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***Abstract:**
This project addresses knowledge, resource, capacity and networking gaps on the theme: 'Strengthening urban governments in planning adaptation.'
The main objective of this project is to develop an adaptation framework for managing the increased risk to African local government and their communities due to climate change impact. The ultimate beneficiaries of this project will be African local governments and their communities. The guiding and well-tested ICLEI principle of locally designed and owned projects for the global common good, specifically in a developing world context, will be applied throughout project design, inception and delivery.

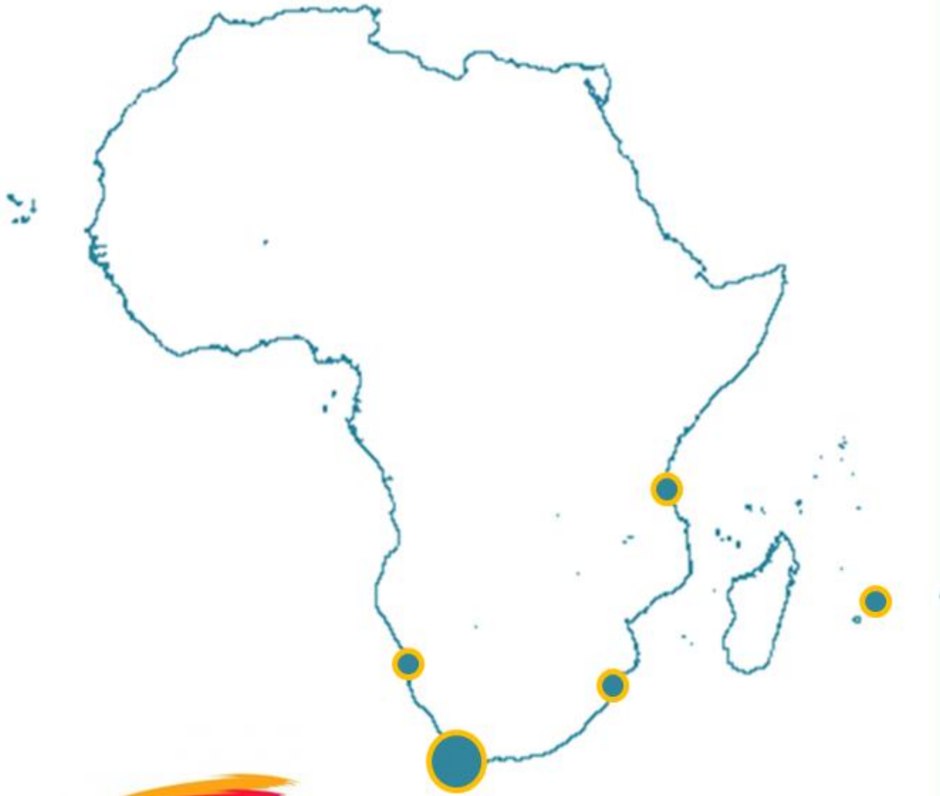
Additionally, the research will test the theory that the most vulnerable living and working in different geographical, climatic and ecosystem zones will be impacted differently and as such, will require a different set of actions to be taken. Potential commonalities will be sought towards regional participatory learning and wider applicability. The five urban centres chosen for this study, based on selection criteria, include: Cape Town, South Africa, Dar es Salaam, Tanzania; Maputo, Mozambique; Windhoek, Namibia; and Port St. Louis, Mauritius.

Through a participatory process, this project will carry out a desk-top study, long-term, multi-discipline, multi-sectoral stakeholder platforms in five Southern African cities comprising of academics, communities and the local government in order to facilitate knowledge-sharing, promote proactive climate adaptation and resource opportunities available for African cities, develop five tailor-made Adaptation Frameworks and explore regional applicability. A network of stakeholders within each urban centre will be established, feeding into a larger regional network of local authorities and partners in Sub-Saharan Africa, and globally through existing ICLEI global (e.g. the ICLEI Cities for Climate Protection programme), ICLEI Africa and UCLG-A members and networks, ensuring global best practice, roll-out, and long-term sustainability.

Key words: Adaptation, Africa, Climate Change, Local Governments, Participatory Action Research, Policy.

Sub-Saharan African Cities:
A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action

Baseline Study



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Sub-Saharan African Cities: A five-City Network to Pioneer Climate Adaptation through Participatory Research & Local Action

Cape Town Baseline Study

February 2011

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List of acronyms

CAPA	City Adaptation Plan of Action
CCAA	Climate Change Adaptation Africa
DFID	Department for International Development
DWAF	Department of Water Affairs and Forestry
GDP	Gross Domestic Product
HAB	Harmful Algal Blooms
IDP	Integrated Development Plans
IDRC	International Development Research Council
IMEP	Integrated Metropolitan Environmental Policy
IPCC	Intergovernmental Panel on Climate Change
LTMS	Long Term Mitigation Scenarios
NEMA	National Environmental Management Act
NEPAD	New Partnership for Africa's Development
NWRS	National Water Resource Strategy
RDP	Reconstruction and Development Programme
SDF	Spatial Development Frameworks
SST	Sea Surface Temperature
UNFCCC	United Nations Framework Convention on Climate Change

Preface

The global climate is controlled by complex interactions between marine and terrestrial systems. These interactions generate a variety of climatic variables across different regions and exert significant controls on day-to-day developments at the global, regional and local levels. Climate change is defined by the International Panel for Climate Change (IPCC) as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (IPCC 2007). Climate change may be a result of natural internal processes, external forcing or from anthropogenic changes such as increased carbon dioxide (CO_2) emissions. However the United Nations Framework Convention on Climate Change (UNFCCC) makes a clear division between anthropogenic causes that alter the composition of the atmosphere and the natural causes attributing to climate variability. Climate change, as defined by the UNFCCC, is any 'change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is in addition to natural climate variability over comparable time periods' (IPCC 2001) and the IPCC (2007) concur that anthropogenic forcing is a major driver.

Climate change is expected to have severe physical, social, environmental and economic impacts on cities worldwide, both directly and indirectly. These are anticipated to be felt with greater intensity in the developing world, particularly Africa. Although there are some uncertainties surrounding the understanding of earth's complex systems, there is strong evidence in current literature and climatic measurements to demonstrate that, as a result of increasing greenhouse gas emissions, atmospheric and sea surface temperatures (SSTs) are rising.

Some of the changes likely to manifest from the projections are:

- changes in rainfall and precipitation patterns (flooding and drought),
- increases in temperature,
- increasing frequency and intensity of storm surges or extreme events,
- increasing average global sea levels due to melting glaciers and thermal expansion (permanent and non-permanent inundation) and,
- changes in wind speed.

This baseline study aims to identify and discuss the relevant literature pertaining to climate change in Africa with reference to past and projected climatic variability and how this is likely to impact upon local governments as service providers.

Local governments, as the sphere of government closest to their constituents, are required to make decisions and set directions for promoting social, cultural, environmental and economic well-being. Extreme climatic events and variability impact upon local governments and the day-to-day activities and services they provide to the communities that fall within their jurisdiction. These impacts raise challenges and come with risks and vulnerabilities that need to be strategically managed to ensure resilience. The risks associated with climate change pose a serious threat to local governments' ability as service providers to meet their own mandates. These threats may not necessarily arise as a direct result of climate change but rather indirectly as a result of a chain or cascade of events.

A changing climate will affect people's access to, and the quality of, basic goods and services such as water, shelter and food as well as other key priorities for human wellbeing such as education, employment and health. Current literature indicates that although, during extreme climatic events, the entire local human population is impacted upon, it is those who are impoverished who find it harder to recover from climate change related impacts as they have limited access and choices with regard to natural, social political, human, physical and financial capital that forms part of the holistic livelihood assets (IPCC 2007). Deprivation of these assets increases vulnerability to climate change, and climate change in return increases deprivation. Understanding the basis of livelihood assets determines the ability of people to cope with climate-induced vulnerabilities. The key goal is to reduce the vulnerability to changes and to sustain and enhance livelihoods of people, with particular attention to the poor through adaptation and coping mechanisms.

Adapting to climate change is a necessary active initiative to reduce the vulnerability of the natural and human systems. Adaptation is becoming increasingly vital as climatic changes currently experienced are reportedly increasing in magnitude and frequency. Therefore the magnitude and frequency make the reduction of vulnerability an increasingly difficult task to achieve, particularly for developing nations who, comparatively to developed nations, have limited capacity and resources to implement coping mechanisms.

1. Project context

The official mandate of **ICLEI[1] – Local Government for Sustainability** - **Africa** – is to work with Sub-Saharan African countries towards sustainable development and this project works towards that. The project is entitled *Sub-Saharan African Cities: A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action*. ICLEI-Africa falls under the auspices of the Climate Change Adaptation Africa (CCAA) programme funded by International Development Research Council (IDRC) and Department for International Development (DFID). The "Five City Network" project aims to address the knowledge, resource, capacity and networking gaps by strengthening the ability to plan for, and adapt to, impacts associated with climate change.

Increased adaptive capacity at the local government level, by building understanding and awareness of projected threats, would enable future planning and decision-making abilities to encompass climate change. This would reduce the vulnerability of the communities, services and infrastructure that fall within their jurisdiction. The first step is to identify the impacts and risks associated with climate change variability and subsequently make informed decisions. This leads toward the identification of mechanisms that increase adaptive capacity and climate preparedness thus enabling local governments to cope with such impacts. The first phase of the project is to identify the risks and impacts at a local level, looking at various local government sectors. The Risk Assessment comprises of a number of stages namely:

- An overview of the risks and impacts associated with climate change that have already been documented (a baseline literature review – referring to this report).
- A southern African climatic variable overview of the past, present and projected changes for: sea level, temperature, wind speeds, rainfall and precipitation patterns.
- A cost-benefit analysis of present and projected risks at the local level.

Five urban centres were chosen for this project; **Cape Town** in South Africa, **Dar es Salaam** in Tanzania, **Maputo** in Mozambique, **Walvis Bay** in Namibia and **Port Louis** in Mauritius.

These cities were chosen as they are large, home to a significant number of people, are rapidly developing and are coastal economic hubs with harbours that contribute to their national GDP. Adaptation needs to be initiated quickly so that each city can contribute to the understanding of climate change, its vulnerabilities and adaptation strategies. Each city is represented in an individual

1 ICLEI – Local Governments for Sustainability is an international association of local governments and national and regional local government organizations that have made a commitment to sustainable development. ICLEI was founded in 1990 as the International Council for Local Environmental Initiatives. The organization is now officially called 'ICLEI - Local Governments for Sustainability', encompassing a broader mandate to address sustainability issues. ICLEI – Local Governments for Sustainability – Africa (ICLEI Africa) is the regional secretariat based in Cape Town, South Africa.

case report. Port cities form a nexus between growing population and trade, and thus an excellent focus for investigating impacts and adaptation needs under changing climate.

This report focuses on the coastal city of **Cape Town** (Figure 1) in South Africa. It was chosen for the following reasons: i) it is the largest coastal city and second most populous in South Africa; and ii) its harbour is an important hub of economic activity for the entire country.

This report gives an overview of the climatic changes in Africa with regard to temperature followed by a downscaling approach focusing at a regional level (South Africa) and then lastly narrowing the study to the Cape Town area; examining the associated municipal sectoral impacts and risks felt at the local level with relation to increased temperature and climate change. The Cape Town study will also comprise of a report on the findings of the Mamre community surveys and workshops. The municipal sectors that will be focused on for this assessment are water and sanitation, energy, transport, health and livelihoods.

