stakeholder Input: National Committee on Climate Change Meeting
A workshop was held with NCCC stakeholders in September 2007 to gain consensus on the format and content of the TNA Synthesis Report.
Review and finalisation of the TNA Synthesis Report
Comments from the NCCC workshop in September 2007 were used to finalise the TNA synthesis report. This report was submitted first to the South African Cabinet for approval, and then to the UNFCCC.

Activity 3 outcomes:

- Circulation of template and feedback from relevant departments.
- The TNA Synthesis Report which was submitted to the UNFCCC.

3 ANALYTICAL FRAMEWORK

3.1 Criteria for prioritisation

South Africa, with its combination of a dynamic and sophisticated private sector, well-developed civil society organisations, and strong government, is likely to have several parallel pathways for technology transfer.

Different criteria and priorities may apply to each pathway. Criteria that were considered addressed two groups of technologies, mitigation and adaptation. Most criteria apply to both groups but, in some cases, a particular criterion is relevant only to one. For example, "reduction in warming potential" applies only to measuring mitigation technologies. The criteria below are structured to contain a number of measures relevant to a particular criterion. Each measure is ranked on scale of 0 to 3, with 0 indicating zero impact, non-applicability or a negative ranking, 1 a low ranking, 2 a medium and 3 a high ranking. The prioritisation of technology options was done in phases. Firstly, the maturity of the technology was considered. Only options where commercialisation has not yet occurred on a large scale in South Africa and where technology transfer from developed countries is required were selected for the prioritisation matrix. Each measure selected was then weighted on a scale of 1 to 3 (as a zero weighting would mean that the measure made zero contribution to the total). A weighting of 1 means the measure has low importance, 2 indicates medium impact or importance, while 3 is selected for measures that are really critical.

For each selected technology option, experts allocated scores for every measure (Appendix 2). Each score was multiplied by the relevant weighting and a total was calculated for each technology. Each result was then normalised by multiplying it by 100% and dividing by the total maximum possible score of 66 (The total maximum score was calculated by multiplying the individual maximum score of 3 by the sum of the weighting factors, i.e. 22).

In the next phase of the prioritisation, technology options were arranged in a hierarchical order and all the options that contained a score of 1 or 0 for one or more measures were removed from the prioritisation matrix. The only exception to this rule was the measure "indigenous knowledge". Although it is important in a developing country, for many technological options it was scored 0 or 1. Counting the lack of contribution by indigenous knowledge to a transfer of technologies doubly penalises a technology which, because there is no enabling environment, does not qualify for support. A comparison can be drawn to situations where the prioritisation process has identified local barriers for implementation, such as a lack of local skills, a lack of supporting systems, cultural preferences, etc. Most of these barriers could be addressed at a national level to create an enabling environment for technology transfer. The economic and social benefits of resolving these barriers will have positive impacts beyond the mitigation of climate change impacts, and will support sustainable economic development. The criteria and measures, as well as the weighting for each, are summarised in the table below.

Table 1: Summary of criteria

Criteria groups		Short description	Measures – full description	Weighting
1	Relevance to climate change	Mitigation potential	Mitigation-measured by net reduction of global warming potential	3
		Vulnerability	Vulnerability and resilience	3
2	Alignment with national goals	Strategies and targets	Alignment with existing national policies and strategies	2
		Sustainability	Level of sustainability ('no regret' solutions)	3
		Competitive advantage	National competitive advantage	1
	Market potential	Costs/Benefits	Full economic costs and benefits	3
		Utilisation scale	Potential scale of utilisation	1
		Maturity	Technology maturity	1
3	Skills and capacity building	Support systems	Systems in place to support transfer/implementation	2
		Users	Cultural preferences and/or understanding of technology by users	2
		Indigenous Knowledge	Indigenous knowledge (know-how, skills, attitude and value)s	1
	Total			22

These criteria were applied to all technologies highlighted in the TNA resource document (Appendix 3). Key technologies for prioritisation are highlighted in this synthesis report on the basis of the total score on application of the above criteria, input from relevant government departments and key stakeholders.

For the purpose of this analysis, sectors used in the TNA resource document were regrouped. The Energy Sector includes electrical energy generation, industry and mining and waste management. The buildings and domestic commercial energy use sector was renamed "Built Environment and Infrastructure Sector". The Agricultural and Forestry and Land Use Sectors were merged. Technologies in the commercialisation phase were omitted for prioritisation. Cross-cutting issues and financial mechanisms are overarching issues and are discussed separately in section 6.

3.2 Key sectors and technologies for prioritisation

A list of the priority adaptation and mitigation technologies for each of the key sectors are summarised in Table 2. The priority given key sectors was based solely on the numbers of adaptation and/or mitigation technologies associated with them. This is illustrated in Figure 2, from which it is evident that both adaptation and mitigation are equally important for South Africa. Most technologies for mitigation belong to the Energy Sector. The key sectors for adaptation were identified as Agriculture, Land Use and Forestry, Water Resources, Human Health, and Built Environment and Infrastructure. A mix of adaptation and mitigation options was evident for the Agricultural Sector.

The prioritized mitigation and adaptation technologies identified are discussed on a sectoral basis in Section 4 and 5 respectively.

A group of technologies which are overarching in nature were identified as playing an important role in terms of addressing climate change in South Africa. This group was further divided into two sub-groups, namely, cross-cutting issues and methodologies for the application of financial mechanisms. For the purposes of this synthesis report, only the Top 3 technologies in each of these categories are addressed (Table 3). The overarching issues and are discussed in Section 6.

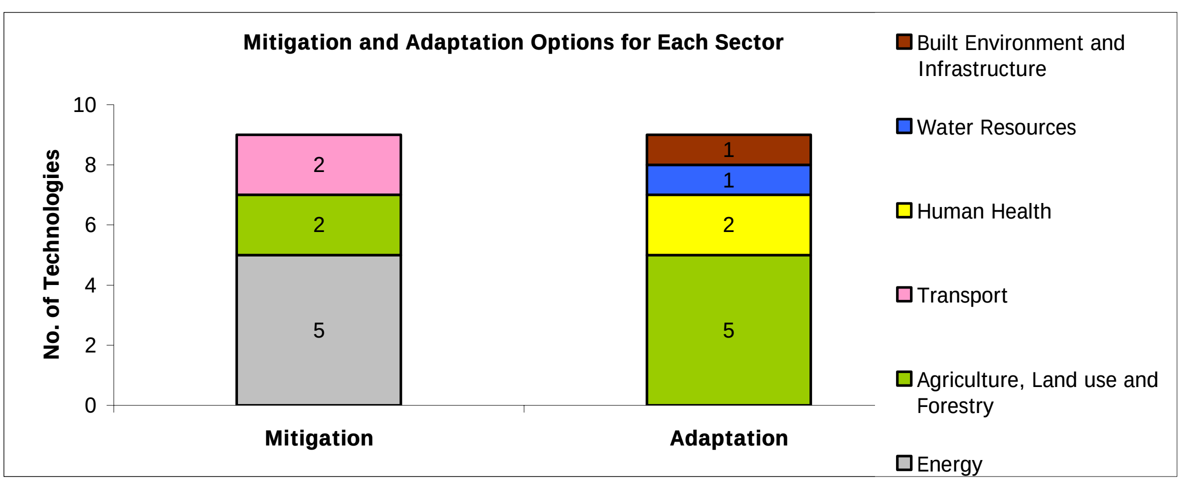

Fig. 2. Prioritised sectors for and number of associated adaptation and mitigation technologies

Table 2: Key sectors and associated prioritised technologies

Response	Sector	Subsector	Measures/technology options	Total score (%)
Mitigation	Energy	Electrical energy generation	Solar power	85,6
			Clean coal technologies	75
			Wind power	75
		Industry/mining	Boiler improvement	78,8
		Waste management	Promote the source reduction, recycle and reuse	84,8
	Agriculture, Land Use and Forestry		Conservation agriculture	83,3
			Control of biomass burning in wildfires (including forests)	81,8
	Transport		Improvement of urban mass-transport systems	81,8
			Fuel-efficiency improvements	81,1
Adaptation	Human Health		Provision of water supply and sanitation	90,4
			Control of the spread of vector-borne disease	87,1
	Agriculture, Land Use and Forestry		New crop species and cultivars	88,6
			Information technology	87,1
			Macro-economic diversification and livelihood diversification in rural areas	82,6
			Pest management	80,3
			Vulnerability research	80,1
	Water Resources		Technologies that promote water efficiency	81,8
	Built Environment and Infrastructure		Climate-sensitive building design	81,1

