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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:
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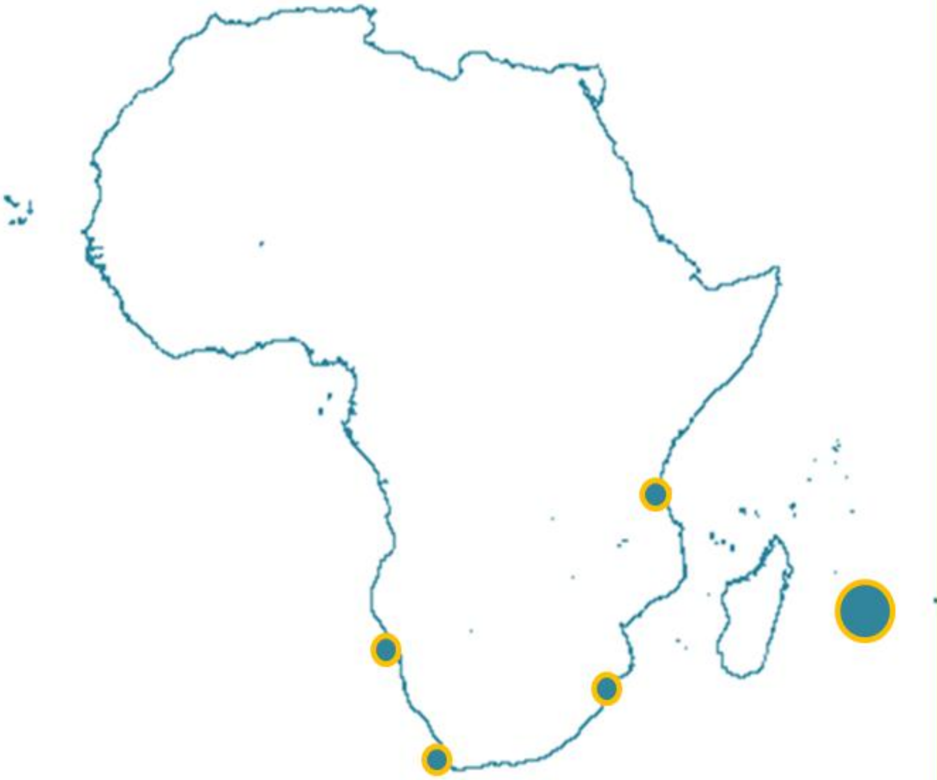
Baseline Study



Port Louis

ICLEI Local Governments for Sustainability

CITIES ADAPT

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

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Contents

List of Acronyms

AAP	Africa Adaptation Programme
CCAA	Climate Change Adaptation in Africa
CEB	Central Electricity Board
CWA	Central Water Authority
DFID	Department for International Development
ENSO	El Nino Southern Oscillation (see Glossary)
EPA	Environment Protection Act
IDRC	International Development Research Council
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
MENDUM	Ministry of Environment and National Development Unit Mauritius
NEAP	National Environmental Action Plan
NEP	National Environment Policy
SST	Sea Surface Temperature
SIDS	Small Island Developing States
SWIO	South West Indian Ocean
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation

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 (2007a) concurs 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 – Local Government for Sustainability - Africa**[1] –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 infrastructures that fall within their jurisdiction. The first step is to identify the impacts and risks associated with climate change variability and thus inform decisions that will lead toward the identification of mechanisms that increase adaptive capacity and climate preparedness for 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.

The focus of this report is **Port Louis**, the capital city of Mauritius, a small island in the Indian Ocean. In the IPCC 4th Assessment report (2007) small islands were described as highly vulnerable to climatic change. Modelling has shown that in a future with a warmer climate, cyclones will show increased peak wind speeds along with mean and peak precipitation intensities (IPCC 2007). Port Louis, located on the western coastal zone of Mauritius, is exposed to high intensity storms associated with cyclones originating in the warm Pacific Ocean. These storms are known to produce sea storm-surges, flooding, coastal erosion and direct and indirect damage to infrastructure, services and property.