Figure 1. Study focus area - Cape Town, South Africa[2,3]

[2] © Oxford Cartographers: http://www.thecommonwealth.org/YearbookHomeInternal/139444/.
[3] And Google Earth and Theodora Maps.

2. Legislation and international obligations

South Africa is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. As a developing country it is currently not obliged to reduce its greenhouse gas emissions. However, since South Africa is such a large emitter, the South African National Government has recognised the need to plan for a future of lower carbon development, and take on commitments at the post-Kyoto negotiations in Copenhagen in 2009. The ruling African National Congress (ANC) committed to setting a target for greenhouse gas reduction at its 52nd National Conference, held in Polokwane in 2007. In 2008 government published the Long Term Mitigation Scenarios (LTMS), which use models to explore the consequences of various policy interventions aimed at reducing greenhouse gas emissions.

South African environmental legislation is largely based on the traditional "command and control" model where the threat of punishment is designed to deter any aberrant behaviour (Gunn 2007) and although more incentivised legislation may be applicable, South Africa has much strong legislation in place.

National context – South Africa's environmental sustainability strategies

1965 - **The Atmospheric Pollution Prevention Act - No. 45**: This was established to provide legislation for the prevention of the pollution of the atmosphere.

1996 - **The Constitution of South Africa - Act No. 108:** This presents an overarching obligation to sustainable environmental management, which requires that local government provide services in a sustainable manner, provide a safe and healthy environment for all communities, promote social and economic development, and ensure transparent governance. In the **Bill of Rights (Chpt 2; Art 24)** environmental rights are presented in context of human health, stating "Everyone has the right to an environment that is not harmful to their health or well-being;" As well as recognising the rights of future generations in the context of sustainable development by stating "to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

1989 - **Environmental Conservation Act - Act No. 73**: This aims to reduce potential negative environmental impacts of activities related to development and to promote sustainable development. Specific sections of this Act set out procedures for Environmental Impact Assessment that must be complied with, in order for activities as defined in the Act, such as water supply and wastewater treatment works, to commence.

1998 - **National Environmental Management Act (NEMA) – Act No. 107:** This provides for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith.

1998 - **National Water Act - Act No. 36 & Water Services Act - Act No. 108 of 1997**: In response to the National Water Act, the Department of Water Affairs and Forestry (DWAF) has developed a draft National Water Resource Strategy (NWRS) to address the management of water resources to meet the development goals of the country. One of the key objectives of the NWRS is to identify areas of the country where water resources are limited and thereby constrain development, as well as areas where water resources are available to support development opportunities. In addition, industrial users are now required to develop and submit water management plans if they draw their water directly from a water source.

2000 - **Municipal Systems Act - Act No. 32**: This has certain implications and obligations for environmental management by local government, which must be incorporated in the institutional framework and policies of the local government authority. It provides the core principles, mechanisms and processes that are necessary to enable municipalities to move progressively towards social and economic upliftment.

2002 - **Disaster Management Act - Act No. 57**: This focuses on preventing and reducing the risk of disasters, mitigating their severity, emergency preparedness, rapid and effective response and post-disaster recovery. Further guidance is provided by the National Disaster Management Framework (2005). Several critical obligations for municipalities related to infrastructure management and development flow from these documents (Holloway 2005).

2004 - **National Environmental Management: Air Quality Management Act – Act No. 39**: To reform the law regulating air quality in order to protect the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development while promoting justifiable economic and social development; to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government; and for specific air quality measures.

2004 - **Biodiversity Act - Act No. 10**: The act aims to provide a regulatory framework to protect South Africa's valuable species, ecosystems and biological wealth. It also provides for the development of a National Biodiversity Framework. Municipalities must align their Integrated

Development Plans (IDPs), and thus their Spatial Development Frameworks (SDFs), with the National Biodiversity Framework and any published bioregional plans.

2008 - **Integrated Coastal Management Act**: To establish a system of integrated coastal and estuarine management in the Republic to promote the coastal environment and maintain the natural attributes of coastal landscapes and seascapes, and to ensure that the development of natural resources within the coastal zone are socially and economically justifiable and ecologically sustainable. This act has important implications for development when taking climate change into affect at local government level.

Other Acts that relate to local authorities and potential climate impacts:
- Atmospheric Pollution Prevention Act (Act No. 45 of 1965);
- Conservation of Agricultural Resources Act (Act No. 43 of 1983);
- Health Act (Act No. 63 of 1977);
- Marine Living Resources Act (Act No. 18 of 1998);
- National Heritage Resources Act (Act No. 25 of 1999);
- National Veld and Forest Fire Act (Act No. 101 of 1998);
- Nature Conservation Ordinance (Ordinance No. 19 of 1974);
- Seashore Act (Act No. 1 of 1935);
- World Heritage Convention Act (Act No. 49 of 1999).

Provincial context – Western Cape's environmental sustainability strategies

1999 - **Western Cape Planning and Development Act – No. 7:** Co-ordinate and harmonise environmental policies, plans, programmes and decisions made by government bodies that are responsible for the promotion and protection of a sustainable environment.

2002 - **Western Cape Environmental Implementation Plan:** This is a written strategy or sectoral plan that deals with environmental concerns in a particular area and includes an environmental strategy or environmental management plan as contemplated in other provincial and national legislation.

Local context – Cape Town's environmental sustainability strategies

2003 - **Integrated Metropolitan Environmental Policy (IMEP)** in which environmental education is identified as both a strategy, and a tool in other sectoral environmental strategies. This Environmental Education and Training Strategy is a framework for planning and implementation.

2003 - **Coastal Zone Management Strategy** is to ensure that the coastal zone of Cape Town is protected, enhanced and optimised with a new and integrated approach to coastal management.

2003 - **Biodiversity Strategy** is an overarching framework for a consolidated approach to protecting and enhancing the rich biodiversity of the City of Cape Town.

2005 - **Cultural Heritage Strategy** for the City Of Cape Town ensures that the diverse cultural heritage of the City of Cape Town is protected and enhanced.

2007 - **Energy and Climate Change strategy** aims to improve quality of life by improving energy efficiency and energy supply options, guiding transport issues and contributing to sustainable growth and development through cost-effective energy provision.

2008 - **Integrated Metropolitan Environmental Policy (IMEP)** is the result of a 5-year review that now assigns measureable environmental targets and goals across City of Cape Town line functions from 2009-2014.

3. Africa - climate change and increase in temperatures

Africa, covering more than one fifth of the total land area of earth, is the second largest continent and host to one billion people (United Nations Population Fund 2007, UN-Habitat 2010). It is a continent with abundant natural resources but remains the most underdeveloped continent globally. Extreme poverty, poor access to water, sanitation and health services and malnutrition from inadequate food supplies slows her progress (Sandbrook 1985). This means that the average sub-Saharan African will bear a three-fold population-based risk of suffering adverse effects of climate change when compared to a global total (Byass 2009), a heavy burden to bear for the population group that has contributed least to the forcing of climate change (IPCC 2007). The Stern Report (2006) concludes for Africa: 'The poorest will be hit earliest and most severely. In many developing countries, even small amounts of warming will lead to declines in agricultural production because crops are already close to critical temperature thresholds. The human consequences will be most serious and widespread in sub-Saharan Africa, where millions more will die from malnutrition, diarrhoea, malaria and dengue fever, unless effective control measures are in place' (Stern 2006).

Projections

TEMPERATURE: Africa is experiencing the same physical effects of climate change and variability as experienced worldwide. Consensus in the scientific community's projections gives us a warming of approximately 0.7^{O}C, increasingly more so in the southern regions than in the central regions (IPCC 2007). Between 1961 and 2000 an increase in warm spells over southern and western parts of Africa was observed, with a decrease in the number of extremely cold days (New *et al.* 2006). According to the IPCC (2001), mean surface temperatures are projected to increase between 1.5^{O}C and 6^{O}C by 2100. This warming trend is anticipated to give rise to changes in precipitation, which will be accompanied by sea level rises and increased frequency of extreme events in Africa, such as sea storm surges, floods, gale force winds and cyclones (Desanker 2009).

RAINFALL: Projections give a 10-20%decrease in rainfall by 2070 and a fall in river-water levels of as much as 50% by 2030, in various parts of Africa (UNECA 2010). Projections indicate that 230 million

Africans will face water scarcity by 2025 as a result of decreasing water resources and as a result of increasing constraints on water resources, especially in hotter climates. Much water infrastructure will require upgrading to maintain adequate supplies for meeting current needs and increased demands in the future. This will need harmony among the wide diversity of water usage for agricultural production, fishing, navigation, industrial production, domestic consumption, and ecosystem sustainability (UNECA 2010).

FREQUENCY & INTENSITY: Increasing frequency and intensity of severe weather is expected on the African continent to be greater over the next 50 years. The IPCC (2007b) states it is likely that "future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing sea surface temperature increases". The scientific, peer reviewed studies used to inform the assessment, as well as studies that have since been published, indicate that climate change will affect the intensity, frequency and paths of strong storm and wave events. They also indicate a global trend towards increased intensity of hurricanes over the past few decades – most notably in the North Atlantic and Indian oceans (IPCC 2007).

Vulnerabilities

Africa is particularly vulnerable to climate change and associated climate variability as the situation is aggravated by the interactions of 'multiple stresses'. These 'multiple stresses' include: i) endemic poverty, complex governance and institutional dimensions; ii) limited access to capital, including markets, infrastructure and technology; iii) ecosystem degradation; and iv) complex disasters and conflicts. These in turn have contributed to Africa's weak adaptive capacity leaving the continent most vulnerable to deal with impending changes (IPCC 2007).

Food security (including access to food) in many parts of Africa is likely to be severely compromised. Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020 (IPCC 2007), and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected (Venton 2007).

Climate change will aggravate the water stress currently faced by some countries, while some countries that currently do not experience water stress will become at risk of water stress. Climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa. Even without climate change, several countries in Africa, particularly in northern Africa, will exceed the limits of their economically usable land-based water resources before 2025. About 25% of Africa's population (~200 million people) currently experience high water stress. The population at risk of increased water stress in Africa is projected to be between 75-250 million and 350-600 million people by the 2020s and 2050s, respectively (IPCC 2007).

Changes in a variety of ecosystems are already being detected, particularly in southern African ecosystems, at a faster rate than anticipated. Climate change impacts on Africa's ecosystems will likely have a negative effect on tourism as, according to one study, between 25 and 40% of mammal species in national parks in sub-Saharan Africa will become endangered(IPCC 2007). Local food supplies are projected to be negatively affected by decreasing fisheries resources in large lakes due to rising water temperatures, which in turn, may be exacerbated by continued overfishing (IPCC 2007).

Human health will be further negatively impacted by climate change and climate variability. It is likely that climate change will alter the ecology of some disease vectors in Africa, and consequently, the spatial and temporal transmission of such diseases. Most assessments of health have concentrated on malaria but the need exists to examine the vulnerabilities and impacts of future climate change on other infectious diseases such as dengue fever, meningitis and cholera, among others (IPCC 2007).

Climate change is a real challenge when dealing with **natural disasters**. Climate is often thought of as only the long-term averages of weather elements, however, impacts of the local climate is likely to depend more upon changes in the frequency and intensity of extreme events than on changes in the average conditions. The increased frequency and/or severity of extreme events will increase human vulnerability to natural disasters such as droughts, floods, mean sea level rise and storm surges and cyclones. Semi-arid areas and coastal and deltaic regions are particularly vulnerable. Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. This will be both in terms of inundations during storm surge events and salt-water intrusion that will occur when sea-level rise starts to affect groundwater. The cost of adaptation could amount to at least 5-10% of GDP in Africa (IPCC 2007).