Table 3: Prioritized overarching issues

Overarching Issues	Measures / technology options	Total Score (%)
	Weighting factor	**57**
Cross Cutting	Improved data management, processing and integration	75,4
	Improved communication and response in Disaster management	74,6
	Networks for information sharing and data integration	72,8
Financial Mechanisms	Incentives for energy efficiency	88,6
	Incentives for renewable energy	75,4
	Disincentives for high fuel consumption vehicles	72,8

4 PRIORITY SECTORS FOR MITIGATION AND KEY TECHNOLOGIES FOR PRELIMINARY ACTION

4.1 Mitigation

It is well documented that global GHG emissions need to fall below 1990 levels within a few decades and be reduced to a fraction of that (60% or more) after that if we are to prevent the worst excesses of climate change occurring from the second half of the 21st century onwards. After the stabilisation of GHGs has been achieved, temperatures will continue to rise for a century or more, while the sea level is projected to rise for many centuries. The slow transport of heat into the oceans and the slow response of ice sheets mean that it may take a millennium or more before a new climate system equilibrium is reached. Regardless of the final outcome, it is acknowledged that reducing emissions will delay and reduce the damage caused by climate change (IPCC 2007).

4.2 Energy Sector

4.2.1 Overview of sector

South Africa's Energy Sector is critical to the economy, contributing about 15% to the country's gross domestic product. Due to its large coal deposits, South Africa is able to offer electrical power that is cheap by international standards. Since 80% of GHG emissions are related to energy production, this is the most important sector when mitigation is considered (Winkler 2006). The industrial sector consumes almost 50% of the total energy generated in South Africa. The low cost of energy has given local industries a competitive advantage and encouraged energy-intensive industries. Commercial and residential energy users are, directly and indirectly, responsible for about 2% of South Africa's GHG emissions. This sector is growing rapidly due to urbanisation, and its energy consumption is rising even faster (because of rising wealth and a policy of energy service provision). Therefore, there is potential for significant mitigation in this sector.

4.2.2 Prioritisation of Energy Sector technologies

The technologies were evaluated using the criteria matrix and the results are presented in the table below.

Table 4: Evaluation matrix for Energy Sector

	Measures/technology options	**Strategies and targets**	**Sustainability**	**Competitive advantage**	**Mitigation potential**	**Costs/Benefits**	**Utilisation scale**	**Maturity (global)**	**Support systems**	**Users**	**Indigenous knowledge**	**Total score (%)**
Subsector	**Weighting factor**	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Electrical energy generation	Solar power	3,0	3,0	3,0	2,5	2,5	3,0	2,0	2,0	2,3	1,0	85,6
	Wind power	3,0	3,0	2,5	2,0	2,5	1,5	3,0	2,0	1,5	0,0	75,0
	Clean coal-based technologies	2,5	2,0	3,0	2,5	2,0	2,5	1,5	3,0	2,0	0,0	75,0
Industry and mining	Boiler improvement	3,0	3,0	2,0	2,0	2,0	2,0	3,0	3,0	2,5	0,0	78,8
Waste management	Avoidance, minimisation and reuse	3	3	3	2	3	3	3	2	2	0	84,8

4.2.2.1 Electrical energy generation

4.2.2.1.1 Renewable energy technologies

The South African government generally supports renewable energy technologies (RETs). Its RETs policy stipulates a voluntary target of 10 000 GWh to be supplied from renewable sources by 2013. The target is approximately 10% of the country's electricity demand, less than 1% of which is currently met from renewable sources. By late 2005 the Department of Minerals and Energy (DME) had completed a Renewable Energy Target Monitoring Framework to ensure that progress towards the 2013 target was effectively monitored (DME 2005).

Solar power: South Africa experiences high levels of solar radiation, with average daily solar radiation of between 4,5 kWh and 6,5 kWh per square meter. This resource is relatively predictable and well distributed throughout the country, with some regional variations. However, RETs are not widely disseminated in South Africa.

Photovoltaic

This usually consists of panels that absorb the sun's energy and convert it into electricity. These conductors are called photovoltaic (PV) devices or solar cells. An inverter and a regulator are needed to even out the current and the power can be stored in batteries to be used when the sun is not shining so brightly. It is best for household use or when relatively small amounts of electricity are needed. In South Africa, no electricity from solar power is generated for the national grid, but PV systems are widely used in rural areas. Current use of this technology is on a small scale and there is indeed a need to ensure much greater uptake of this technology in both rural and urban settings.

Concentrating solar power

This technology can be accessed through three different systems: parabolic trough, parabolic dish and power tower. The parabolic trough is the most mature of the technologies. However, the power tower has potentially lower costs and more efficient thermal storage.

Wind power: Wind energy electricity generation is a new technology in South Africa. South Africa has abundant wind, especially along the coast. The technology for wind power generation is readily available and has potential, but implementation is limited by local wind conditions and cost (AGAMA Energy 2003). Currently, in South Africa, no electricity on the national grid is wind generated. However, wind has been important traditionally, and continues to be so, for pumping water on farms (Banks and Schaffler 2006).

4.2.2.1.2 Clean coal-based technologies

Improved power-generation technologies will help the nation make more efficient and environmentally-responsible use of its abundant domestic coal reserves. Accordingly, advances in technologies for central coal power plants and in turbine combustion for power plants are sought.

Integrated gasification combined cycle (IGCC) – IGCC-based systems are attractive alternatives to current pulverised coal technologies in large-scale stationary applications. IGCC systems are very efficient, with efficiencies ranging from 35 to 45% (depending on system configuration and size). They also are environmentally friendly, emitting lower levels of criteria pollutants and particulates. Enabling technologies for higher efficiencies and lower emissions will include advances in combustion modeling and oxy-syngas combustion.

Gasification technology increases the efficiency of the coal power-generation cycle by combining two or more energy cycles: a high-temperature gas turbine cycle and a steam turbine cycle. The exhaust gases from the gas turbine are cooled in a heat-recovery steam generator and the steam is sent to a steam turbine for additional electricity generation. The benefits of the IGCC include very low stack emissions, efficiencies of up to 48%, very high (98%) sulphur removal rates and the potential to remove carbon dioxide from the syngas for carbon sequestration.

Fluidised-bed combustion (FBC) - This new technology has been tested in many countries, but has not yet been used in South Africa. Coal is burnt in a "bed" or dense cloud of aerodynamically suspended particles. The environmental advantage of FBC is reduced nitrogen oxide emissions. FBC allows for fuel flexibility as lower grade (high sulphur content) coal can be used and the coal can be supplemented with different types of biomass. In the case of South Africa, where the discard coal produced is in excess of 1 billion tonnes, the case for FBC to consume this discard is promoted as the technology should allow for the clean-up of the discard already being produced and dumped. Fluidised-bed combustion provides a further benefit in that it can operate and perform in-situ desulphurisation without additional water requirements. The possibility of South Africa getting legislation regulating sulphur dioxide emissions warrants a strategy for water consumption associated with the coal-generation technologies. FBC provides an attractive alternative option for coal power generation in a country which is considered water-scarce, and where coal deposits are concentrated inland.

The Integrated Resource Plan of South Africa's nation energy regulator envisages the implementation of FBC by 2013 (National Electricity Regulator 2004). Over a longer term, coal-powered fuel cells (Winkler 2006) and ultra-supercritical coal-fired power generation is expected.