The first section of this report will provide an overview of potential impacts of climatic changes in Africa, and then in particular the Indian Ocean with regard to global sea surface temperatures (changes in wind speed associated with changes in frequency, magnitude and intensity of cyclones). The report will then look at a finer scale at first a regional (focusing on Mauritius) and then a local level; Port Louis (Figure 1). Here, particular attention will be paid to potential risks and impacts upon the infrastructure and services that fall under the municipality's jurisdiction in relation to variability in wind speed.

Figure 1. Study focus area – Port Louis, Mauritius[2].

2. Africa: climate change and changes in wind speed

Africa, covering more than one fifth of the total land area of earth, is the second largest continent and host to one billion people (UN 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, 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 (2000), 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

[2] GoogleEarth for Port Louis sat image, www.theodora.com for globe map and www.blackhorns.net/photography-blog/uploaded_images/060330_map-724086.jpg for Mauritius map.

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 (2007a) 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 2007b).

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 2007a).

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 2007a).

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 (Figure 2). 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 20% 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 2007a). Local food supplies are projected to be negatively affected by decreasing fisheries resources in large lakes due to rising water temperatures, which may be exacerbated by continued overfishing (IPCC 2007a).

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.

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 are likely to depend more upon changes in the frequency 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. The cost of adaptation in Africa could amount to at least 5-10% of GDP (IPCC 2007a).

Tropical cyclones and associated winds facing Mauritius

The project city Port Louis, capital of the island Mauritius, is situated in the South West Indian Ocean (SWIO), an area that already experiences increased frequency and intensity of tropical cyclones. The Indian Ocean, covers about 20% of the water on the Earth's surface, is the third largest and the warmest ocean in the world (Figure 2).

Figure 2. The extent of the Indian Ocean[3].

Tropical cyclones are, depending on their location and strength, known by various terms: hurricane, typhoon, tropical storm, cyclonic storm, and tropical depression. Tropical cyclones are low-pressure weather systems that develop over the warm waters of the oceans, typically between the latitudes

[3] www.skaubryn.webs.com.

of 30°N and 30°S. Cyclonic storms with wind speeds surpassing 118 kph are termed tropical cyclones (Keim 2006). Tropical cyclones in Mauritius usually occur in summer months which span from November to May (MENDUM 2010). They usually develop above the ocean some 2,000 km northeast of Mauritius. Water temperatures of more than 26°C are required as water condenses very quickly at high temperatures, causing large clouds to form. The rotation of the earth causes the clouds to spin, and they are driven westward by the trade winds.

Tropical cyclones (such as Cyclone Anja, Figure 3) are always accompanied by torrential rain. A single storm may yield up to 3,000 mm of rain and may give rise to floods. Heavy rains sometimes occur for many days after landfall and are also very destructive. As a result of the steep pressure gradient, strong winds occur. The wind speed rises rapidly from nearly zero in the eye to its maximum value at a radius between 10 and 100 km from the centre. The strongest winds occur near the leading edge ("in front") of the storm.

The destruction associated with tropical cyclones results not only from the force of the wind, but also from the storm surge and the waves it generates. The storm surge is experienced as a rapid rise of sea level near that portion of the eye wall associated with onshore winds, sometimes reaching a height of more than 6 metres and accompanied by very large wind-driven waves. Much of the death toll in tropical cyclones is due to the storm surge. The net result of the raised sea level, strong winds and torrential rains is to inflict severe damage on coastlines affected by the storm, especially those which are low-lying (SAWS 2010).

Whether the characteristics of tropical cyclones have changed or will change in a warming climate — and if so, how — has been the subject of considerable investigation, often with conflicting results. Large amplitude fluctuations in the frequency and intensity of tropical cyclones greatly complicate both the detection of long-term trends and their attribution to rising levels of atmospheric greenhouse gases. Trend detection is further impeded by substantial limitations in the availability and quality of global historical records of tropical cyclones. Therefore, it remains uncertain whether past changes in tropical cyclone activity have exceeded the variability expected from natural causes. However, future projections indicate that the globally averaged intensity of tropical cyclones will shift towards stronger storms, with intensity increases of 2–11% by 2100. Existing modelling studies also consistently project decreases in the globally averaged frequency of tropical cyclones, by 6–34%. Balanced against this, higher resolution modelling studies typically project substantial increases in the frequency of the most intense cyclones, and increases of the order of 20% in the precipitation rate within 100 km of the storm centre. For all cyclone parameters, projected changes for individual basins show large variations between different modelling studies (Knutson *et al* 2010).