Increasing temperatures facing Southern Africa

Although there is debate about the way in which climate change will manifest, increased temperatures have been identified as a significant threat to human livelihoods and sustainable development.

Observed climatic trends

The historical temperature trend for global anomalies since 1860 to 1990 shows evidence of the warming conditions that the world has been exposed to since the 1980's (Figure 2).

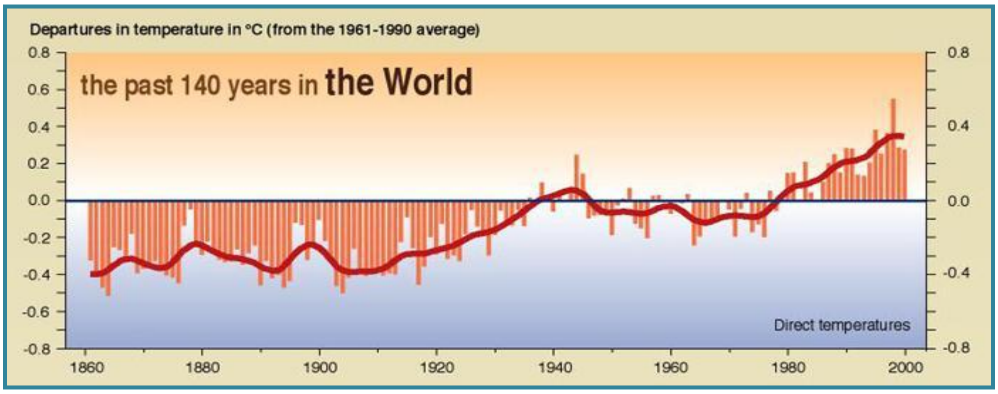

Figure 2. The Average global temperature trend since 1860's to 1990[4].

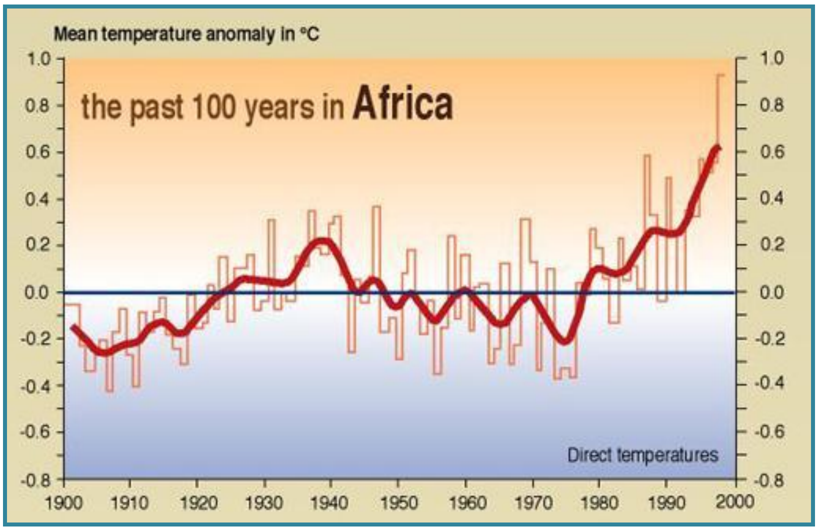

Figure 3. Africa's temperature trend in the past 100 years[5].

Africa follows the global trend of recent increases in temperature with a notable difference; the anomaly for Africa at the start of the century was 0.2°C higher than that of the world's temperature anomaly. With a higher decadal warming in Africa, the continent is bound to feel the effects of climate change directly and indirectly (Figure 3).

According to the historical climate records, most of the African continent shows evidence of approximately 0.7°C warming, more so in the southern regions than in the central regions (IPCC 2007). Hulme *et al.* (2001) stated that observational records show the continent has been warming at a rate of about 0.05°C per decade with slightly larger warming in the June-November season than

[4] Source: World Meteorological Department (WMO), United Nations Environmental Programme (UNEP), Climate Change 2001, *Impacts, Adaptation and Vulnerability*, and Synthesis Report.
[5] Source: World Meteorological Department (WMO), United Nations Environmental Programme (UNEP), Climate Change 2001, *Impacts, Adaptation and Vulnerability*, and Synthesis Report.

in the December-May season. It must be noted that although observed temperature trends across Africa are consistent they are not always uniform.

The decadal warming rate in the African tropical forests was 0.29°C (Mahli and Wright 2004), compared to the South African warming trend ranging between 0.1 to 0.3°C for the same period (Kruger and Shongwe 2004). Between 1961 and 2000 there was an observed increase in warm spells over southern and western parts of Africa, with a decrease in the number of extremely cold days (New *et al.* 2006). However, coastal weather stations located on the eastern parts of Africa have experienced decreasing trends in temperature (King 'uyu *et al.* 2000). By the year 2000, the 5 warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years. This rate of warming is not dissimilar to that experienced globally, and the periods of most rapid warming – the 1910s to 1930s and the post-1970s-occur simultaneously in Africa and the world (Hulme *et al.* 2001).

Projections

A number of authors have projected future air temperatures with the use of Global Circulation Models (GCMs) and Regional Climate Models (RCMs) under different emissions scenarios. The temperature projections for the African continent are as follows:

- Temperature increase of 7°C for southern Africa between 2070 and 2099 – using GCM A1F1 emission scenario (Ruosteenoja *et al.* 2003);
- Temperature increase of 3.7°C in summer and 4°C in winter in southern Africa by 2080 from the 1980 – 1999 benchmark – using HadRM3H RCM A2 emission scenario (Hudson and Jones 2002);
- Warming across the continent by 2100 ranging between 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Hulme *et al.* 2001 and Desanker & Magadza 2001).

According to the IPCC (2000), mean land surface temperatures are projected to increase between 1.5°C and 6°C by 2100, this warming trend is anticipated to give rise to changes in precipitation that will be accompanied by mean sea level rise and increased frequency of extreme events in Africa, such as sea storm surges, floods, gale force winds and cyclones (Desanker 2009). In the Southern African region, temperatures in southern Africa 'will increase by up to six degrees Celsius, while rainfall will drop by as much as 40 percent in some parts of the region' (Palitza 2009).

4. South Africa and its vulnerabilities

The Republic of South Africa occupies the southernmost part of the African continent with a surface area of 1,219,090 km^2. The coastline stretches for about 3,000 km from Namibia in the west to Mozambique in the east. Two major ocean currents, the Mozambique Agulhas and the Benguela systems, sweep the South African coastline. The former is a warm, south-flowing current skirting the east and south coast as far as Cape Agulhas. The Agulhas current is relatively warm (20 to 25°C) and the plant and animal diversity is high. The Benguela Current on the other hand, is cold (16 to 21°C) and flows northwards as far as southern Angola along the west coast (DEAT 2000). Climate is also moderated by the cold Southern Atlantic Current (Figure 4).

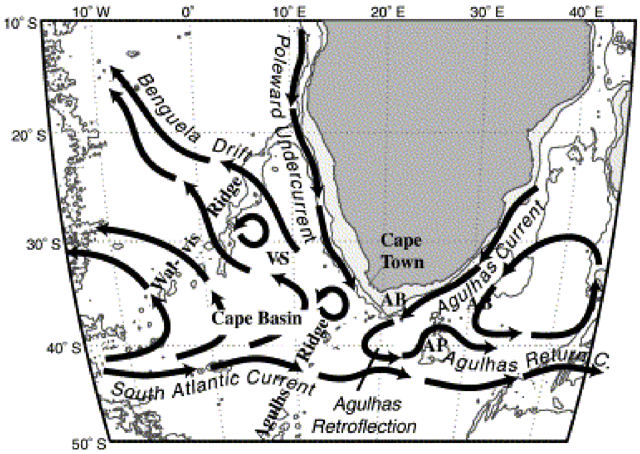

Figure 4. The three currents that moderate South African temperatures in the southern hemisphere[6].

Climatic conditions generally range from Mediterranean in the south-western corner of the country to temperate in the interior plateau, and subtropical in the northeast with a desert climate in the northwest. The steep rainfall gradient from west to east is partly as a result of the cold Benguela current on the west coast and the warm Agulhas on the east.

The climate in South Africa is typically warm and dry, with daytime winter temperatures rarely falling below 0°C, and summer maxima often above 35°C. The subtropical location (around 30°S) accounts for warm temperate conditions. The country also falls within the subtropical belts of high pressure, making it dry, with an abundance of sunshine (DEAT 2000).

Frost often occurs on the interior plateau during cold, clear winter nights. The frost season is longest (from April to October) in the eastern and southern plateau areas, which border on the escarpment that separates the coast from the high inland plateau. Frost decreases to the north, while the coast is virtually frost-free. Average annual relative humidity readings show that the air is driest over the

[6] Source: The Agulhas Undercurrent Experiment http://www.rsmas.miami.edu/personal/lbeal/current.html.

western interior and over the plateau. Along the coast, the humidity is much higher (up to 85%) (DEAT 2000).

South Africa lies within a drought belt with an average rainfall of only 464 mm, with fluctuating rainfall patterns. Furthermore, the rainfall is typically unreliable and unpredictable with a low rainfall:run-off ratio. The central and eastern parts of the country receive summer rainfall, whilst the south-western part of the country is a winter rainfall region (DEAT 2000).

South African weather is also controlled by the global pressure systems. Temperature and rainfall vary in response to the movement of the high pressure belt that circulates the globe between 25 and 30 degrees latitude during winter (June, July and August) allowing low-pressure systems to affect the south parts of South Africa. In summer (December, January and February) this high-pressure belt moves southerly blocking the low pressure systems allowing subsiding air to dominate with warm temperatures in the south (DEAT 2004).

The South African population was estimated at 49.99 million in 2000 with a 2.1% annual growth rate that the governments aims to stabilise at 80 million or 1.9% growth rate by 2100 (Statistics SA 2010; DEAT 2003). South Africa's population comprises a diverse range of cultures and eleven official languages are spoken. In 2000, approximately 50% of the population resided in urban areas, with an expected increase to almost 60% by the year 2010 (DEAT 2000).

Unemployment is high and increasing. It has been estimated that approximately 30% of the population was unemployed in 2000, growing at a rate of 2.2% per annum (Statistics SA 2000). The majority of the unemployed are black men and women under the age of 35 years. Approximately 26% of South African households have an income of less than R500 per month (Statistics SA 2000). This situation contributes to malnutrition that is estimated to affect 2.5 million children. Poverty also exacerbates the major health risks, such as malaria, tuberculosis and HIV/AIDS. It is estimated that there are 410,000 new HIV infections each year (Statistics SA 2010). It was predicted that by the year 2010, 21.7% of the adult population will be infected with HIV. Life expectancy in South Africa has reduced from 61.5 years in 1994 to 55 years in 1999 - 2010, which is likely attributed to the incidence of HIV/AIDS. Malaria is currently endemic in the low-altitude areas of the Northern Province with 23,282 cases reported in 1998 of which 158 were fatal (DEAT 2000).

South Africa has a stable and growing economy with a GDP of US$ 354 billion in 2010 (IMF 2010). The economy was originally built on natural resources, with mining and agriculture being the main contributors. The financial sector is now the largest industry in the country followed by manufacturing. Tourism and related industries together with agriculture have been recognised as the key drivers for job opportunities and economic empowerment (DEAT 2003). South Africa remains at the forefront of multilateral initiatives aimed at promoting a more equitable, pro-poor developments and ensuring a better future for Africa's people. South Africa has played a critical part in the African Union and the New Partnership for Africa's Development (NEPAD)[7], as well as in regional conflict resolution. This is opening up a new era of growth and investment in sub-Saharan Africa (DEAT 2000).