4.2.2.2 Industry/Mining

4.2.2.2.1 Boiler improvement

In South Africa there is a need to improve coal-fired boiler efficiencies, oil-fired boiler efficiencies and gas-fired boiler efficiencies. The effect of improving coal-fired boiler efficiencies extends the life of local reserves, and reduces local pollutants. The effect of improving oil-fired boiler efficiencies reduces oil consumption and therefore crude imports and reduces local pollutants. The effect of improving gas-fired boiler efficiencies reduces gas consumption, and therefore for liquid petrol gas, crude imports, natural gas, gas imports, and synthetic gas lower local outputs. More efficient technologies that can be applied to boilers burning low-grade coal have the potential to significantly reduce emissions (Trikam 2002). The trade-off efficiency gain and associated life-cycle cost must be evaluated to identify the benefit of implementation within the local context.

Boiler technologies where co-firing has been practised, tested or evaluated include wall-fired and tangentially designed pulverised coal boilers, coal-fired cyclone boilers, fluidised-bed boilers and spreader stokers. Research and development (R&D) is needed in this area.

4.2.2.3 Waste management

4.2.2.3.1 Avoidance, minimisation and reuse

The National Waste Management Strategy has identified a hierarchy of approaches to the effective management of waste, which encompasses avoidance, minimisation and reuse strategies. This represents a shift from focusing on improved methods for treating and disposing of waste, towards efforts at reducing the amounts of waste produced. The avoidance strategy seeks to avoid the production of waste by changing production processes. The minimisation strategy seeks to minimise waste production by introducing new procedures to existing technologies, e.g. lower temperature production procedures that save energy. The recycling strategy identifies ways in which disposable items can be used for other applications without posing additional safety risks to waste handlers and the public. In some cases the costs and health risks for recycling (e.g. of mercury) may show that recycling is not viable in South Africa. Better opportunities therefore need to be explored for minimising or avoiding waste creation, e.g. stock control, or use of alternative technologies for temperature measurement.

The importance of investing in the cleaner production approach is the self-funding nature of improvements in efficiency.

4.3 Transport sector

4.3.1 Overview of sector

Transport using liquid fuels, and road transport in particular, accounts for about a fifth of the national GHG emissions and is growing rapidly. Transport-related emissions, which can be expressed as emissions per person, per person-kilometre and per ton-kilometre, are all relatively high at present. Potential co-benefits from the reduction of these emissions are the increased competitiveness of exports due to the lower logistic costs, the reduction of pollution and congestion, and reduction in the high loss of life and disability due to road-accidents (Wright and Fulton 2005).

The technologies identified for the Transport Sector (here limited to road traffic) serve both mitigation and adaptation objectives.

4.3.2 Prioritisation of Transport Sector technologies

Table 5: Evaluation matrix for Transport Sector

Measures/technology options	Strategies and targets	Sustainability	Competitive advantage	Mitigation potential	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
Weighting factor	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Improvement of urban mass-transport systems	3,0	3,0	3,0	2,0	3,0	3,0	2,0	2,0	1,5	0,0	81,8
Fuel-efficiency improvements	2,5	3,0	3,0	2,0	3,0	3,0	3,0	1,5	2,0	0,0	81,1

4.3.2.1 Improvement of urban mass-transport systems

At present South Africa has a poor urban mass-transport system, with the public transport system being dominated by minibus taxis. Even though the majority of South Africans are dependent on public transport, it is currently inefficient and unsafe. There are a number of options that could be considered for the improvement of urban mass-transport systems, such as rapid rail transport, trams, and incentives to encourage people to use public transport instead of their own vehicles. Affordable safe and efficient public transport is critical for economic development. Inefficient single occupant private car usage is a cause of growing congestion, especially in metropolitan municipalities. The Department of Transport is promoting the development and implementation of measures to address congestion under its Travel Demand Management Strategy. Public transport systems will require major improvements in road and communication infrastructure, and developing this infrastructure will entail significant investment.

4.3.2.2 Improvement of traffic flow in urban areas

Traffic flow can be improved by city planning, including bicycle lanes, pedestrian assistance and traffic light synchronisation. Traffic light synchronisation technology requires computer-assisted traffic-control systems. There are a number of opportunities to improve existing traffic flow systems in South Africa. The South African Gautrain is the largest planned project, but is expected to mitigate only about 70KtCO_2/a. The Monorail project is one example with several advantages: it will be environmentally friendly, improve energy efficiency, decrease pollution and reduce road traffic congestion.

Electric and hybrid-electric vehicles have considerable savings potential for both costs and GHG, and South Africa has a history of (largely un-commercialised) innovation in this sector. Recent developments suggest that South Africa also has emerging competitive advantage in this key sector.

In addition to mitigation, a number of adaptation options are imperative for this sector, including -

- loss prevention, e.g. an assessment of the potential risks disturbances and structural impacts posed by climate change for various modes of transport (i.e. road, sea traffic, railways and air traffic) and identifying and implementing solutions;
- loss sharing, e.g. an investigation of potential insurance issues pertaining to road infrastructure damage as a result of climate change; and
- behavioural modification, e.g. implementation of a National Fleet Smart Programme to maximise the efficiency of all government vehicles.

4.4 Agriculture, Forestry and Land Use Sector (Mitigation)

4.4.1 Overview of sector

Agriculture generates about a 20th of South African emissions, in equal amounts of methane and nitrous oxide. The former is predominantly from enteric fermentation in ruminants (livestock).

4.4.2 Prioritisation of Agriculture, Forestry and Land Use Sector technologies (Mitigation)

Table 6: Evaluation matrix for the Agriculture, Forestry and Land Use Sector (Mitigation)

Measures/ technology options	Strategies and targets	Sustainability	Competitive advantage	Vulnerability	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
Weighting factor	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Conservation agriculture	3	3	2	3	2	3	3	2	2	1	83,3
Control of biomass burning in wildfires (including forests)	3,0	3,0	2,0	2,0	3,0	3,0	3,0	1,5	1,5	2,0	81,8

4.4.2.1 Conservation agriculture

Conservation agriculture makes use of soil biological activity and cropping systems to reduce the excessive disturbance of the soil and to maintain the crop residues on the soil surface in order to minimise damage to the environment and provide organic matter and nutrients. To achieve an increase in crop production, while conserving the environment, conservation agriculture adopts three basic principles, i.e. minimal soil disturbance, permanent soil cover and crop diversification (FAO 2007). Additional principles are integrated soil fertility management and integrated weed and pest management.

Minimal soil disturbance

Minimal mechanical disturbance of soil is promoted to help maintain and restore soil organic matter and residual biomass (Dumanski et al. 2006). Conventional tillage is associated with a loss of soil water due to compaction or surface sealing, destruction of soil structure, increased erosion risk, high operation costs and high demand on power, time and equipment. Methods and equipment used to reduce soil disturbance, include zero- or minimal tillage, handheld equipment or animal traction (FAO 2007).

Permanent soil cover

Permanent soil cover helps to increase and maintain the soil organic matter supply through the preservation of crop residues and cover crops (Bon and Benites 2005; Dumanski et al. 2006). Soil cover enhances water infiltration, and reduces evaporation from soil surface, therefore increasing water content in soil. Increased soil water content helps maintain soil erosion, improves soil aggregation, biological activity, and soil biodiversity, and increases soil carbon sequestration. Permanent soil cover is maintained during crop growth phases as well as during fallow periods, using cover crops and maintaining residues on the surface.

Crop rotation

Crop rotation and intercropping can be used to maintain soil fertility, nitrogen fixation biocontrol and efficient use of the soil profile. This practice could reduce requirements for pesticides and herbicides, control off-site pollution and enhance biodiversity, food security and fodder availability. Crop rotations and associations can be in the form of crop sequences, relay cropping and mixed crops.

Research and technology transfer is indeed needed to enhance the application of these technologies for South Africa.

4.4.2.2 Control of biomass burning in wildfires

Veld fires are a common feature of the South African landscape. Some frequency of fires is necessary in savanna areas in order to maintain their ecological health. Furthermore, the fires are to a degree inevitable, given the seasonally dry climate in South Africa. Nonetheless, the current return frequency of fires can be reduced significantly without causing ecological damage, while at the same time realising savings in loss of life, livestock, grazing and infrastructure. A draft report has been produced to assess the current situation and future approaches to integrated veld fire management in South Africa (Forsyth et al. 2006). The carbon dioxide emissions from wildfires are mainly reabsorbed, but methane and nitrous oxide emissions are a significant source of GHG emissions.