Two basic factors drive the intensification of tropical cyclones: sea surface temperatures and moisture content of the environment of the storm. Both of these factors have been observed to increase with enhanced warming of the earth's atmosphere (IPCC 2007). For Mauritius, data (MSM 2010°) does not show any increase in the number of storms in the SWIO tropical cyclone basin. However, a plot of the number of storm formations over the last 32 years (1975-2008) clearly shows an increasing trend in the number of storms reaching tropical cyclone strength (winds above 165 km/hr). Furthermore, since the last decade observations indicate rapid or even explosive intensification of tropical storms.

Figure 3. Cyclone Anja: a medium-sized cyclone with tropical storm-force winds extending out to 100 miles from its centre, and cyclone-force winds out to 45 miles from its centre. Anja generated waves as high as 24 feet but did not threaten any land masses[4].

Although an increase in frequency is debated, a mean sea-level rise is no longer debated and the consequence of this on the extent that storm surges will create disaster remains. The impacts of tropical cyclones are (Fairhurst 2009):

- impacts on coastal habitats;
- coastal infrastructural damage such as destruction, damage and disturbance to harbours, jetties, boat ramps and beachfront promenades and service infrastructure such as roads, storm water outlets, electrical substations, main water pipes;
- increased salt water intrusion and raised groundwater along the coast;
- potential tourism loss resulting in damage to infrastructure and loss of beaches; and
- loss of coastal wetlands resulting from saline inundation, increased erosion and landslides.

There appears to be a consensus that 'increased storminess' is likely under climate change, this in turn could take the form of strong winds and/or heavy rainfall. If, as a result of climate change, winds become only 10% stronger, then wave height increases by 26%, and coastal sediment transport rates potentially increase by 40% to 100%. The increase in storm activity and severity is likely to be the most visible impact and the first to be noticed. For example, higher sea level will

[4] http://leah-newman.blogspot.com.

require smaller storm events to overtop existing storm protection measures (Theron and Rossouw 2009).

3. Legislation and international obligations

National context – Mauritius' environmental sustainability strategies

Mauritius has realized its vulnerability in the face of global climate changes and was the first country in the world to sign the **United Nations Framework Convention on Climate change (UNFCCC)** on 10 June 1992 and acceded to the Kyoto Protocol on 9 May 2001 (MENDUM 2010).

Some of the main policy achievements (Rajoo 2010) for managing Mauritius sustainably are:

2000 - **National Environmental Action Plan II** (NEAP II) and **Initial National Communication** for the UNFCCC.

2002 - **The Environment Protection Act (EPA)** which provides for the protection and management of the environmental assets of Mauritius so that their capacity to sustain the society and its development remains unimpaired. To foster harmony between quality of life, environmental protection and sustainable development for the present and future generations; more specifically to provide for the legal framework and the mechanism to protect the natural environment, to plan for environmental management and to coordinate the inter-relations of environmental issues, and to ensure the proper implementation of governmental policies and enforcement provisions necessary for the protection of human health and the environment of Mauritius.

2004 - **Planning and Development Act** provides for the preparation, adaptation, maintenance and regular review of a National Development Strategy, which shall "*consist of plans, policies and guidelines with mechanisms for their implementation, which aim at creating and stimulating investments in the public and private sectors so that economic growth and social development in relation to land development can be undertaken in a sustainable and equitable manner, so as to maintain and enhance the natural and built environment*". As a result of this, the Republic of Mauritius has implemented a National Development Strategy that came into effect in 2005.

2005 - **The Mauritius Declaration and the Mauritius Strategy** for the further implementation of the Programme of Action for the Sustainable Development of Small Island Developing States (SIDS): the new definitive documents for implementing sustainable development in SIDS.

2006 - **Environment Protection (Waste Oil) Regulations & Undersized Fish Regulations**; **Fisheries and Marine Resources Act**.