South Africa's role in climate change

South Africa's greenhouse gas emissions are very high, ranking it within the top 20 greenhouse gas emitting countries globally. This means that it emits well above the developing country average – and more than many developed countries. This is mainly (79%) as a result of reliance on coal for electricity (DEAT 2010).

Projections

- The average **temperature** in South Africa is projected to increase by between 1 and 3°C, up to 4°C in the interior and the daily maximum temperatures in summer and autumn in the western part of South Africa are also likely to increase. That means more extremely hot days (Fairhurst 2009, DEAT 2009).
- With regards to **rainfall**, the country's rainfall is projected to decrease by 5-10%. The east of the country is projected to become wetter, but the distribution of rainfall within the rainfall season (summer) will also change, with the rainfall season beginning later and the annual average falling over fewer days with an increase in extreme events. The west of the country (the winter rainfall region) will become drier (UNFCCC 2009), with most of the models indicating a net drying on the western two-thirds of the subcontinent, south of about 10 °S (DEAT 2009). The Western Cape is predicted to face a shorter rainfall season, with the eastern interior portions of the province likely to experience increased late summer rainfall (DEAT 2009).
- Other potential changes include more floods and droughts and stronger, more frequent temperature inversions, exacerbating air pollution problems (DEAT 2009).

Vulnerabilities

Measurements in South Africa indicate that climate change is already occurring, with increases in surface temperature evident over both southern and South Africa (Kruger & Shongwe, 2004; New *et al.*, 2006, IPCC 2007). South Africa's mean temperature anomaly (Figure 5) for 28 selected South African climate stations from 1961 to 2007 demonstrates the increased trend in temperature over the last few decades. Whether this change is associated with global warming or natural inner annual variations remains debated, however, temperatures are increasing.

[7] NEPAD has now been integrated into the AU under the NEPAD Planning and Coordinating Agency (NPCA).

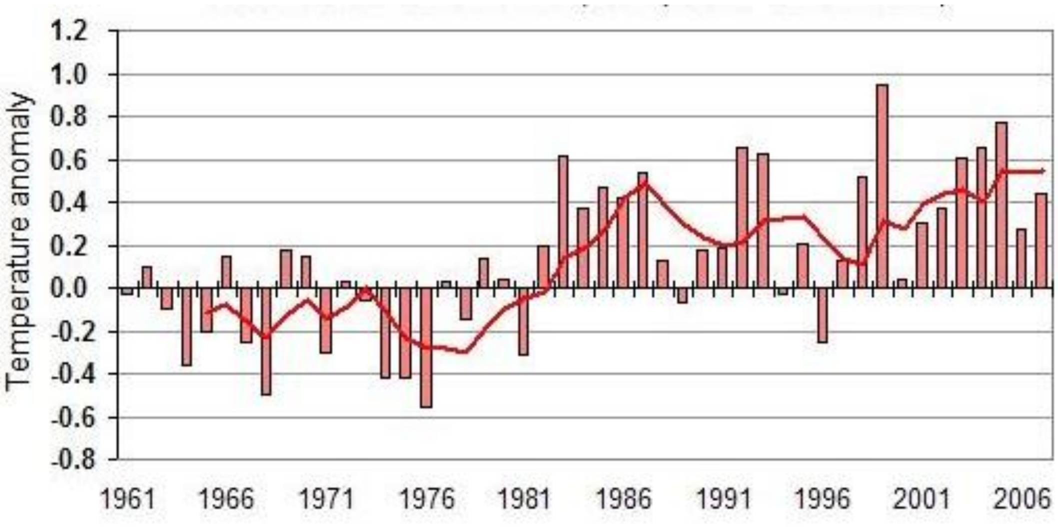

Figure 5. Mean temperature anomaly for 28 selected South African climate stations from 1961 to 2007 (base period: 1961 to 1990)[8].

Changes in climate already affect various sectors of South African society and economy as well as the biophysical environment, and the effects are projected to be significant in future. The areas of highest vulnerability are the health sector, water resources, agriculture (particularly rangelands maize production), biodiversity and air quality (DEAT 2009).

Health impacts: These can be expected and are both direct and indirect impacts. Direct impacts may include death or injury from extreme weather events such as floods. Indirect impacts are ones that manifest after an extreme event has passed but is no less threatening to human health. These can include an increase in the occurrence of strokes, skin rashes, dehydration and the incidence of non-melanoma skin cancers. Health impacts result from environmental responses to climate change such as an increase in the incidence of water-borne diseases such as cholera. Vector-borne diseases such as malaria could also increase with significant expansion of the malaria prone areas. This is already a problem in Tanzania but has also been projected in climate change scenarios for South Africa as a result of increasing temperatures (DEAT 2004).

Water: South Africa's rainfall is already highly variable in spatial and temporal distribution. Much of the country is arid or semi-arid and the whole country is subject to droughts and floods. Bulk water supplies are largely provided via a system of large storage dams and inter-basin water transfer schemes that take years to develop. Thus a reduction in the amount or reliability of rainfall, or an increase in evaporation would exacerbate the already serious lack of surface and ground water resources. Water availability in the arid and semi-arid regions is particularly sensitive to changes in precipitation. Desertification, which is already a problem in South Africa, could be exacerbated by

[8] *DEAT 2009, Data obtained from the South African Weather Service (http://soer.deat.gov.za/313.html).*

climate change. Furthermore, climate change may alter the magnitude, timing and distribution of storms that produce flood events.

Agriculture: South Africa consists of natural and semi-natural ecosystems that provide rangelands (70% of the land cover) for large herbivore species, both livestock and indigenous populations of game. Aridification of this type of land is projected, especially where rangelands are already marginally productive. In addition, bush encroachment into grassland areas is likely to increase and frequency of fire outbreaks is predicted to increase significantly (DEAT 2004) thus negatively impacting on rangelands.

Maize production, which accounts for 70% of total grain in South Africa, will decrease by up to 20%, mostly in the drier western regions. This is likely to force a shift to more drought-tolerant crops such as sorghum (UNFCCC 2009). Speciality crops requiring specific environmental conditions will also be negatively impacted and increases in pests, diseases and invasive species would also have a detrimental effect on agriculture. Forestry is sensitive to climate change as it is based on plantations of non-indigenous species, located in relatively marginal areas, which comprise about 1.5% of the land area of the country.

Biodiversity, provision of resources and sustaining ecosystem functioning: Climate change modelling suggests a reduction of the area covered by the current biomes by up to 55% in the next 50 years as desertification takes hold, especially in the western, central and northern parts of the country. Species composition is expected to change, which may also lead to significant changes in the vegetation structure in some biomes, and even lead to total species loss. With regard to animal taxa, climate modelling projects that most animal species will become increasingly concentrated in the proximity of the higher altitude eastern escarpment regions, with significant losses in the arid regions of the country. Some species are predicted to become extinct (DEAT 2004).

Marine biodiversity is likely to be impacted as well. The projected rise in sea surface temperature would result in the migration of species residing along the coast. Changes in sea temperature may increase the intensity and frequency of upwelling events, causing alterations of near-shore currents thus impacting on rocky shore ecosystems (the nutrient and larval supply to the coast would be affected influencing community structures). In addition there would be an increase in the occurrences of the harmful algal blooms (HAB) events on the west coast that cause mass mortalities of fish, shellfish, marine mammals, seabirds and other animals, and can result in illness and death in persons who eat contaminated seafood (DEAT 2004, UNFCCC-NAM 2009).

Urban air **pollution** from low-level sources, such as domestic emissions, will become a greater problem, as a result of the enhanced occurrence of temperature inversions resulting from climate change. These inversions serve to trap the smoke from such sources near ground level giving rise to excessive ambient concentrations. That said, if South Africa adapts now and plans for an altered climate, putting green technologies in place and adapting to a low carbon economy, changes can be positive (UNFCCC 2009).

4.1. Cape Town and its vulnerabilities

Cape Town is home to a population of around 3.7 million, inhabiting a million households at an average density of 12 people per hectare. The population is growing at an average of 4% a year but the growth rate is skewed to informal settlements where the annual growth rate is 13% that can partly be accounted for by migrations from rural areas. Cape Town has an unemployment rate of 21% but a GDP of R 130 billion a year. The Cape Floristic Kingdom is a true global hotspot of biodiversity, being the smallest and richest on Earth. The city lies within the Cape Floral Region, a UNESCO World Heritage Site and had the highest number of threatened plant species in the world of any city.

Cape Town falls within the Mediterranean climate region; with mild, wet winters, and dry, warm summers. Winter lasts from the beginning of June to end of August; large cold fronts come from the west across the Atlantic Ocean with heavy precipitation and strong north-westerly winds. The winter months are wet and cool, with an average minimum of 7.0 °C and maximum of 17.5 °C (WMO 2010). Most of the city's annual rainfall occurs in wintertime, but due to the mountainous topography of the city, rainfall amounts for specific areas can vary dramatically from region to region. The valleys and coastal plains average 515 mm of rain per annum, while mountain areas can average as much as 1,500 mm per annum (SAWS 2010).

Summer lasts from November to March and is typically warm and dry. The Peninsula gets frequent strong winds from the south-east, known locally as the Cape Doctor. This strong wind destabilizes the inversion layer, blowing away the pollution and cleaning the air (SAWS 2010). The south-easterly wind is caused by a high-pressure system over the South Atlantic to the west of Cape Town, known as the South-Atlantic High. Summer temperatures are mild, with an average maximum of 26.5°C. Cape Town can be uncomfortably hot when the berg wind, "mountain wind" blows from the Karoo mountains in the north to the coast warming the air adiabatically (1°C/100m) for a couple of weeks in February or early March (SAWS 2010).

Projections

The assessment of the implications of climate change for South Africa’s Western Cape Province (Midgley *et al.* 2005) indicates that significant warming trends are evident for particular seasons over the Western Cape. Further, significant temperature increases are evident in the records for minimum and maximum temperature. Drier conditions are predicted for the south west of the country in both seasons. Rainfall intensity is likely to increase, but to not necessarily imply an increase in total rainfall. Greater evaporation rates are likely to increase drought incidence and intensity (as defined by the response of available soil moisture and available free water), possibly even in regions where total rainfall increases (DEAT 2010).

Vulnerabilities

Cape Town has over 307 km of coastline, making it the city with the longest stretch of sea frontage of any metropolitan authority in South Africa; it is particularly vulnerable to sea level rise and an increase in the intensity and frequency of sea storm surge events. Areas within Cape Town that are particularly at risk are those situated mainly in low lying areas or close to estuaries and include Milnerton Lagoon, Fish Hoek, Strand, Gordon's Bay and Sea Point (Cartwright 2008).

Based on existing available literature, a number of climate induced impacts for the City of Cape Town were identified (from Mukheibir *et al.* 2006).These impacts include:

• Increased water stress in the City as a result of forecast reduction in rainfall and increased evaporation due to **increased temperature**. This will be coupled to increasing demand with increasing populations and industrial needs.

• A rise in sea-level will increase the vulnerability of beaches, shorelines and coastal developments and infrastructure to storm surges and erosion.

• **Increased temperatures** could lead to changes in fire intensity and frequency, which may also trigger the destruction or migration of sensitive plant and animal species that are already at the limits of their temperature and rainfall tolerance.