5 PRIORITY SECTORS FOR ADAPTATION AND KEY TECHNOLOGIES FOR PRELIMINARY ACTION

5.1 Adaptation

Increasingly, it is evident that governments cannot leave adaptation entirely to social or market forces. To some extent, adjustment decisions will indeed take place in a dispersed and fairly autonomous fashion, at the household or individual level: farmers, for example, may react to changes in temperature by growing different crops, or homeowners or businesses may respond to hotter weather by buying air-conditioning systems. But other essential forms of adaptation will demand that institutions, both public and private, plan their strategies and take action in advance (UNFCCC 2006). Coastal authorities, for example, will aim to address rising sea levels by building dykes, and housing authorities that want future constructions to withstand climate changes will need to introduce appropriate building codes. This distinction between reactive and anticipatory adaptation is illustrated in the table below. Clearly, natural systems can only react but human systems, both public and private, can and should anticipate and plan ahead.

Table 7: Classification of adaptation options (Source IPCC 2001)

		Anticipatory	Reactive
Natural systems			• Longer or shorter growing seasons • Migration of wetlands • Changes in ecosystems
Human systems	**Private**	• Changing architecture of buildings • Buying hazard insurance • Devising new consumer products	• Changing insurance premiums • Buying air-conditioning systems
	Public	• Installing early warning systems • Establishing new building codes • Constructing dykes	• Offering compensation or subsidies • Enforcing building codes • Beach nourishment

In many cases people will adapt to climate change simply by changing their behaviour by moving to a different location. But often they will employ different forms of technology, whether "hard" forms, such as new irrigation systems or drought-resistant seeds, or "soft" technologies, such as insurance schemes and crop rotation patterns. They could also use a combination of hard and soft technologies, as with early warning systems that combine hard measuring devices with soft knowledge and skills that can raise awareness and stimulate appropriate action. Local communities have, for example, used traditional technologies to cope with regular flooding by building houses on stilts, and many communities continue to do so, even if they use more modern materials such as concrete pillars or corrugated iron roofs. Other technologies might be considered "modern", dating from the industrial revolution in the late eighteenth century. Farmers have taken advantage of technological advances to cope better with arid environments, introducing new crop hybrids and making better use of scarce water, as with systems of drip irrigation. Nowadays human societies can also take advantage of "high" technologies such as earth observation systems that can provide more accurate weather forecasts, or crops that are based on genetically modified organisms. Finally, people can look forward to technologies yet to be invented or developed – which might include crops that need little or no water, or a malaria vaccine. Whatever the level of technology, its application is likely to be an iterative process rather than a once-off activity.

5.2 Agriculture, Forestry and Land Use Sector (Adaptation)

5.2.1 Overview of sector

Agriculture and forestry are inherently sensitive to the climate and are vulnerable sectors. The climate projections for southern Africa are for significantly higher temperatures (negatively affecting the deciduous fruit and dairy industries in particular) and possibly less rainfall. On the other hand, rising carbon dioxide levels, will help offset some or all of the production losses, and agriculture and forestry are projected to continue to be viable (all else being equal) over much of the current cropping, livestock and tree-growing regions. Different tree, livestock and crop varieties may have to be used in many areas. The options for growing frost-sensitive crops may even improve in some currently cold parts of the country. The modelling of climate change impacts and general statistical information is best for maize, which is also the largest field crop. According to the models, there is a reasonable degree of certainty that major damage could be expected within the maize sector (DST, 2006).

The commercial agriculture and forestry sectors have a relatively high autonomous adaptation capacity (coping ability) due to their organised nature, relatively large scale (and thus access to expertise and capital) and have demonstrated a capacity to be very agile. However, the national investment in R&D has been reduced, while private investment with increasingly strict intellectual property rights is growing. For example, private plant breeding research quadrupled in US between 1970 and 1990.

5.2.2 Prioritisation of Agriculture, Forestry and Land Use Sector Technologies (Adaptation)

Table 8: Evaluation matrix for the Agriculture, Forestry and Land Use Sector (Adaptation)

Measures/ technology options	Strategies and targets	Sustainability	Competitive advantage	Vulnerability	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
Weighting factor	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
New crop species and cultivars	1,5	3,0	3,0	3,0	3,0	3,0	3,0	3,0	2,0	2,0	88,6
Information technology	2,5	3,0	2,5	3,0	2,0	3,0	2,5	2,5	2,5	2,5	87,1
Macro-economic diversification and livelihood diversification in rural areas	2,5	3,0	2,5	3,0	2,0	3,0	2,0	2,0	1,8	2,5	82,6
Pest management	2,5	2,5	2,5	2,5	2,0	3,0	2,5	2,5	2,0	2,0	80,3

5.2.2.1 Development of new crop species and cultivars

New varieties of crop species and cultivars that are more heat tolerant and, in some cases, more drought tolerant, will be needed. This is an option, which requires links with major international agricultural research centres, the application of gene technologies and possibly some indigenous knowledge. The Agricultural Research Council has initiated various R&D collaborations in this regard.

5.2.2.2 Information technology

The development of information, raising of awareness and knowledge sharing are critical components in an adaptation strategy for agriculture.

To improve the resilience of the agricultural sector there is a need for economic tools to help farmers adjust quickly to change. One such tool is a dynamic economic optimisation model, integrating scientific knowledge and expert opinion on climatic impact, livestock production systems and economic and financial information. Decision support systems provide a mechanism to quantify the financial risks and vulnerability of different livestock production systems by integrating livestock production with other agricultural enterprises suited or adapted to the proposed climatic changes (DoA 2006). Similarly, crop simulation models should be enhanced to become decision support systems for local farmers.

5.2.2.3 Macro-economic diversification and livelihood diversification in rural areas

Another way of adapting to increased rainfall variability and the possible reduction in precipitation is by way of diversification. Macro-economic diversification is suitable for commercial farmers as a means of evaluating and testing alternative crops to enhance diversification of production and the reduction of risk. However, livelihood diversification for rural subsistence farms should also be supported. The focus for this option is on education and knowledge sharing, an option that is regarded as a "soft technology".

5.2.2.4 Pest management

Heavy flooding leads to outbreaks of rift valley fever, which could cause acute abortions among livestock. Increased temperatures coupled with higher rainfall conditions may result in the spread of certain tick species beyond their endemic distribution into areas where transmission of disease organisms to susceptible livestock hosts could reach epidemic proportions. Increases in temperature could also result in a wider distribution of tsetse flies and increase their potential to spread nagana. The Agricultural Research Council has taken the lead in investigating a new vaccine, diagnostic methods and other control technologies (DoA 2006). It is important that further investments are made in this domain.

5.3 Human Health Sector

5.3.1 Overview of sector

Climate change and its impact on health may place additional strain on South Africa's health care system. Thus, there is a need to ensure that health and social services can cope with the predicted increase in the frequency of extremes of temperature, flooding, UV radiation, vector-borne diseases, waterborne diseases and storms (IPCC 2001).

The anticipated impacts associated with climatic change for the health sector may be exacerbated by factors such as poverty, poor housing conditions, inadequate education, and accessibility to medical care. People with existing health conditions such as cancer, HIV/Aids, obesity and diabetes may be more susceptible to waterborne and vector-borne diseases and to physical stresses, such as those experienced during cold spells, floods or severe storms. Adequate protection from these stressors is important and depends upon access to sanitation, adequate housing conditions, safe drinking water and proper health care services (CSIR 2006).

Each anticipated adverse health impact could be lessened by the implementation of a range of social, institutional (e.g. an enhanced and informed public health infrastructure), technological (e.g. health-oriented management of the environment, including air and water quality, food safety, urban and housing design, and surface water management), and behavioural adaptation options. A linear thinking approach is imperative to deal with climate change effects on the health sector.