2007 - **Vallee D'Osterlog Endemic Garden Foundation Act (Act No. 19).**

2007 - **National Environment Policy (NEP)** establishes a clear policy framework and sets appropriate environmental objectives and strategies. It is based on a review of key environmental issues, challenges and opportunities that are specific to Mauritius' national context and it sets a policy framework under which the republic aims to mainstream environmental considerations in all development programmes and projects. The goal of this environmental policy is therefore two-fold - it will help in the management of the ecosystems which supports the economic growth of the country and contribute towards the improvement of the quality of life of the Mauritian population. This policy is implemented mainly through the revised National Environment Strategy and Action Plan detailing strategies and action plans and setting time-frames and targets (MENDUM 2007).

2008 - **Environment Protection Amendment Act 2008 (no 6).**

2008 – **'Maurice Ile Durable' Programme** - climate change activities in the Republic have been consistent towards sustainable development goals. The concept of a sustainable island is clearly defined in the "Maurice Ile Durable" programme. Since then both public and private sectors are making efforts to integrate climate change in new developments strategies – specifically increasing reliance on renewable energy, while aiming to decrease importation and so reduce use of non-renewable fossil fuels.

2010 - **Mauritius Strategy for Implementation / National Assessment Report -** In this document, climate change and environmental challenges are discussed as central themes for the future development of Mauritius (MENDUM 2010).

2010 – The **Africa Adaptation Programme** (AAP) is a twenty-country programme implemented by the United Nations Development Programme (UNDP). Mauritius is one of the twenty programme countries. It aims to mainstream climate change adaptation into the institutional framework, including core development policies, strategies and plans. This is hoped will enhance the adaptive capacity to climate change risks, promote early adaptation through evidence based solutions and initiatives for action and lay the foundation for long-term investment to increase resilience to climate change across the African continent.

The following also have relevance when examining general resilience and ecosystem health:

1970 - **Continental Shelf Act.**

1983 - **The Forests and Reserves Act.**

1993 - **Wildlife and National Park Act.**

1998 - **Fisheries and Marine Resources Act.**

Local Context – Port Louis' environmental sustainability strategies

There is limited literature available about Port Louis specifically. There is however strong political will to further enhance the existing policies in order to develop resilience to adverse impacts of climate change and to ensure the achievement of sustainable development goals within Mauritius structures and laws (MSM 2010).

4. Small Islands like Mauritius and vulnerabilities

Small Islands

Small islands, by virtue of being small land masses surrounded by ocean, are highly vulnerable to natural disasters, often of a climatic or geological nature. Tropical islands are often largely populated areas, with high growth rates and densities. Many small islands have poorly developed infrastructure and by nature of their boundaries have limited natural, human and economic resources. In addition they are highly dependent on marine resources to meet their protein needs. They are vulnerable to external forces, such as changing terms of trade, economic liberalisation, and migration flow and as a consequence their ability to adapt to global climate change is generally low, though traditionally there has been some resilience in the fact of environmental change (IPCC 2007). The present and future detrimental impacts of climate change on Small Island Developing States (SIDS) are established facts, and the situation seems to be irreversible for a number of SIDS with topographies just above sea level (MENDUM 2010).

Evidence pertaining to projected changes in wind intensity, magnitude and direction is not certain, however, climatic models do indicate that with warmer atmospheric temperatures, cyclones will show an increase in peak wind speeds and increased mean precipitation intensities (IPCC 2007). Furthermore, wind intensities are likely to increase 5-10% by 2050 (Walsh 2004).

Mauritius and its vulnerabilities

The Republic of Mauritius is one of these small island nations which include the islands of St. Brandon, Rodrigues and the Agalega Islands in the Indian Ocean (Fig. 4). These islands are located east of the Madagascar mainland and are clustered together with other small islands (Seychelles, St Brandon, and Reunion) which form part of the Mascarene Island group. The Mascarene Islands also include Cargados Carajos shoals and three now submerged islands: the Saya de Malha, Nazareth and Soudan banks. The island of Mauritius, with an area of only 2,040 km², has a population of 1,277,851 (CSO 2009).

From a supported mono-crop economy, predominantly dependent on sugar cane, with a burgeoning population and massive unemployment, Mauritius successfully diversified its economic activities by carving out special niches in textile, tourism and financial services. Whilst the share of agriculture in the economy dropped from 3.2% in 2005 to 1.7% in 2009, and textile from 6.7% to 5.3%, that of financial intermediation increased from 10.3% to 11.7% (NAR 2010). Mauritius is now classified as a middle income country and ranks, on the basis of the Human Development Index for 173 countries, 67th globally, 40th among developing countries and second in Africa (Government of Mauritius, 2005). However, the recent recession resulted in increasing unemployment from the textile sector as global business decreased as well as a 20% decrease in tourism.