• The impacts of severe storms may result in damage to infrastructure, both coastal and inshore.

• Health and livelihoods may be indirectly affected, especially through the risk of fires and reduction in air quality as **temperatures rise**.

A number of previous disasters and events have been associated with weather conditions and should serve as a warning for future conditions given current projections of such events occurring on a more frequent and intense basis. These include the Cape Flats floods (1994 and 2001), the Manenberg wind storms (1999 and 2002), South Peninsula fires (2000, 2009, 2010), Joe Slovo informal settlement fires (2000, 2009), cut-off low severe sea storms (2003, 2004, 2005) and severe drought (such as 2002-2005) (Mukheibir *et al.* 2006).

The Mamre Community and its vulnerabilities

The Environmental Resource Management Department of the City of Cape Town has undertaken the ***Mamre Ceiling Project***: a sustainable livelihoods project that aims to provide ceilings for approximately 200 RDP (Reconstruction and Development Programme) homes in Mamre, Cape Town (Figure 6 and 7a). As a ceiling has a significant impact on a home’s temperature control, the project hopes to provide insight into the effect of ceiling installations upon livelihoods of local communities. ICLEI-Africa has partnered with the City of Cape Town to assess the impact of the newly installed ceilings and to involve the Mamre Community in climate change adaptation and mitigation. Mamre is located north of Cape Town about seven kilometres north of Atlantis on the West Coast.

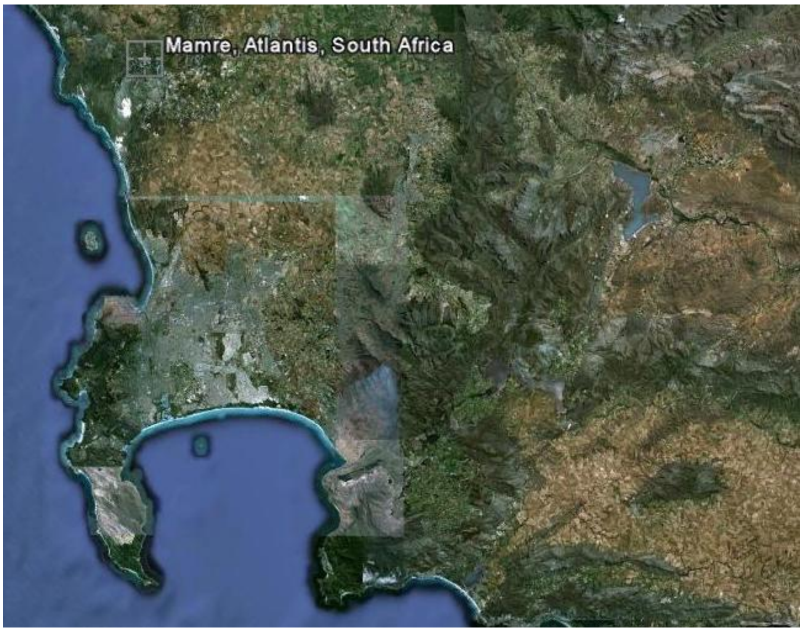

Figure 6. Mamre, north of Cape Town[9].

Mamre History**:** Willem van der Stel, governor of the Cape, established a military and cattle post here in 1701, to prevent settlers' cattle being stolen by the indigenous Khoi people. In 1808, when the Cape Colony was again under British control, the governor Lord Caledon established a mission under supervision of Kohrhammer and Schmidt, two Moravian missionaries from Germany. In 1967 the church and parsonage in Main Road were declared national monuments. The original water mill has been restored and is today used as a museum. Hottentot "hartbeeshuisies" (reed houses) with stark whitewashed walls were built by local inhabitants who attended the mission in the early days (Figure 7b) A variety of fruit trees planted on the site remain as a testament to the German missionaries.

[9] GoogleEarth.

Figure 7. a) Low cost RDP house in Mamre, Cape Town and) Whitewashed historical house [10].

Mamre is positioned around 13 km inland from the cool Atlantic Ocean; known for strong cold upwelling in the summer months (December, January and February). These sea waters influence the temperatures experienced on the western parts of Cape Town. The warmest months are December, January, February and March with maximum averages of 25.96°C, 26.82°C, 27.66°C and 26.07°C the coldest months are experienced in June, July and August with minimum average temperatures of 6.6°C, 5.86°C and 6.5°C respectively. The difference between the maximum and minimum monthly averages is roughly 12°C (Figure 8).

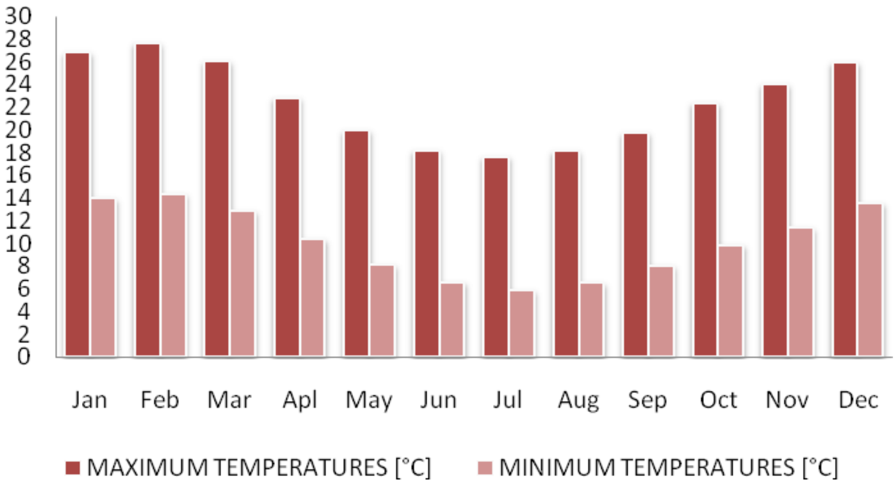

Figure 8. Maximum and minimum temperatures in Atlantis, Cape Town [11].

There are notable differences when comparing average temperatures between two different geographical locations within the Cape Town jurisdiction. For example, the maximum and minimum average temperatures for the same time period for both Atlantis in the north and Groot Constantia in the south (Figure 9). Compared to Groot Constantia, Atlantis experiences greater fluctuations

[10] © ICLEI Africa.
[11] Data source: Agricultural Research Council (ARC), Stellenbosch.

between high and low temperatures and also experiences more extreme temperatures, as a result of the relative exposure of the west coast. A comparison of the averaged, observed winter temperatures, between the two locations demonstrates a greater difference than the summer months, signifying that the winter conditions are more severe on the west coast than in the southern coastal areas of Cape Town.

This temperature data can therefore be used to illustrate the vulnerability of the impoverished Mamre community when one considers the impacts and risks that are associated with variability in temperature and the impact that this may have on their livelihoods and well being.

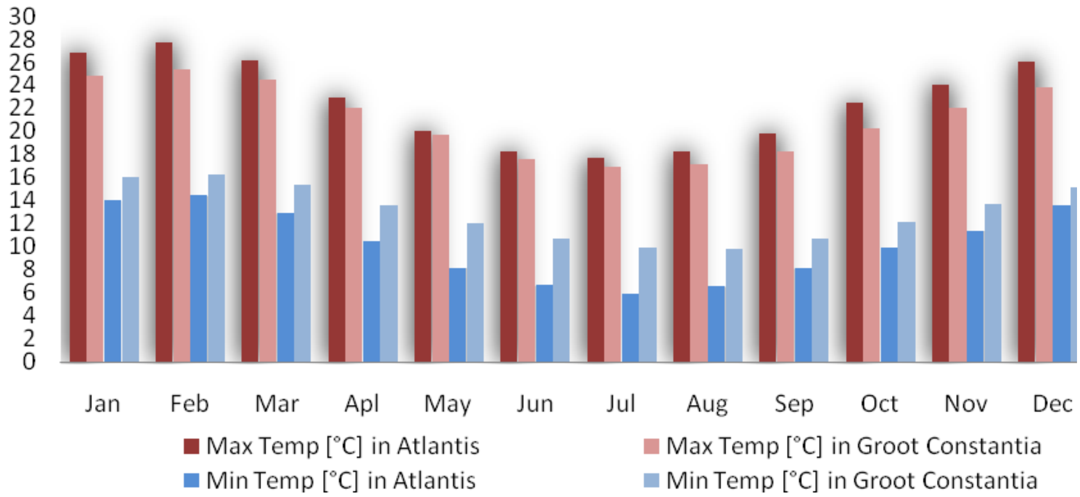

Figure 9. Average temperatures compared between Atlantis, Northern Cape Town and Groot Constantia, Southern Cape Town 1979 - 2004[12]**.**

For more details on projected climate change in the region see the ICLEI Tadross and Johnston (2011) report: *Projected climate change over southern Africa; Mauritius, Mozambique, Namibia, South Africa and Tanzania*.

[12] Data source: Agricultural Research Council (ARC), Stellenbosch.

5. Sectoral impacts associated with increased temperatures

This report focuses specifically on the impacts of increasing temperatures. The impacts of flooding, sea-level rise and increased storm intensity have not been undervalued but have been addressed specifically in the other ICLEI suite of reports. For more information on flooding refer to the ***ICLEI Maputo, Mozambique*** report, for drought the ***ICLEI Dar es Salaam, Tanzania*** report, for sea-level rise the ***ICLEI Walvis Bay, Namibia*** report and for increased storm activity the ***Port Louis, Mauritius***.

5.1. Livelihoods

The term 'livelihoods' is defined as the way and the means of 'making a living' (Chambers and Conway 1992; Bernstein *et al.* 1992; Carney 1998; Ellis 1998; Batterbury 2001; Francis 2000; and Radoki 2002); the capabilities, activities and assets (both material and social resources) required for a means of living (Carney, 1998) and 'refers to people and their dependence upon their surrounding resources for their well-being, such as water, shelter, land, agriculture, livestock, knowledge, money, social relationships and so on' (Chambers and Conway, 1992). These vital resources however cannot be disconnected from the issues and problems of access and changing of structural systems such as political, economical, socio-cultural and especially environmental circumstances. This study will investigate the likely impacts and risks upon services and the cascade of risks and impacts that may lead to livelihood alteration or deprivation.

Changes in the environment and environmental degradation associated with climate change are likely to impact on the resources that people depend on for their livelihoods and thus their survival. Urban dwellers rely more on service providers (for water and sanitation, energy and a means of transport to and from work places and markets) than directly from the natural environment. Peri-urban and rural communities rely on some of these basic services in addition to natural resources such as grazing for livestock and soil and water for crop production. Many communities have to cope with risks and uncertainties but those living closer to the land are most affected by erratic rain, diminishing resources, grazing pressure, spreading of diseases, increase in food prices and inflation. If climate variability and extreme events occur more frequently and more intensely, these impacts are likely to disrupt day-to-day business activities and delivery of basic services, impacting people's ways of living and their ability to maintain a sustainable livelihood. These impacts and risks are likely to influence management and use of resources and the choices that people make.

The basic services provided by local governments are vulnerable to changes in climate and its associated risks and impacts. For the purpose of this study, the general vulnerabilities associated with extremes in temperature upon the local government services are discussed with the aid of international case studies. The four sectors of interest to be discussed further are:

- Water and sanitation;
- Transport;

- Health;
- Energy.