Table 9: Some health effects of weather and climate (UNFCCC 2006)

Event	Some potential damaging health effects
Warmer climate	• Can create conditions for the spread of new vectors such as those for malaria, dengue, tick-borne encephalitis, and Lyme disease • Shorter times for pathogens to develop
Drought	• Less water for hygiene • Reduced food supplies cause malnutrition • Forest fires reduce air quality
Heat waves	• Heatstroke and increases in mortality from cardiovascular and respiratory diseases
Floods, landslides and windstorms	• Deaths and injuries • Disruptions to water-supply and sanitation systems and health-care infrastructure • Post-traumatic stress disorders • New breeding sites for mosquitoes

5.3.2 Prioritisation of Human Health Sector technologies

Table 10: Evaluation matrix for Human Health Sector

Measures/ technology options	Strategies and targets	Sustainability	Competitive advantage	Vulnerability	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
Weighting factor	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Provision of water supply and sanitation	3,0	3,0	2,0	2,5	3,0	3,0	3,0	3,0	2,3	1,7	90,4
Control of the spread of vector-borne disease	2,3	3,0	2,3	3,0	3,0	2,0	3,0	2,7	2,3	2,0	87,1

5.3.2.1 Provision of water supply and sanitation (include decentralised water purification)

Improved water storage, water supply and sanitation are very important for the control of waterborne diseases. In South Africa about 5 million people are still without any form of sanitation and about 16 million do not have waterborne sanitation (flush toilets). As waterborne sanitation is not always possible in water-stressed rural areas, ecological (dry sanitation) methods are promoted. Improved sanitation has the co-benefit of reducing water pollution and it is a national priority.

This option should be supplemented by improved personal hygiene. Education campaigns on personal hygiene are underway, but there is limited capacity to carry out these campaigns in rural areas.

5.3.2.2 Control of the spread of vector borne diseases

South Africa has access to advanced medical technology and research capabilities. In particular, the impact of climate change on cholera outbreaks has been modelled (Lipp et al. 2002) and is being investigated by the CSIR.

The environmental control of snail hosts of schistosomiasis needs further research.

The main barrier to the control of the spread of vector-borne disease is the availability of financial resources in the light of other urgent public health issues, such as tuberculosis and HIV/Aids. Similarly to that of waterborne diseases, the main limiting factor is capacity to roll out large campaigns in rural areas.

There are a number of personal protection devices and strategies, from bed nets to house spraying, are available for use against disease carried by invertebrate vectors (malaria). Government-supported measures, such as the distribution of infused mosquito nets, increasing vaccinations and awareness campaigns, should also be considered.

Prevention and control programmes should be provided by local government, which has adequate budget and staff in large metropolitan centres, but very limited capacity in poor, rural districts.

5.4 Water Resource Sector

5.4.1 Overview of sector

Despite remaining uncertainties regarding the exact nature, magnitude and pattern of future rainfall changes in South Africa, it appears likely that water resources, already under pressure as a result of growing water demand in relation to a finite and limited supply, will be under even greater pressure in the future as a result of climate change. This is a result of three factors: the projected decrease in rainfall over much of the country (a result predicted by most, but not all, models), increased evaporation resulting from higher temperatures (only partly offset by rising levels of carbon dioxide), and the amplifying effect that the hydrological cycle has on climate change.

Adaptation will principally involve changes in water allocation, from uses that generate less economic or social value per unit of water consumed to uses that generate more. Thus all sectors that use water will be under pressure to be more water efficient, especially irrigation agriculture.

Since the energy generation sector in South Africa is based on coal-fired thermal power plants, it will face an indirect climate change adaptation challenge if water for cooling becomes scarcer and more expensive. The option of using "dry cooling" decreases plant efficiency.

South Africa has already developed a comprehensive integrated National Water Management Strategy (DWAF 2004). Unfortunately, the existing strategy has not yet taken the impact of climate change into consideration. It is hoped that it will be included when the strategy is revised in 2009 in terms of the National Water Act, 1998.

5.4.2 Prioritisation of Water Resource Sector technologies

Table 11: Evaluation matrix for Water Resource Sector

Measures/ technology options	Strategies and targets	Sustainability	Competitive advantage	Vulnerability	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
Weighting factor	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Technologies that promote water efficiency	3,0	3,0	1,5	3,0	2,5	3,0	2,5	2,0	1,8	0,5	93,2

5.4.2.1 Technologies that promote water efficiency

Three main technologies that promote water conservation are -

- water pricing;
- improvement of irrigation efficiency, and
- reduction in reticulation losses.

Improvements in irrigation efficiency are particularly important, as the irrigation sector is still the largest consumer of water. Soil moisture conservation technology such as use of surface mulches, could be used to compliment traditional irrigation efficiency technologies. This technology is linked to no-till technology that has the advantage of improving soil carbon storage.

Significant urbanisation and a policy of supplying free basic water, has significantly increased reticulation losses. In some cities "unaccounted for water", consisting mainly of reticulation losses and losses from illegal connections, is as high as 30% of the water supply. Reduction of water pressure at night has helped to reduce reticulation losses, and prepaid water meters are used for effective revenue collection and the combating of illegal connections.

In this project all water efficiency technologies were prioritised as one group. However, they have different characteristics and specific technologies for each have therefore been identified. These are outlined in the table below.

Table 12: Adaptation options for water use efficiency (UNFCCC 2006)

Use category	Supply	Demand
Municipal or domestic	Increase reservoir capacity Desalinate Make inter-basin transfers	Use "grey" water Reduce leakage Use non-water-based sanitation
Industrial cooling	Use lower-grade water	Increase efficiency and recycling
Pollution control	Enhance treatment works Reuse and reclaim materials	Reduce effluent volumes promote alternatives to chemicals
Flood management	Build reservoirs Protect and restore wetlands	Improve flood warnings Curb floodplain development
Agriculture (rain-fed)	Improve soil conservation	Use drought-tolerant crops
Agriculture (irrigated)	Change tilling practices Harvest rainwater	Increase irrigation efficiency Change irrigation water pricing

5.5 Built Environment and Infrastructure Sector

5.5.1 Overview of sector

All human settlements are critically dependant on many types of infrastructure, from power and water supply to transportation and waste disposal systems. In many parts of the world, particularly in developing countries, infrastructure is already under severe strain, as a result of population growth, rural-urban migration, high levels of poverty and the demand for more roads and vehicles. All these strains are likely to interact with, and be exacerbated by, different aspects of climate change.

Table 13: Adaptation technologies for infrastructure (UNFCCC 2006)

Hard technologies	Soft technologies
Building sector	
• Lay out cities to improve the efficiency of combined heat and power systems and optimise the use of solar energy • Minimise paved surfaces and plant trees to moderate the urban heat island effects • Reduce the energy required for air-conditioning	• Limit developments on flood plains or potential mud-slide zones • Establish appropriate building codes and standards • Provide low-income groups with access to property
Transportation sector	
• Cluster homes, jobs and stores • Control vehicle ownership through fiscal measures such as import duties and road taxes as well as through quotas for vehicles and electronic road pricing • Develop urban rail systems	• Promote mass public transportation • Use a comprehensive and integrated system of planning • Link urban transport to land-use patterns
Industrial sector	
• Use physical barriers to protect industrial installations from flooding	• Reduce industrial dependence on scarce resources • Site industrial systems away from vulnerable areas

5.5.2 Prioritisation of the Built Environment and Infrastructure Sector technologies

Table 14: Evaluation matrix for the Built Environment and Infrastructure Sector

Measures/technology options	Strategies and targets	Sustainability	Competitive advantage	Vulnerability	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
Weighting factor	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Climate-sensitive building design	3	3,0	3,0	2,5	2,0	2,5	2,5	2,5	2,0	2,0	1,5

5.5.2.1 Climate-sensitive building design

The principles of orientation, heat storage and cooling can be combined with specific building materials to achieve climate-sensitive design. An energy-efficient housing design principle encompasses all the available techniques of creating a "healthy" interaction between indoor and outdoor climate conditions in buildings.