Mauritius has a mild maritime climate with annual mean temperatures of about 22°C, and a mean annual duration of sunshine of between 7 and 8 hours daily. Mauritius only experiences two seasons: summer from November to April (warm and wet) and winter from May to October (cool and dry) (AMAS 1997). Although precipitation occurs throughout the year, it is most common during the summer when tropical cyclones bring heavy rain and strong winds.

The spatial distribution of these rainfall events is highly influenced by the south easterly trade winds and by the islands' topography. In the north and northwest portions of the island, it is relatively drier than in the south and southeast because the area is less exposed to the south east trade winds. It is also sheltered by the mountain belts that circle the central plateau. These mountain belts force air parcels to discharge their water in the south and central plateau before descending upon these areas.

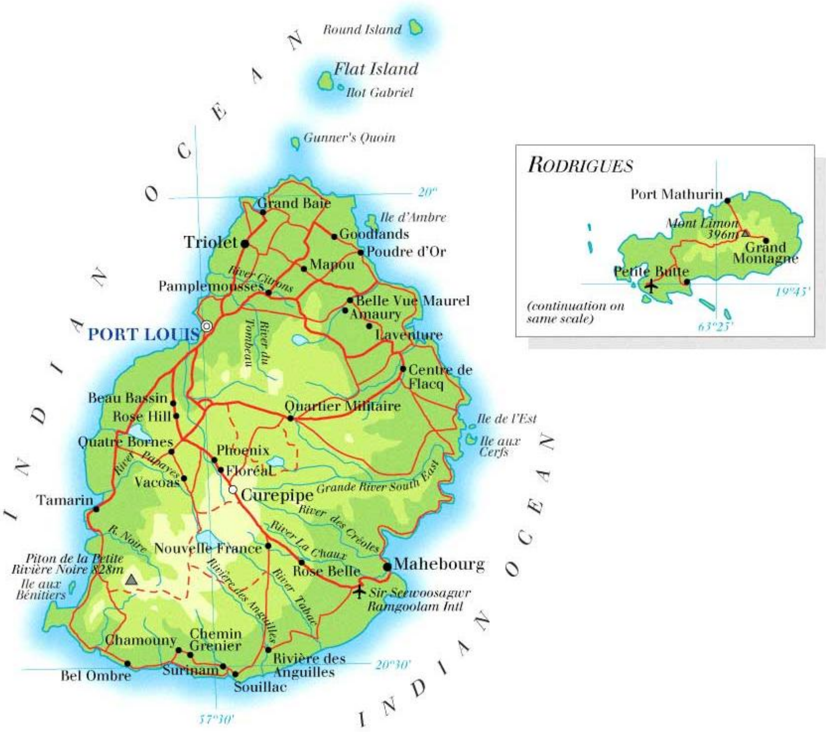

Figure 4. Map of Mauritius and surrounding islands[5].

[5] http://en.18dao.net/Map/Mauritius.

Typical average annual rainfall values are as follows: 900 mm in the north-western coastal area, 4,000 mm in the central plateau and 1,300 mm in the south-eastern coastal areas. Port Louis which is situated in the mid northwest portion of the island has an average annual temperature of 23°C and an average annual rainfall value of 1,719 mm (UGD 2010).

Variations in both the intensity and timing of the movements of the Inter-Tropical Convergence Zone (ITCZ), from one year to the next, cause inter-annual variation in the wet season rainfall. The most well documented cause of this variability is the El Niño Southern Oscillation (ENSO) which causes warmer and drier than average conditions in the wet season of Eastern Africa in its warm phase (El Niño) and relatively cold and wet conditions in its cold phase (La Niña). During the wet and warm, season the islands of Mauritius experience tropical cyclones and hurricanes (Sweeney *et al*. 2008) and as a consequence Mauritius and its surrounding islands are often affected by extreme weather. The cyclones, tidal surges and torrential rains commonly cause flash floods and landslides (MENDUM 2010). Whenever a cyclone comes within a 100 km of Mauritius, wind gusts of the order of 120 km/h or more are likely to be experienced and are often accompanied by heavy rains (MENDUM 2010).