5.2. Water and sanitation

Background

The City of Cape Town receives the majority of its water supply from dams located mainly outside of the Cape metropolitan area. Only 15% of water supply comes from dams belonging to and within the jurisdiction of the City of Cape Town, up to 75% comes from dams under jurisdiction of the Department of Water and Forestry (DWAF). The six major dams that supply the City of Cape Town with water are Wemmershoek (15%), Steenbras Lower and Upper (10.7%), Voëlvlei (20%), Theewaterskloof (43%) and Berg River Dam (8.3%) (Figure 10).

Figure 10. The main storage dams that supply water to Cape Town[13].

There are also the following minor dams (supplying the remaining 2.5% of the water required): Simon's Town (Lewis Gay Dam and Kleinplaas); Land en Zeezicht Dam (from Lourens River) and Table Mountain (Woodhead, Hely-Hutchinson, De Villiers Dam, Victoria Dam and Alexandra Dam).

[13] GoogleEarth

From these dams water gravitates through a number of large diameter pipelines to the water treatment works and bulk storage reservoirs from where water is distributed directly, but also through internal service reservoirs to consumers by bulk connections. The DWAF has identified the greater Cape Town area as the first major urban region in South Africa where the demand for water will exceed the total potential yield if the projected climate change and growth scenarios manifest themselves (DWAF 2004).

Both surface and groundwater resources are exploited and in some places, the rate of exploitation is considered to be unsustainable. At the same time, sufficient water must be left in the rivers to maintain acceptable levels of ecological integrity. The growing metropolitan area of Cape Town demands a greater share of the water resources, and new ways of meeting these demands will have to be found within the short- to medium term future. The projected general drying of the Western Cape region has serious implications for socio-economic development as well as maintaining the ecological integrity of the wetlands, rivers and estuaries that also depend on that same water (Mukheibir *et al.* 2006).

Based on the potential economic growth and population growth, it is estimated that the unconstrained water demand growth in the City will vary between 2.7% and 3.7% per annum (CCT 2006b). This needs to be matched by the available supply. Under projections of current demands into the future scenario, the City will have a water deficit by 2013. Demand management initiatives such as elimination of automatic flushing urinals, leakage repair, tariffs metering and credit control have been effective in bringing the current demand under the available supply.

Impacts & Vulnerabilities

As discussed above, an increase in demand for potable water, with the increase in the Cape Town human population, highlights a question around the sustainability of the resource and whether current sustainability can be maintained in light of a changing climate.

Increased temperatures will lead to evaporation of surface waters, which if rains are less predictable, will hinder the City's ability to ensure enough water can be held in its storage dams. Evaporation, combined with a rise in sea level, will increase the chance of saline intrusions into fresh groundwater in coastal areas. Sea level rise will compromise aquifers, such as the Cape Flats aquifer, which is being recharged with treated wastewater (CSIR 2009). The aquifer under Khayelitsha is relatively safe from sea level rise, but the water table will rise, increasing damp areas, which is a concern for housing in Khayelitsha. The aquifer sits on a saline wedge from the sea. Sea level rise will push it inland, and thus push the water table up. Concerns were also expressed about a decrease in the quality of freshwater due to sewerage intrusions in the event of storm water drainage failure and flooding (CCT 2008).

Increased temperatures will not only reduce the amount of available water but will in itself increase the demand for water as demand for cooling facilities increases. In some areas conflict has arisen over the availability of good water as users fight over priority to available water (see the case study in section 5.4). Heat waves can cause deaths (see case study 1) and many indirect health issues, particularly amongst the old, infirm and children. In Cape Town, people living with HIV may be further compromised as their immune systems may not be strong enough to tolerate the heat. As demand for water increases it is likely that the price of water will increase. There is a large sector of the Cape Town population that already struggles to afford the current water prices; any increase will further marginalise them and increase their vulnerability. In addition as the cost of water increases, the cost of food will increase as producers absorb new costs and pass them on to the end consumers. Again this is a cost that many residents will be unable to meet without a decrease in living standards.

Heat waves also severely increase the risks of wild fires. If the fire frequency increases above the natural fire regime for the specific vegetation type, then vegetation cover may change and even and lead to a scorched earth which in turn exacerbates erosion. Many of the alien vegetation species in and around Cape Town (such as the pines and wattles) have resins that burn at a higher temperature than the natural fynbos; these hotter fires are harder to control and thus increase the likelihood that they may destroy infrastructure.

Table 1: Water and Sanitation sector: Impacts and vulnerabilities associated with variability in temperature.

Potential impacts upon Water and Sanitation sector	Impact on livelihoods
• Increased demand on water resources for human consumption. • Increased demand on water for irrigation. • Increased demand on water for cooling purposes. • Increased temperatures may affect water quality stored in storage tanks. • Increased temperatures causing growth of algae in water storage facilities. • Increased temperatures causes increased surface water evaporation.	• Altered geographical dispersal of water borne diseases • Decreased availability of fresh, pure water supply in extreme heat conditions • Decreased water supply causing dehydration • Decreased water supply reduces sanitation and hygiene • Costs of service provision may rise above what many impoverished communities are able to pay • Costs of water provision may rise with consequent rise in food prices • There is the potential of conflict for water if it becomes scarce • Lack of water and good sanitation is correlated to low hygiene levels and increases the risk of disease transmission

Case studies

1. Prior to the onset of the Southwest Monsoon rains in 2010, northern **India** and **Pakistan** baked as a heat wave scorched the region near the end of May. The Pakistan Meteorological Department

reported record temperatures for several days during the last week in May. A maximum temperature of 53.7°C was recorded in Mohenjo-daro on May 26th 2010. This was the warmest temperature ever recorded in Pakistan and possibly the fourth warmest temperature ever recorded anywhere in the world. It caused 232 heat-related deaths in Pakistan alone (NASA 2010).

2. In 2007 an extreme heat wave swept central and south-eastern **Europe** killing more than 1000 people, with temperatures sparking forest fires, and damaging crops. In Romania, an industry group estimated the agriculture sector had suffered more than US$1.6 billion in damages due to severe drought. The government declared a state of disaster in 34 out of 42 counties. Greece's Fire Service reported 115 fires, and fire fighters had struggled to contain a blaze at an old army base near Athens, where temperatures reached 41°C. High heat combined with high UV radiation led to a health crisis and threat to life. More than 30 people died in Romania and in Hungary another 500 deaths were reported (mostly the elderly and infirm) (IFRC 2007).

3. In **Kenya,** the Kilimanjaro mountain ice cap is reducing due to warming temperatures. Increased evaporation during dry seasons is depleting lakes and aquifers devastating agriculture and livestock production as they have no major dams or sophisticated irrigation infrastructure to store and capture glacier runoff. Receding snow lines reduces the additional water being held underground. The loss of fresh water storage associated with a substantial snowline altitude increase is disastrous for both farmers and livestock producers. Meanwhile, demand for water is expected to increase—both because of the hotter climate and population growth (Thompson *et al.* 2003).

5.3. Transport

Background

The City of Cape Town's transport sector is vital to the city's economy. The passage of commodities and passengers through air, sea, road and rail transport types within the city are well linked to national and international networks and economies. The potential impact of climate change on the transport sector is an emerging field and has become an area of increased focus over the past years (CCSP 2008).

In general, Cape Town's transport use is weighted more heavily towards road transport than rail (see Figure 11, a map produced for the Fifa 2010 World Cup) but amongst those using public transport, 52% use rail each day, while 39% use minibus taxis and 9% use buses. Cape Town's rail network is the most extensive of any city in South Africa and forms the backbone of the public transport system. Rail system upgrading and maintenance has been inadequate in recent years, resulting in declining service standards and levels of use, poor security standards, the removal of train sets from service, and more pressure on less efficient transport modes. The minibus taxi sector has captured a growing share (over 30%) of the public transport commuters. Urban sprawl and the location of townships far from employment areas result in long daily commutes. Despite rail being cheaper and more energy-efficient, there is a high annual growth in private motors being used, leading to more congestion on already stressed roads. Inadequate public transport infrastructure largely affects the poor, since they are generally most dependent on public transport. Improving the welfare of the poor is therefore also linked to improving public transport. Quality public transport is not feasible unless it has the required urban density to support it. Walking and cycling is not well catered for in city planning.

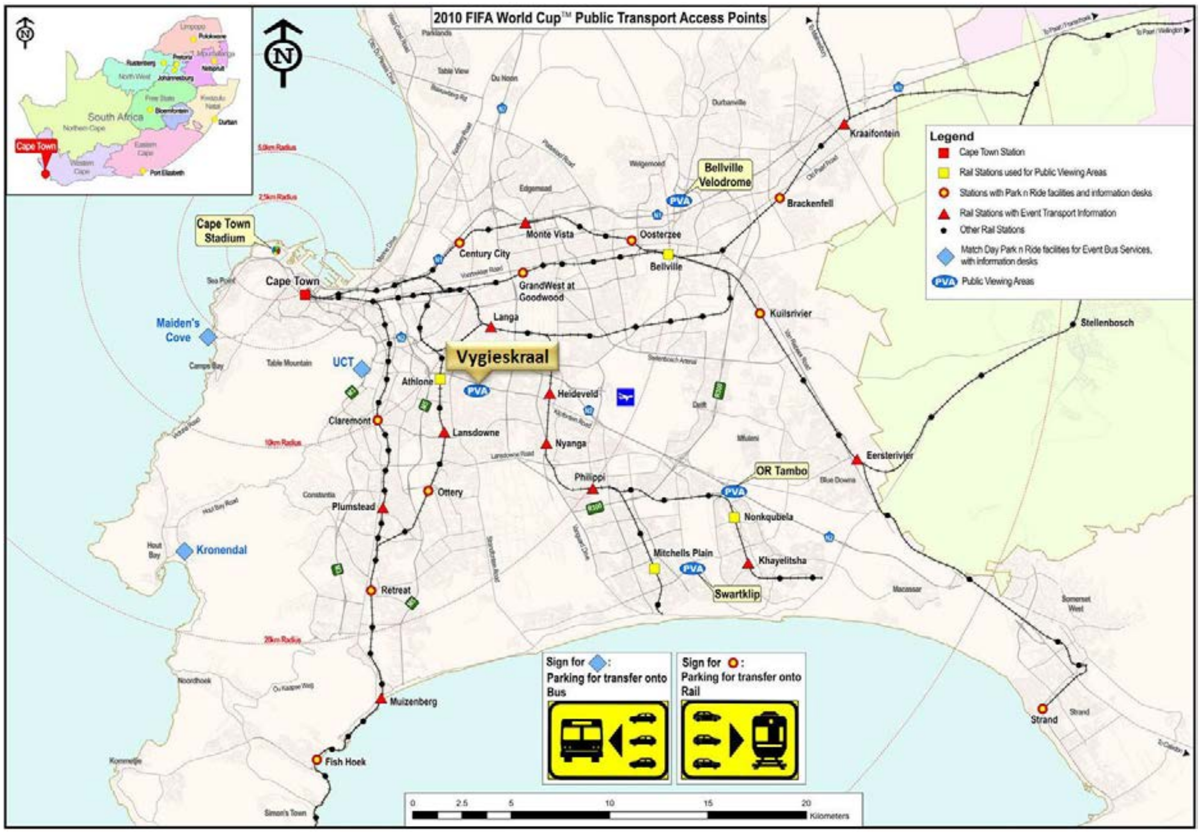

Figure 11. Transport infrastructure within the city of Cape Town[14].

Impacts & vulnerabilities

The transport sector is responsible for more than half of the total energy use in Cape Town (54%); (with the flowing breackdown: petrol (68%) and diesel (32%)) and is the main contributor to local air pollution problems and responsible for about a third of Cape Town's total CO^2 emissions.