Climate-sensitive design principles can be incorporated to various degrees in office buildings and low and high-income housing. Incorporating energy-efficient design principles, especially in the delivery of low-cost housing, would have numerous benefits to the poor families living in these houses. Low-cost houses may be cheap to build, but their running costs are astronomical. Because of the use of energy-inefficient materials, it is sometimes warmer outside the house than inside. The costs of keeping these houses heated come out of the earnings of the people who can least afford to pay them – heating can cost poor people up to 60% of their income. Furthermore, poor families use dirty, dangerous fuels such as coal and paraffin to heat their homes. These fuels cause indoor and outdoor air pollution and respiratory diseases, as well as being dangerous in terms of causing fires and burns.

6 OVERARCHING ISSUES

6.1 Introduction

Internationally and in South Africa, there are a number of challenges which need to be addressed to make progress on climate change mitigation and adaptation. These include (DEAT 2004) -

- improving climate models and scenarios at detailed regional level, especially for extreme weather events, to reduce the high level of uncertainty;
- advancing understanding on "good practice" in adaptation measures through exchange and information sharing on feasibility, costs and benefits;
- involving the public and private sectors and the general public at both local and national level;
- enhancing coordination and collaboration both within and between countries to ensure the coherence of adaptation measures with other policy objectives and the allocation of appropriate resources.

The critical cross-cutting and financial issues to address these concerns are highlighted below. Here the top three issues for each these domains are addressed.

6.2 Prioritisation of technologies for overarching issues

Table 15: Evaluation matrix for overarching issues

	Measures/ technology options	Strategies and targets	Sustainability	Competitive advantage	Costs/Benefits	Utilisation scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total score (%)
	Weighting factor	**3**	**3**	**2**	**3**	**2**	**1**	**2**	**2**	**1**	**57**
Financial mechanisms	Incentives for energy efficiency	3,0	3,0	3,0	3,0	3,0	2,0	2,5	2,3	0,0	88,6
	Incentives for renewable energy	3,0	3,0	2,5	1,5	2,5	2,5	2,0	2,0	0,0	75,4
	Disincentives for high fuel consumption vehicles	1,0	2,5	2,0	3,0	3,0	2,5	3,0	1,8	0,0	72,8
Cross-cutting issues	Improved data management, processing and integration	3,0	2,5	2,0	2,5	2,5	1,0	2,0	1,8	1,5	75,4
	Improved communication and response in disaster management	2,5	2,0	2,5	2,5	2,5	2,5	1,5	2,0	2,0	74,6
	Networks for information sharing and data integration	2,0	2,5	2,5	2,5	2,0	2,5	2,0	1,8	1,5	72,8

6.2.1 Cross-cutting issues

6.2.1.1 Improved data management, processing and integration

Data collection is a first step in the data value chain. The conversion of data into knowledge is a complex process requiring various systems and techniques.

6.2.1.2 Improved communication and response in disaster management

The use of new information and communication technologies in disseminating warning messages is useful in expanding coverage and reducing delays. In South Africa, however, the ability to deliver warning information to the public is not yet what it needs to be. Local mechanisms for communicating risks are weak and often the community does not respond, either because the message is poorly constructed or because of lack of choice. It has been suggested that improved communication could be achieved in both urban and rural communities by means of cellphone text messaging (e.g. warning of disease outbreaks).

Early warning should be accompanied by response capability, which should include an intervention plan. Institutional capacity, arrangements and links therefore need to be strengthened to reduce predicted risks.

6.2.1.3 Networks for information sharing and data integration

To enhance adaptive capacity there is a need to establish networks for information sharing and data integration. The following information, in particular, is essential:

- Sustainability reporting
- Product and company sustainability information
- Environmental goods and services (including green energy) market information.

The more relevant, accurate and up-to-date the information is, the more targeted and effective the implementation of adaptation strategies will be. Large-scale global and regional data repositories have been established and many data sources can be accessed, displayed and downloaded from the Internet.

6.2.2 Methodologies for application of financial mechanisms

Since the first democratically elected government came into power in 1994, South Africa has undertaken comprehensive tax reforms aimed at improving economic growth, development and employment creation, as well as encouraging investment and enterprise development. There are a number of environmentally-related taxes already in place, which account for approximately 2% of gross domestic product (over 70% of this revenue is collected from the general fuel levy). The National Treasury published *A framework for considering market-based instruments to support* *environmental fiscal reform in South Africa* (National Treasury 2006). This framework recognised that "[m]arket-based instruments, particularly environmentally-related taxes and charges, may have certain advantages over traditional regulatory (command-and-control) approaches; and may be a more efficient way to address certain environmental concerns while also contributing to fiscal objectives". It suggested options for reforming existing taxes and introducing new ones.

The introduction of financial mechanisms does not require massive investment. To support the interventions, new systems and processes may need to be established, and computer software and training may be required.

6.2.2.1 Incentives for energy efficiency

In the past, South Africa's low electricity prices have reduced the incentive to work efficiently with energy, which makes this a fruitful field for cost-effective GHG savings through a reduction of GHG emissions.

In particular, appropriate interventions are required in poor electrified households. "Access to energy in physical terms needs to be accompanied by affordability in economic terms. The findings suggest that a relatively small subsidy can make energy efficiency interventions economic for poorer households. The order of magnitude of the subsidy required to make efficient housing as affordable for poorer households as for richer ones is less than R1 000." (Winkler, 2006). This is comparable with the subsidies for water and sanitation that have already been implemented in some areas of South Africa.

Energy efficiency incentives are a very important intervention. Another focus here would be on technologies like full life-cycle and macro-economic analyses and modelling, which would enable and support effective environmental fiscal reform and preferential procurement.

6.2.2.2 Incentives for renewable energy

In late 2005, the Renewable Energy Finance and Subsidy Office were established by the DME. The Office’s mandate includes the management of renewable energy subsidies and the provision of advice to developers and other stakeholders on renewable energy finance and subsidies, including the size of awards, eligibility and procedural requirements. The DME has identified options where international institutions could assist. The initiatives for incentives for energy efficiency should be coordinated with incentives for renewable energy.

6.2.2.3 Disincentives for high fuel consumption vehicles

Disincentives for high fuel consumption vehicles (fee bates for less efficient vehicles) and for imports of energy-inefficient technologies, is an option that has not been included in the National Treasury Framework (2006).

Efficiency and demand in the Transport Sector is relatively insensitive to fuel price. Therefore, options involving taxation of fuels are unlikely to have the desired effect, even at taxation levels, which could produce large responses in other sectors. Especially in the private car market, consumer perceptions and requirements for safety, utility and performance are the dominant factors. Focused mechanisms, such as disincentives, are therefore needed to affect consumers' choices and behaviour.

7 GENERAL BARRIERS TO TECHNOLOGY TRANSFER

There are a variety of mechanisms through which South Africa can obtain preferential access to climate change technologies. These mechanisms will also facilitate the adoption of the technologies. South Africa, in the context of the World Summit on Sustainable Development, has expressed strong opinions on the role of technology transfer in African development, and the appropriate mechanisms to be used. In brief, the position is that balanced partnership arrangements, in which the technology needs are determined by the receiving partner, and where, if possible, the receiving partner is involved over a long period of time in the co-development and local adaptation of the technology, are preferable to donor-driven, hit-and-run, technology dumping exercises. The key issue is ensuring a receptive environment for the technology before it is transferred. This places a large emphasis on human resource capacity development, which needs to take place before the physical transfer of the technology. The creation of an enabling environment and supporting systems is crucial for successful technology transfer.

The global intellectual property rights (IPR) regime has been suggested as a barrier to technology transfer. Stern (2006) concludes that IPR is not generally the key barrier to technology transfer, as IP protection is important mainly in a few industries, such as pharmaceuticals and scientific equipment. The World Intellectual Property Organization (http://www.wipo.int/patentscope) has free information services for developing countries that can help them to identify and evaluate relevant technology for technology transfer.

The acceptance of open-source solutions in architecture and software development is one way of addressing IPR constraints. However, these and other approaches do not fully remove the barrier. Critical mitigation and adaptation technologies need to be treated as global public goods. Alternatively, the establishment of an international code of compulsory licensing for mitigation technologies (along the lines of the approach taken for HIV/Aids) might be worth pursuing.

The barriers for adaptation technologies are different to the barriers for mitigation technologies, because most of the former are already available in contexts outside climate change adaptation.