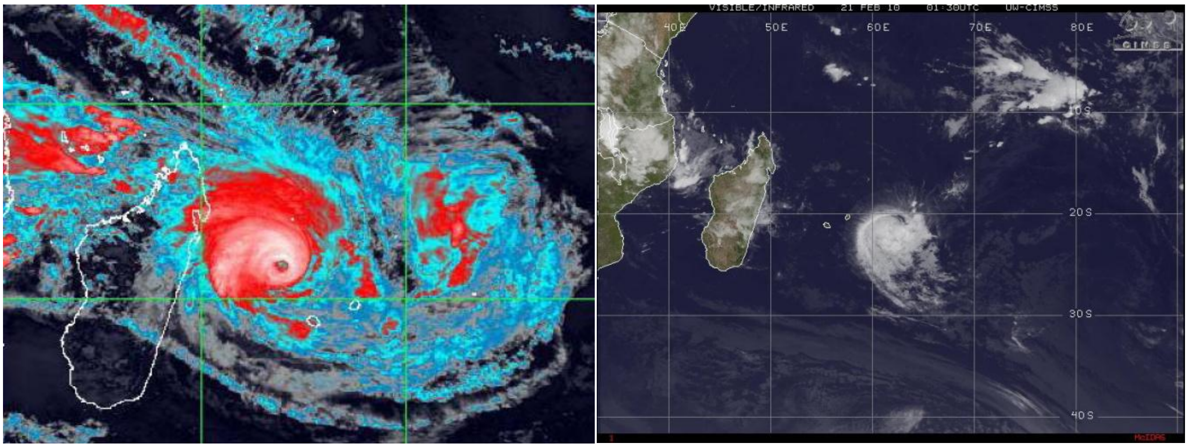

Figure 5. a) Intense Tropical Cyclone Gamede on 25 February 2007, Mauritius[6] and b) Tropical Cyclone Gelane fading on Mauritius on 20 February 2010[7].

[6] Source: Natural Disasters affecting the Republic of Mauritius. Meteorological Services, 2009; in: Ministry of Environment and National Development Unit Mauritius, 2010.
[7] Source: http://www.google.co.za/imgres?imgurl=http://feww.files.wordpress.com/2010/02/gelanr-final.png .&imgrefurl=http://feww.wordpress.com/tag/indian-ocean/.

Figure 6. a) Flooding and b) Broken bridge on the Saint-Étienne River.

Observed trends

In Mauritius, meteorological records indicate that the average **temperatures** are increasing, mean sea level is rising and intermittent heavy rainfalls are causing flash floods, which deviate from past patterns. Analyses of the temperatures recorded within Mauritius and its outer islands show a definite warming trend. Average temperature at all stations show an average ascending rate of 0.15°C per decade and has risen by 0.74 – 1.2°C when compared to the 1961-1990 long term mean. Similar warming trends have also been observed within the surrounding islands of Rodrigues, St Brandon and Agalega (MENDUM 2010). There is insufficient daily temperature data available from which to determine trends in daily temperature extremes (Sweeney *et al*. 2008).

The large inter-annual and inter-decadal variations in **rainfall** in this part of the world mean that it is difficult to identify long term trends. Whilst there is no evident trend in annual rainfall, annual rainfall has decreased over the period 1960-2006, at an average rate of 7.7 mm per month (8.7%) per decade. There are insufficient daily rainfall observations available to identify trends in daily rainfall extremes (Sweeney *et al*. 2008). A lengthening of the intermediate dry season, the transition period between winter and summer, has been observed. There has been a shift in the start of the summer rains. This shift in the onset of the rains has a tremendous impact on various economic sectors, as it translates into much pressure on the water sector to meet increasing demands of agricultural, tourism, industry and domestic requirements. The number of consecutive dry days is increasing while the number of rainy days is decreasing. Even though the number of rainy days is decreasing, heavy rainfall events leading to numerous flash floods and temporary interruption of certain socio-economic activities during the summer months of February and March has increased. The **frequency** and intensity of extreme weather events, heavy rains and storms of tropical cyclone strength or higher, has increased substantially over the last two decades (MSM 2010).