In the Cape Town Sea-Level Rise Assessment (2008) it is projected that in 25 years there is likely to be an 85% probability of 61 km^2 (2% of the metro area) being covered by sea for a short period. The estimated real estate loss is set at R20 billion. This will include transport infrastructure (CCT 2008), including the Cape Town harbour. The expected increase in frequency and intensity of storms is likely to impact on vessels at sea, berthing, loading and storage facilities for oil and gas. Storms have impacted upon transport systems in the past in low lying area such as the main road in Fish Hoek

[14] Fifa 2010 CCT.

that has experienced flooding. There has also been disruption of the public rail transport in this area as the tracks run within meters of the current high-tide mark and is expected to become increasingly affected by rising sea levels. Traffic congestion has been problematic in the past in areas where the transport systems such as roads have been affected by flooding (CCT 2008).

In addition there are a number of generic impacts on transport that have been reported that may concern the city of Cape Town. Heat waves can cause rail tracks to buckle (case study 1) and bitumen road surfaces to melt (case study 2). This requires maintenance and some research into exploring alternative road surfaces or bitumen types that won't melt. Any blockages in the transport network due to damage by rising sea-levels, floods, heat or sea storm surges will lead to livelihood losses, both at the time and after as cascade effects are felt throughout the economy of Cape Town. Access to medical facilities becomes compromised and the need for cooling and/or ventilation in public areas, public transport, domestic and commercial buildings will increase. If the need for cooling is not met in times of heat waves health risks will increase. As such a large proportion of Cape Town's population relies on public transport the need to ensure that this transport is cooled is important to prevent dehydration, sunstroke and other more serious health risks. Increased temperature can, after flooding events, cause subsidence of roads, which leads to greater maintenance costs and reduced efficiency in the transport network.

Table 2. Transport sector: Impacts and vulnerabilities associated with variability in temperature.

Impacts upon Transport	Impact on livelihoods
• Increased heat events cause damage to transport infrastructure such as melting of bitumen road surface, resulting in limited access to market and schools. • Affecting the transport of goods and commodities resulting in an increased amount of energy and investment required for cooling and insulation for the transport of fresh goods. • Public transport may be impacted upon by heat stress and discomfort on trains, busses and taxis. • Increased frequency of heat stress may lead to the requirement of an assessment for ventilation and cooling needs in the long-term.	• Overheating or freezing conditions may cause transport cancellations to and from locations, local, national or international • Transport blockages causing delays to work, markets that may result in food spoilage, reduced income, increased emergency situations • Extreme heat may reduce working hours and delay transportation of goods to destination

Case studies

1. Extreme temperatures of 40+°C caused standstill of the Connex suburban passenger rail service in Melbourne, **Australia**, when the rail system failed as tracks buckled and trains broke down for two consecutive days in January 2009. Temperatures reached 43.4°C, the highest maximum temperature since 2003. Rail commuters were forced to take alternative tram routes and replacement buses to

and from destinations. The heat wave caused cascade affects on alternative transport types as air-conditioning failures and overheating amplified further delays and cancellations (Ham 2009).

2. Virginia, **United States of America**, experienced extreme summer temperatures in 2010 when roads buckled as road bituminous, asphalt melted at temperatures of 66°C. During the summer months, asphalt and concrete absorb the heat during the entire day. The blacktop retains the heat until the summer sun sets and then it releases it slowly overnight. During the extreme heat, however, heat cannot be released and can cause a roadway to crumble (AAA-Mid-Atlantic, 2010).

5.4. Health

Background

Climate can affect human health in three ways (IPCC 2001). Firstly, there are direct health impacts that are usually caused by extreme weather events, such as flooding and heat waves. Secondly, processes of environmental change and ecological disruption that occur in response to climate change can have health consequences. And lastly there are those with diverse health consequences, including traumatic, infectious, nutritional, psychological and other, which occur in vulnerable populations in the wake of climate-induced economic dislocation and environmental decline.

The City of Cape Town Health Services includes both Environmental Health and Personal Primary Health Care Services. They are well integrated and delivered within the District Health System, which divides the City into eight decentralised sub-districts. Municipal Health Services include water quality monitoring, food control, waste management, health surveillance of premises, surveillance and prevention of communicable diseases, vector control and environmental pollution control. These services and infrastructure are likely to be impacted upon by changes in climatic patterns, which may lead to infrastructure failures leading to extreme shortages of basic social services and increased pollution from transport, water and electricity (CCT 2011).

Many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heat waves, to altered transmission of infectious diseases and malnutrition from crop failures. Climate change increases the range of tropical and sub-tropical infection bearing pests, such as malaria and dengue carrying mosquitoes (Lomborg 2004). In Cape Town the risks are highly likely to be from cholera and other water-borne diseases.

Impacts & vulnerabilities

Extreme heat can lead to immediate deaths (especially amongst children, the elderly and the infirm – case study 1), or physiological stress from dehydration. For marginalized communities the costs of climate control within their homes is likely to be prohibitive and thus heat stress may become a common health complaint and will impact negatively on livelihoods.

Insufficient research has been done to fully understand what health effects a change in temperature and rainfall would have in the Western Cape, although it is clear that air pollution is an appropriate initial focus. Warmer average temperatures combined with a change in precipitation can alter the pattern of exposure to temperature extremes and resultant health impacts, in both summer and winter. This has historically been a minor problem due to the frequency of the south-easterly winds in summer and frequent rain events in winter. However, the rapid growth of motor vehicle transport in the city has changed the spatial nature of the pollutants. Over 500,000 commuters from all over the Peninsula drive to and from work every day, either by bus or private vehicle emitting about 15,000 tons of industrial and domestic by-products into Cape Town's atmosphere every day (Wicking-Baird *et al.* 1997).

When the "brown haze" descends on Cape Town, which occurs often when there is a temperature inversion, the build-up of photochemical smog reduces visibility and exceeds accepted international standards for pollutants (Mukheiber *et al.* 2006). The climate projections of a reduced number of rainy days and increased number of days with a temperature inversion will increase the frequency of brown haze days (Shannon and Hewitson 1996). Of the pollutants, particulate matter poses the most serious health risk as it can penetrate deep into the lungs and has been linked to respiratory problems and cancer (Kinney 1999). Khayelitsha air has consistently exceeded guidelines during winter when inversion layers are more common. This is of particular importance for people living in informal housing, where there is little insulation and thus of particular importance in light of the Mamre project.

Flooding is a key concern in the Western Cape, because there are many vulnerable groups living on or near the poverty line and that are susceptible to flooding because of the high water table in the Cape Flats area. Flooding can also lead to immediate loss of human life. It is highly likely that flooding will continue and possibly increase in frequency, as rainfall is likely to become more intense but it is clear that the current disaster management system is not adequate. An increase in flooding would place an increased burden on flood response and the associated health stress. Food security is both directly and indirectly related to climate variability. It is particularly important that food security is monitored, given the numbers of HIV/AIDS infected people in the Western Cape that are more susceptible to malnutrition and opportunistic infections (Mukheibir *et al.* 2006). Flooding stresses sewage and storm-water systems leading to water pollution associated with excessive levels of micro-organisms and the subsequent increase in waterborne diseases that manifests as diarrhoea and dehydration (cholera and dysentery). This can be widespread and is especially dangerous to the elderly and children as symptoms can lead to death if there is not adequate health care. It is estimated that climate change was responsible for approximately 2.4% of worldwide diarrhoea in 2000 (WHO 2002). Malaria and dengue fever are linked to one of the most detectable changes in human health (WHO 2003). In the Western Cape this is not a key concern, although the range of malaria could spread southwards in future and should not be ignored. It should be noted that food-borne infections (e.g. salmonellosis) have been known to peak in warmer months.

Increased health impacts can affect the social system as increased mortality and increased deaths have a direct burden on the health system. And increased morbidity can impact on treatment costs (direct cost) and days of work lost (indirect cost) (Turpie *et al.* 2002). The value of the loss of human life is hard to quantify, but impacts at many levels. An increase in disease associated with climate change can therefore have widespread economic and health costs.

Some of the general impacts associated with extreme heat on health and livelihoods (Table 3) show how important the link between health and livelihoods are, particularly when an extended household may only have a single breadwinner as is often the case where HIV/AIDS has impacted on a family.

Table 3. Health sector: Impacts and vulnerabilities associated with variability in temperature.

Impacts upon Health	Impact on livelihoods
• Increased temperatures causes discomfort. • Extreme heat events causes dizziness, heat stress and illnesses. • Heat may have an impact upon the rate of infection of certain diseases and the distribution of disease vectors. • Increased temperatures increases vulnerability of individuals, especially young and elderly whom have less ability to cope with extreme conditions. • Individuals with compromised immune-systems may be extremely vulnerable to heat further depressing immune-system functioning and allowing for opportunistic infections, particularly of air pollution is high in association with the heat. • Variability in temperature is a particular health risk as vulnerable individuals are more sensitive and less resilient to extreme heat and/or coldness.	• Increased temperatures cause heat stress, discomfort and illnesses that all impact upon the quality of livelihoods and the ability to function to the fullest. • If a workforce is compromised by heat, work hours would be reduced and production would decrease. If workers are not on permanent contracts, which is becoming an increasing problem as employees seek to circumvent labour laws, they will lose pay when heat shuts down production.

Case studies

1. Extreme heat conditions, particularly heat waves pose serious health risks specifically in densely populated urban areas where the 'heat island' and air pollution amplifies the condition and severity of the situation. In the summer of 2010, Rio Janeiro in **Brazil** experienced the worst heat wave in 50 years, which killed at least 32 people as temperatures reached 40 to 50 degrees Celsius. The majority of the victims who perished were between the ages of 65 and 90 (Moran 2010).

2. It is not just heat waves that are a problem with climate change; extreme cold weather events are occurring too. In Iowa, **USA**, temperatures are 30 degrees below normal making a near-record low. Beijing, **China**, is facing the coldest temperatures in decades and in Pichccahuasi, **Peru**, bitter cold may cause the extinction of communities of alpaca farmers suffering from pneumonia and other respiratory problems (Seymour 2010).

5.5. Energy

Background

The city of Cape Town has six main energy demand sectors; residential, industry, commercial buildings, government buildings and transport. The energy-use profile is dominated (89%) by petrol, electricity and diesel, the remainder; paraffin, liquid petroleum gas (LPG), coal, heavy furnace oil and wood. The transport sector is responsible for over half of total energy use, followed by industry and commerce, and households. Cape Town's transport system is becoming increasingly inefficient, with under-resourced public transport and a steady growth in private vehicle numbers, and associated road congestion (CCT 2006). A clear vision for the future is seen the acknowledgement that while the City of Cape Town local authority consumes a relatively small portion of total, as a single large user and large employer (25 000 employees), it has the power to implement programmes that have a significant impact on its energy consumption, as well as setting an important example.

Cape Town does have heavy industry but its economy is not as energy-intensive as other parts of the country where heavy industry is more evident. Almost 70% of this sector's energy needs are met by electricity. The City of Cape Town generates very little of its own electricity; the vast majority is purchased from the national Eskom electricity grid. Around 95% of the national grid electricity is coal-generated, about 5% comes from nuclear and small amounts from hydropower. Although Koeberg nuclear plant located just north of Cape Town could meet almost all of the city's electricity needs, it is however, not dedicated for Cape Town use but is part of the national grid (CCT 2006).