Two barriers are highly interactive: the accessibility of locally available technologies and the need to strengthen local capacity to implement the technologies. Accessibility could be constrained by a lack of funds. This constraint can be eased by the provision of international funds to assist the adaptation process as is currently being done on a relatively small scale under -

- the Least Developed Country Fund (which is not applicable to South Africa); and
- the Special Climate Change Fund, the strategic priority provisions of the Adaptation Fund under the Global Environment Facility.

The indications are that these funds will have to grow considerably if the need for additional adaptation funds is to be met as the climate changes. Alternatively, some new or consolidated funds might be created especially with technology transfer in mind.

A complete list of barriers and suggestions for an enabling environment are provided in the table below. This list can be used as a checklist for evaluating intervention strategies and clarifying which of the technology needs discussed could benefit from technology transfer from the developed world. Suggestions for the enabling environment that require technology transfer from developed countries are marked in bold.

The specific barriers for the prioritised sector technologies will be analysed in the next phase of the TNA, i.e. the development of an implementation plan, by means of workshops and consultation with stakeholders.

Table 16: Barriers and suggestions for enabling environment

Barriers	Suggestions for enabling environment
Intellectual property issues: payments required limit innovation in developing countries	**International and bilateral negotiations, research partnerships,** treating critical technologies as public goods
Technology contributes to the advancement of knowledge on climate change, but is too costly	Government support; **International cooperation and knowledge transfer; international funding**
New technology with promise for local application (or specific for Africa/developing countries), but too costly to develop	Government support; **International cooperation and knowledge transfer; international funding**
Technology has not yet been proven for local application	**Pilot and case studies in cooperation with developers**
Physical resource constraints	Examine possibility of applying in other Southern African Development Community countries
Lack of knowledge by potential users of the technology and its benefits	Communication and education; development of a critical mass of human capital via appropriate policies; development of adequate support for the national education system, awareness and marketing (branding)
Lack of technical capacity to establish and maintain the technology	**International cooperation and knowledge transfer; technology-related capacity building;** development of a critical mass of human capital via appropriate policies; development of adequate support for the national education system
High cost of establishment of the technology	Re-evaluation taking full cost into account; R&D for local substitutes; removal of import tariffs, **international funding** or subsidies
High cost of operation and maintenance for the technology	Re-evaluation taking full cost into account; R&D for local substitutes; subsidies
Various market failures, including the lock-in of existing technologies due to large investments in them in the past	Strategic planning and interventions at appropriate level
Cultural preferences impeding uptake of technologies	Communication and education; culturally appropriate modification of the technology
Inadequate macro-economic policies	Changes in the macro-economic environment; improving financial and administrative efficiencies
Low perception of importance by economic actors	Necessity of an explicit national policy supporting technology development

Barriers	Suggestions for enabling environment
Low savings potential	Measures to improve productivity through streamlining of government functions
Lack of suitable small and medium-sized firms for subcontracting	Provision of support to small and medium-sized firms for productive activities in the economy
Lack of appropriate financial systems	Cooperation with financial institutions, such as the Development Bank of Southern Africa
Unfair pricing system, no price signals and barriers to introduction of technologies, e.g. energy efficiency options	Change pricing policies
Monopolistic or oligopolistic market structure	Allow and encourage competition
Absence of feasible and appropriate standards based on local conditions	Establish appropriate standards
Institutional inertia and unwillingness to change	Restructuring and introducing corporate and personal accountability
Lack of adequate government support facilities	Government investments; **international funding**
Lack of access to global information (e.g. expensive technology for attending conferences)	Establishment of effective linkages with national education systems, web-based information dissemination, **international cooperation and knowledge transfer**
Lack of local data (e.g. on performance, banking and insurance) for design of good investment projects and for appraisal (monitoring, assessment and evaluation)	Develop and maintain integrated and accessible information systems
Lack of engineering procedures for testing, commissioning, and supporting equipment purchases (e.g. PV technology), leading to poor performance, maintenance and operation, and making the technology appearing to be dysfunctional	Develop engineering procedures for testing and commissioning of equipment and system of support to users, **international knowledge transfer**
Non-transparent legal system	Legal system reform ensuring compliance, property rights and transparency
Relatively weak enforcement mechanisms for legislation relating to investments and companies	Legal system reform ensuring transparency of investment considering triple bottom line

8 WAY FORWARD

A critical next step would entail a process of translating the TNA results into well defined implementation plans for the successful transfer of the technology (hard or soft). Important components of this process of implementation of technologies will include the involvement of appropriate and effective stakeholders within the framework for technology transfer. Other issues that will have to be addressed by these stakeholders are the availability of financial and human resources for acquiring the technology, and an environment conducive to the smooth flow of technology to the final recipients and users. While elaborating the different steps of the implementation plan for the transfer of a technology, it will be important to identify capacity-building needs and other barriers that will have to be overcome. The eventual outcome may be the preparation of a project document for funding purposes for technologies requiring heavy investments.

Technology implementation plans for mitigation and adaptation may vary significantly. Whereas mitigation technologies mostly concern hard technologies that are more easily transferred once the major stumbling block of funding has been resolved, it is much more difficult to draw implementation plans for the soft technologies required for adaptation. This stems from the fact that mitigation technologies are usually related to the services sector, which is relatively well regulated. Moreover, very often the end users of adaptation technologies are the general public and the poorest communities, who possess lower and less reliable repayment capacities, which are strong deterrents to financiers. The organisations most likely be to be involved in the acquisition, development and implementation of adaptation technologies would be local government agencies and community-based organisations, which would also pose a risk to financiers in terms of repayment. Additionally, recipients of adaptation technologies frequently have limited absorption capacity. Due consideration will have to be given to this issue when dealing with implementation plans for adaptation.

As there is no single recipe for transferring different technologies, it is imperative to draw up an implementation plan that will accommodate all technologies prioritised while paying due attention to the specific nature of the various options. Such an action will lead to the identification of more precise steps, barriers and capacity-building needs, as well as other activities that may be required, such as awareness raising and information communication. R&D partnerships are likely to be a key vehicle by technologies will be transferred. Many of the technologies which have been prioritised fall under the policies of various government departments, and the findings of the TNA will enhance the execution of these policies. It is envisaged that the NCCC will play a key role in monitoring the implementation of the findings of the TNA.

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Appendix 1: List of Project Steering Committee members

Name	Organisation
Imraan Patel	Department of Science and Technology
Linda Manyuchi	Department of Science and Technology
Isabel Bezuidenhout	Department of Science and Technology
Llanley Simpson	Department of Science and Technology
Rina Taviv	Council for Scientific and Industrial Research
Linda Phalatse	Council for Scientific and Industrial Research
Shirley Moroka	Department of Environmental Affairs and Tourism
Tony Surridge	Department of Minerals and Energy
Smangele Mgquba	Department of Minerals and Energy
Elsa du Toit	Department of Minerals and Energy
Leluma Motooane	Department of Minerals and Energy
Jacob Dikgang	Department of Transport
Matiga Motsepe	Department of Agriculture
Bill Rowlston	Department of Water Affairs and Forestry
Johan Bester	Department of Water Affairs and Forestry
Lydia Greyling	Department of Foreign Affairs
Rob Hounsome	Council for Scientific and Industrial Research
Barney Kgope	South African National Biodiversity Institute
Robin Barnard	Agricultural Research Council

Appendix 2: List of experts who contributed to prioritisation matrix

Name	Organisation	Sector
Bob Scholes	Council for Scientific and Industrial Research	All sectors
Harald Winkler	University of Cape Town	Energy
Gerrie Coetzee	South African Weather Service	Cross-cutting issues
Barney Kgope	South African National Biodiversity Institute	Biodiversity
Marina van der Merwe	Council for Scientific and Industrial Research	Human health
Gina Ziervogel	University of Cape Town	Adaptation sector
Chrisna du Plessis	Council for Scientific and Industrial Research	Built environment
Dave Rogers	Council for Scientific and Industrial Research	Mitigation sector