In the South West Indian Ocean (SWIO) an increased rate of **intensification** of tropical cyclones was observed likely as a result of changes in sea surface temperature as a result of increased global temperatures. The intensification of tropical cyclones is affected by the sea surface temperature and the moisture content of the environment of the storm. For example, the summer 2008-2009 experienced abnormally high sea surface temperatures in SWIO, however, analysis of climatic data from Mauritius Meteorological Services (Figure 7) does not show any increase in the number of storms in the SWIO. A decadal plot of the number of storm formations over the last 32 years (1975-2008) does show an increasing trend in the number of intense cyclones (winds above 165 km/hr). Since the last decade, observation indicates rapid or even explosive intensification of tropical storms (Figure7, MSM 2009).

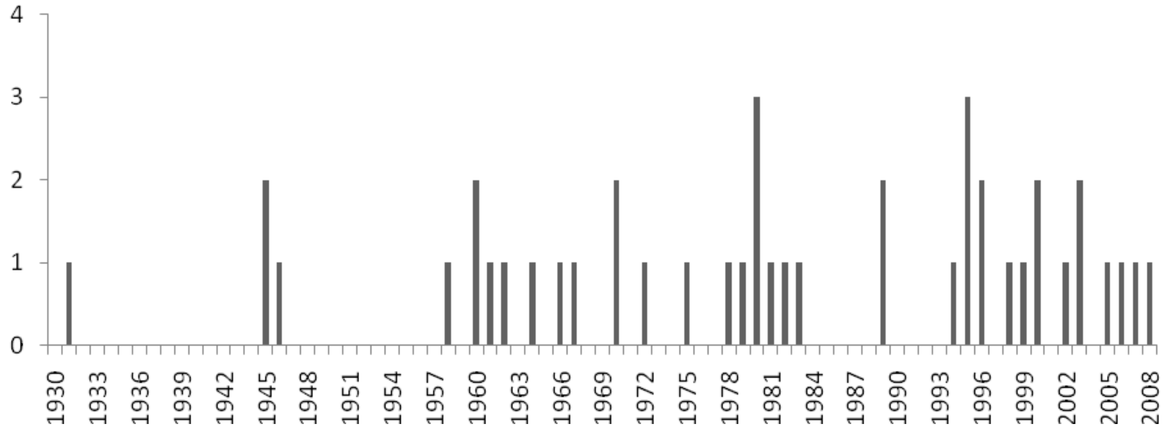

Figure 7. Major tropical cyclones that have affected Mauritius since the early 1930's till 2009, the x-axis representing the number per year[8].

Projections

Land Temperature: The mean annual temperature is projected to increase by 1.0 to 2.0°C by the 2060s, and 1.1 to 3.4°C by the 2090s. The upward trend by the 2090s under any scenario is 1.0-1.5°C. All projections indicate substantial increases in the frequency of days and nights that are considered 'hot' in current climate. Annually, projections indicate that 'hot'[9] days will occur on 29-48% of days by the 2060s, and 33-71% of days by the 2090s (Sweeney *et al*. 2008). Days considered 'hot' by current climate standards for their season are projected to occur on up 100% of days by the 2090s (Sweeney *et al*. 2008).

Nights that are considered 'hot' for the annual climate of 1970-1999 are projected to occur on 29-48% of nights by the 2060s and 32-71% of nights by the 2090s. Nights that are considered hot for

[8] Data from Source: Meteorological Services Mauritius 2009.
[9] 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

each season by 1970-99 standards are projected to occur on up to 100% of nights by the 2090s (Sweeney *et al*. 2008). All projections indicate substantial decreases in the frequency of days and nights that are considered 'cold'[10] in current climate. 'Cold' days do not occur in any projection, under any emissions scenario by the 2090s, and cold nights only occur under the lowest emissions scenario by the 2090s (Sweeney *et al*. 2008).

Sea-surface Temperature*:* Model simulation for the SWIO gives a **sea-surface temperature** increase within the range of 0.51 to 3.77^{o}C and sea level rise between 18 and 59 cm by 2100. Mauritius is likely to experience the same effect (MSM 2009). These projected changes will result in decreasing trend in rainfall, however, increased risk of flash flood, more frequent heat waves, an increase in the number of intense tropical cyclones and several other associated direct and indirect impacts. Frequent extreme climate events such as tornadoes have not been excluded, although they are very rarely observed over land in Mauritius, they are not excluded because with the increase in available energy in the atmosphere they may manifest themselves more often. Until present, even with the most sophisticated equipment, tornadoes have been almost impossible to predict in advance to warn human populations (MSM 2009, Sweeney *et al*. 2008).