The city has developed an Energy and Climate Change Strategy to integrate sustainable energy approaches into its core functions, with a framework that provides a clear vision and direction for the city as a whole in response to the potential short- to medium-term impacts of climate change in the Cape metropolitan area (Muikheiber *et al.* 2006) and this leads to a City Adaptation Plan of Action (CAPA) for the City of Cape Town so that necessary resources can be mobilised to ensure implementation (CCT 2010).

As more pressure is put onto the Cape Town grid system with increasing populations and associated developments will the city be able to meet demand when an increased need for heating and cooling in both domestic and industrial sectors becomes necessary with climate change?

Impacts & vulnerabilities

The large numbers (approximately 240,000) of poor households need a special strategic focus, as conventional market-driven supply systems do not effectively meet their needs because of their low spending power and they suffer energy-related problems such as shack fires, paraffin poisoning, poor indoor and outdoor air quality. This is something that the approximately 530,000 mid-to-high income households don't experience but have a much bigger environmental 'footprint' as a result of their higher (and 'easier') energy consumption (CCT 2006).

There are many impacts of climate change and rising temperatures that will affect the energy sector and its ability to meet its mandate of adequate and affordable energy provision (summarised in Table 4). As temperatures rise, the need for cooling will increase makes increased demands on the energy supply network (see case studies 1 & 2). The ESKOM grid for Cape Town already requires careful management during winter when heating requirements strain the supply flow.

Table 4. Energy sector: Impacts and vulnerabilities associated with variability in temperature.

Impacts upon Energy	Impact on livelihoods

• Increasing the use of energy for cooling in homes, businesses and other buildings and during the transportation of fresh good and the comfort of passengers in public transport.
• Increase demand for electricity.
• Knock on affects on other sectors such as:
  • Increased demand for health services;
  • reduced transportation if rail services malfunction;
  • road chaos if traffic lights cease to function.
	• Illness or death due to heat
	• Spoilage of food if no generator system is in place
	• Increased costs associated with increased power usage
	• Power cuts may lead to reduced working hours that limits income to both the employer and employee
	• Reduced power limits transportation options and thus productivity

Case studies

1. Increased temperatures and extreme heat wave events increase the demand for energy supply and cooling technologies. Warm temperatures increase the evaporation rates and cause low water levels reducing hydropower reservoir capacities. Prolonged heat waves also cause electricity overloads and breakdowns in the electricity network and power plants. On the west coast of **United States of America**, 11,000 residents in Los Angeles lost power as a result of a heat wave in September 2010 (BBC News 2010).

2. When temperatures soared to above 40 ^{o}C in Melbourne, **Australia** in January 2010, 44,000 homes were short of power, while the city was also experiencing the driest spell since 1955, lasting 40 days without rain (World News Australia 2009). Peak power demand in southern Australia surged to a record 3,300mw and increased to marginally higher demands as demand climbed in Adelaide due to 40^{o}C for four consecutive days. During the heat wave it was reported that private energy companies in Victoria, with the government's backing, would install "smart meters", which place a new Aus$ 2 per kilowatt/hour charge on energy used during days when the grid is under pressure. Running an average air conditioning unit during the six hottest hours of the day would cost Aus$ 78 per day. Such exorbitant charges could well lead to more deaths, as people shut off their cooling systems because they would not afford to pay such costs to keep cool.

6. Conclusion

The severe physical, social, environmental and economic impacts of climate change, both directly and indirectly, are anticipated to be felt with greater intensity in the cities of Africa. A changing climate will affect people's access to, and the quality of, basic goods and services such as water, shelter and food as well as other key priorities for human wellbeing such as education, employment and health. Africa is particularly vulnerable as the situation is aggravated by the interactions of 'multiple stresses'. These 'multiple stresses' include endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts. These heavily reduce Africa's adaptive capacity (IPCC 2007).

Even South Africa, which is considered wealthy by African standards is no exception, and Cape Town will be affected by the impacts associated with rising mean temperatures, in conjunction with rising sea levels. Cape Town has already observed some increase in sea-level and flooding and it is projected that these outcomes will intensify with time, regardless of global mitigation efforts. Significant warming trends are already evident for particular seasons over the Western Cape; and significant temperature increases are evident in the records for minimum and maximum temperature. Projected for Cape Town's future are:

- increasing temperatures;
- drier conditions in both seasons;
- rainfall intensity increasing, but not necessarily implying an increase in total rainfall and;
- greater evaporation rates increasing drought incidence and intensity possibly even in regions where total rainfall increases.

The impacts of a warmer, drier Cape Town are significant on all sectors of service provision (see section 5 and Table 5 for a summary). Salt water intrusions to the ground water supply will affect water quality and the quantity of potable water available for domestic and industrial use. Heat waves will have health impacts and associated productivity declines. Heat waves will create a greater energy demand as cooling in houses and commercial premises becomes necessary and fire risk increases. More fires experienced equates to more lives at risk and more vegetation destruction.

These and other impacts that have been discussed are likely to mean, that for an average Capetonian, if the city is unable to adequately meet its mandate of basic service provision, a decrease in quality of life and ability to make a living will be experienced. Already the city is shown to be unable to meet the needs of some sectors, particularly the burgeoning informal settlements and it means that these people will be most vulnerable to the changing climate.

It is important to make plans now to ensure as much resilience as possible to prevent major catastrophe and to allow local government sectors to continue to meet their mandate of basic service provision and thus allow the inhabitants of this port town to continue to make the best livelihoods they can, and to improve their opportunities. Besides mitigating and reducing emission and energy, adaptation is a vital component in order to prepare and increase resilience towards the risks and impacts. Cape Town local authorities need to adapt and plan strategically to build resilience against climate change specifically to variability and extreme cases of temperature. There is a need for adaptation strategies and preparedness in protecting local communities and the environment on which they depend upon for their livelihoods and well-being.

In an IIED 2007 report it was highlighted that strengthening, protecting and adapting the assets and capabilities of individuals, households and communities is far more important in low- and middle-income countries than in high-income countries, because of the following:

- The limitations in urban governments' adaptive capacity, especially in providing needed protective infrastructure and services to low-income populations.
- The unwillingness of many city or municipal governments to work with low-income groups, especially those living in informal settlements, which usually include those most at risk from floods and storms.
- The key role of assets in helping households and communities to cope with disasters.

Adaptive capacity relates to the ability of households and community organizations to make demands on local governments and, wherever possible, to work in partnership with them (Moser and Satterthwaite 2008).

This report on Cape Town focused specifically on impacts and vulnerabilities associated with extreme temperatures and is one of a suite of five reports. The other reports deal with sea level rise (Walvis Bay), drought (Dar es Salaam), flooding (Maputo) and tropical cyclones (Port Louis). These baseline studies and literature reviews will, when combined with the findings of the ICLEI Tadross and Johnston (2011) report: *Projected climate change over southern Africa; Mauritius, Mozambique, Namibia, South Africa and Tanzania*, GIS modelling and cost-benefit analysis, form the Risk Assessment. This will then form the basis from which the adaptation framework for the city will be developed. With this framework the city will be better able to better plan for future development and be better prepared for any climate-related crises. This is best done through participatory action at the local level via government, researchers and communities and in this regard Cape Town can lead the way for South Africa.

Table 5. General impacts associated with climate change related to increased temperatures upon municipal sectors (Fairhurst 2009).

Water and sanitation	• Evaporation is anticipated to alter the availability of fresh water resources, groundwater and aquifers thus affecting water supply available for drinking and irrigation purposes and thus food security. • Increase pressure and demand for water for drinking and for irrigation purposes. • Increase the range and or distribution of waterborne diseases such as cholera or malaria that could result in severe pressure on sanitation and the health sector. • Impacts on aquatic ecosystem and water quality.

	• Algal blooms are likely to become more frequent and start occurring in bulk water storage facilities.
	• The waste water treatment facilities are likely to experience some infrastructure heave and subsidence with changes in soil moisture contents.
	• Reduced water availability of water from aquifers.
	• Increased temperatures, associated evaporation rates and the anticipated drying effects are likely to impact the storm water sector by:
	  ○ Changing base or low and peak river flow that may result in the reduced health of the waterways.
	  ○ Increasing erosion and sand particles being blown into the system – exacerbating present blockage problems.

Transport	• Exacerbate air pollution caused by the transport sector • In the short term, minimal impacts on pavements and structural design are anticipated. In the longer term, higher temperatures may have significant impacts such as rutting on bridges, roads and tail buckling. • Thermal expansion in excess of current designs of transport infrastructure and could therefore lead to damage of infrastructure, increasing safety risks and the need for maintenance operations and upgrades / new designs. • It is probable that construction rates will be impacted upon by increasing temperatures i.e. concrete strength, which is affected by the temperature with which it cures. • Increased need for the use of energy for cooling during the transportation of fresh goods and the comfort of passengers in public transport.
Health	• An increase in the frequency and duration of severe heat waves and humid conditions during summer is likely to increase morbidity and mortality particularly in the young, elderly and sick. • Increased geographical distribution of vectors; food and waterborne disease (i.e. malaria, dengue fever, cholera)
Energy	• Increasing the use of energy for cooling in homes, businesses and other buildings and during the transportation of fresh good and the comfort of passengers in public transport.
Livelihoods	• Increased temperature, in association of dryer conditions and wind, may increase the incidence of wildfire threats. • Temperature increases affect housing, i.e. in high density informal settlements may exacerbate "heat island effect" also the poor construction for passive cooling in dwellings may cause significant discomfort or deaths (health risks: i.e. stroke / dehydration). • Hotter weather may affect crop-yields, ecosystem distribution and species range. This may lead to a decline in food security and / or production may be reduced. • Food stored is likely to spoil quicker, resulting in potential hygiene risks. • Cost of keeping livestock and domestic animals may increase as the need for more water and cooling may increase. • Impacts on viability of other livelihood activities (i.e. forest and agricultural production) Increase of urban food prices as a result of increases in production costs.

7. Glossary

Anthropogenic changes: Human activities that change the environment.

Adaptation: In natural or human systems adaptation is a response to actual or expected stimuli, e.g., climate change or their effects, which moderates harm or exploits beneficial opportunities. In natural systems adaptation is reactive. In human systems adaptation can be both anticipatory and reactive and can be implemented by public, i.e., government bodies at all levels and private actors, i.e., individuals, households, communities, commercial companies and NGOs.

Adaptive capacity: It is the ability of people and systems to adjust to environmental change, e.g., by individual or collective coping strategies for the reduction and mitigation of risks or by changes in practices, processes or structures of systems. It is related to general levels of sustainable development such as political stability, material and economic well-being, and human, institutional and social capital.

El Nińo-Southern Oscillation (ENSO): The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with a basin wide warming of the tropical Pacific east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as El Niño-Southern Oscillation, or ENSO. It is often measured by the surface pressure anomaly difference between Darwin and Tahiti and the sea surface temperatures in the central and eastern equatorial Pacific. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world, through global tele-connections. The cold phase of ENSO is called La Niña.

Resilience: Amount of change the exposed people, places and ecosystems can undergo without permanently changing states. That is, their ability to recover from the stress and to buffer themselves against and adapt to future stresses and perturbations.

Sensitivity: The degree to which people, places and ecosystems are affected by the stress, including their capacity to anticipate and cope with the stress. The effect may be direct or indirect.

Subsistence: The action or fact of maintaining or supporting oneself at a minimum level.

Vulnerability: Vulnerability is the degree to which a system or unit (such as a human group or a place) is likely to experience harm due to exposure to risk, hazards, shocks or stresses. In relation to the concept of poverty, vulnerability is more dynamic since it captures the sense that people move in and out of poverty.

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