Appendix 3: List of technologies identified in the TNA Resource Document

N.B: Cross cutting and financial mechanisms were calculated using the total score of 57 and not 66

	Measures / technology options	Strategies and targets	Sustainability	Competitive advantage	Mitigation potential / Vulnerability	Costs/ Benefits	Utilization scale	Maturity (global)	Support systems	Users	Indigenous knowledge	Total Score (%)
Sector	**Weighting factor**	**3**	**3**	**2**	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**66**
Human health	Provision of water supply and sanitation	3	3	2	2,5	3	3	3	3	2,3	1,7	90,4
Adaptation: agriculture and forestry	Development of new crop species and cultivars	1,5	3	3	3	3	3	3	3	2	2	88,6
Financial systems	Incentives for energy efficiency	3	3	3	3	3	2	2,5	2,3	0	88,6	88,6
Human health	Control of the spread of vector-borne disease	2,3	3	2,3	3	3	2	3	2,7	2,3	2	87,1
Adaptation: agriculture and forestry	Information technology	2,5	3	2,5	3	2	3	2,5	2,5	2,5	2,5	87,1
Buildings/domestic/commercial energy use	Energy efficient appliances and lighting	3	3	2,5	2	3	3	3	2	2,3	1	85,6
Electric energy generation	Solar power	3	3	3	2,5	2,5	3	2	2	2,3	1	85,6
Waste management	Avoidance, minimization and reuse	3	3	3	2	3	3	3	2	2	0	84,8
Agriculture	Conservation agriculture	3	3	2	3	2	3	3	2	2	1	83,3

Adaptation: agriculture and forestry	Macro-economic diversification and livelihood diversification in rural areas	2,5	3	2,5	3	2	3	2	2	1,8	2,5	82,6
Forestry and land use	Control of biomass burning in wildfires (including forests)	3	3	2	2	3	3	3	1,5	1,5	2	81,8
Transport	Improvement of urban mass-transport systems	3	3	3	2	3	3	2	2	1,5	0	81,8
Water resources	Technologies that promote water efficiency	3	3	1,5	3	2,5	3	2,5	2	1,8	0,5	81,8
Transport	Fuel efficiency improvements	2,5	3	3	2	3	3	3	1,5	2	0	81,1
Buildings/domestic/commercial energy use	Green house design and energy efficient heating and cooling systems	3	3	2,5	2	2,5	2,5	2,5	2	2	1,5	81,1
Adaptation: agriculture and forestry	Pest management	2,5	2,5	2,5	2,5	2	3	2,5	2,5	2	2	80,3
Adaptation: agriculture and forestry	Vulnerability research	3	3	2	3	2	2,5	2,5	1,5	1,7	2	80,1
Industry/ mining	Boiler improvement	3	3	2	2	2	2	3	3	2,5	0	78,8
Industry/ mining	Switching to low carbon fuel	2,5	3	1,5	3	1,5	2,5	3	2,5	2,3	0	76,5
Cross -cutting	Improved data management , processing and integration	3	2,5	2	2,5	2,5	1	2	1,8	1,5	75,4	75,4
Financial systems	Incentives for renewable energy	3	3	2,5	1,5	2,5	2,5	2	2	0	75,4	75,4
Electric energy generation	Clean coal technologies	2,5	2	3	2,5	2	2,5	1,5	3	2	0	75
Electric energy generation	Wind power	3	3	2,5	2	2,5	1,5	3	2	1,5	0	75
Cross -cutting	Improve communication and response in disaster management	2,5	2	2,5	2,5	2,5	2,5	1,5	2	2	74,6	74,6
Fishery and coastal zone	Protection of estuarine areas	2,5	2,5	2	2	2	1	2,5	1,5	1,3	1	74,1

Biodiversity	Biodiversity conservation	2	2,5	2	3	2	2	1,8	2,5	2,2	1	73,6
Financial systems	Disincentives for high fuel consumption vehicles	1	2,5	2	3	3	2,5	3	1,8	0	72,8	72,8
Cross -cutting	Networks for information sharing and data integration	2	2,5	2,5	2,5	2	2,5	2	1,8	1,5	72,8	72,8
Cross -cutting	Extend disaster preparedness	2,5	2,5	2	3	1,5	2	1,5	1,8	1,5	71,9	71,9
Cross -cutting	Extend early warning system	2,5	3	2	2,5	2	2	1,5	1,5	1	71,9	71,9
Financial systems	Pollution charges	2,5	3	2	1,5	3	2,5	2	1,8	0	71,9	71,9
Adaptation: agriculture and forestry	Sustainable land use	2	2,5	2,5	2	2	2	2	2	1,8	3	71,2
Cross -cutting	Eco labelling	2	3	3	3	1	2,5	1	1,3	1,5	71,1	71,1
Electric energy generation	Fuel cell technology	1,5	3	3	2,5	2	2,5	2	1,5	1,8	0	70,5
Waste management	Adopt aerobic digestion in manure management	2	3	2	2	2	2	3	2	2	0	69,7
Electric energy generation	Biomass	2	2,5	2,5	2	2,5	2	1,5	1,5	2,3	1	69,7
Water resources	Groundwater management systems	2,5	2,5	2	2	2,5	2	1,5	1,5	2	1	69,7
Agriculture	Manufacture and application of fertilisers	3	2	2	1	2	1	3	3	3	0	68,2
Electric energy generation	Non-carbon based, non-renewable technologies-nuclear power	2,5	1,5	2,5	3	1	3	1,5	2,5	1,8	0	68,2
Biodiversity	Biodiversity protection	2	2,5	2,3	2,8	1,5	1,8	1,5	2	1,9	1	67,4
Human health	Adaptation to thermal stress	2,5	2	1,5	2,5	2	1,7	1,5	2	2	1,5	67,2
Transport	Improvement of traffic flow in urban areas	3	3	2	1	2	2	2	2	1,5	0	66,7
Agriculture	Reduced burning of the agricultural residues	3	3	1	1	2	2	3	2	2	0	66,7
Agriculture	Solar crop drying	1	3	3	1	2	1	3	3	3	0	66,7

Transport	The use of advanced materials and greater recycling	2	3	3	2	1	1	3	2	2,5	0	66,7
Electric energy generation	Compressed air storage	1,5	2	2,5	1	2,5	2,5	3	2,5	2,3	0	65,9
Electric energy generation	Non-coal fossil fuel based technologies-natural gas turbines	2	2	2,5	2	1,5	2	3	2	2,3	0	65,2
Cross -cutting	Life cycle analysis	1,7	2,7	1,7	1,7	2,7	2,7	1,7	1,4	1	64	64
Cross -cutting	Risk and vulnerability reduction technologies	2	2	2	2	3	1,5	1	2	1	64	64
Transport	Electric vehicles	2	2	2	2	2	3	1	2	1,5	0	63,6
Industry/ mining	Reduction of coal mining release of methane	1	3	2	3	1	2	2	2	2	0	63,6
Industry/ mining	Geological carbon sequestration	1,5	2	2	3	1	3	1	2	1,8	0	62,1
Cross -cutting	Extend laboratory and analytical analysis	1	3	2,3	2	1,3	0,3	2	2	1,3	61,4	61,4
Agriculture	Inoculation of sheep and cattle to reduce CH_4 emissions	2	2	3	3	1	1	1	2	1	0	59,1
Electric energy generation	Wave energy	2	3	2	2	1	2,5	1	1	1	0	57,6
Fishery and coastal zone	Research on impacts on marine diversity	1	2	1	1,5	1,5	2,5	1	1	1,3	1	56,8

Industry/ mining	Improve charcoal manufacturing and advanced charcoal stoves	2	2	1	1	2	1	3	2	2	1	56,1
Electric energy generation	Ocean current	1,5	2,5	1,5	2	1	2,5	1	1	1,5	0	53
Cross -cutting	Improved data collection and digitizing of old data	1,5	1,5	2	1,5	1	2	1	2	1	50	50
Agriculture	Improving GHG inventory for agricultural sector	1	3	1	1	2	1	2	1	1,5	0	48,5
Biodiversity	Pollination technologies	0	1	2	2	2	2	1	1,5	2	0,5	47,7