Precipitation: The range of projections in mean annual rainfall from different models is large and straddles both negative and positive changes (-20% to +24%), however the majority of the model projections for the average deviance from the average annual rainfall gather at zero along the x-axis. Seasonally, the projections show a more coherent picture, with rainfall tending towards decreases. Projected changes tend towards increases over the northern islands and decreases over the southern islands in all seasons. The projections of change in the proportion of rainfall that falls in heavy events range between both increases and decreases. Seasonally, projections are indicating decreases, with changes ranging between -13% to +5%. The models are broadly consistent in indicating overall increases in 1- and 5-day rainfall maxima by the 2090's (Sweeney *et al*. 2008).

Vulnerabilities

Mauritius is very vulnerable to sea-level rise; almost half of the population lives within 1 km of the coast. Most of the tourist industry is located in close proximity to the coast including roughly 100 hotels (approximately 10,000 beds). Mauritius is already witnessing unusual weather patterns and events such as rain during the dry season, more flash floods, drier seasons with an upsurge of droughts and floods (Royal Town Planning Institute, 2009). Mauritius' physical size and geographical isolation, its resilience on imports and its low adaptive capacity increases its vulnerability and reduces its resilience to climate variability and change (MSM 2009).

[10] 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

An increase in the frequency of extreme weather events, heavy rains and storms has been recorded. The impacts brought about by such natural disasters have generally been reversible as Mauritius has acquired vast experience, particularly in dealing with cyclones. The Government's central committee mandated to deal with cyclones, floods and other natural disasters and the associated risks and impacts has been an effective national platform which has ensured risk reductions, rescue and relief operations (MENDUM 2010).

Mauritius' Natural Disaster Warning System

Mauritius' robust Early Warning System within the *Cyclone and Other Natural Disaster Scheme* includes a preparedness plan for disaster risk reduction. The warning system takes into consideration the degree of risk of gusts exceeding 120 km/h and the time factor before the advent of such gusts. The threshold value of 120 km/h represents the speed at which appreciable damage to structures may start to occur. The system essentially consists of a numbered series of cyclone bulletins and a summary statement of the class of warning or force . There are four classes of warnings numbering from 1 to 4 and these are issued by the Mauritius Meteorological Services so as to give ample lead time for necessary precautions to be taken (MENDUM 2010).

Classification of cyclones in Mauritius

Class I: Issued 36 to 48 hours before Mauritius or Rodrigues is likely to be affected by gusts reaching 120 km/h.

Class II: Issued so as to allow, as far as practicable, 12 hours of daylight before the occurrence of gusts of 120 km/h.

Class III: Issued so as to allow, as far as practicable, 6 hours of daylight before the occurrence of gusts of 120 km/h.

Class IV: Issued when gusts of 120 km/h have been recorded and are expected to continue to occur.

Termination: Issued when there is no longer any appreciable danger of gusts exceeding 120 km/h.

Port Louis and its vulnerabilities

Port Louis is the capital city of Mauritius and home to around 170,000 inhabitants, a large proportion of the Mauritius urban population. In fact practically the entire urban population of this island is found within the two neighbouring districts of Port Louis and Plaines Wilhems (NAR 2010). Its administrative and economic centre is part of a larger, arched urban area that stretches diagonally across the country from Port Louis to the central plateau (UGD 2010). The city is located five meters above sea level. Port Louis hosts the only port on the island for import and export trade for Mauritius.

During the period 2005-2009, Port Louis harbour recorded unprecedented growth in trans-shipment traffic, following various agreements signed with major shipping consortiums using the port as a trans-shipment hub (NAR 2010). One of the main economic activities is cultivation of sugar which is highly dependent on the islands climate conditions. The sugar bulk terminal, located at the harbour of Port Louis, is where all sugar is stored before being exported to other international countries. The exportation of sugar was once the strength of the Mauritian economy. However, as a result of the introduction of the Euro and the crisis of prices of sugar on a global scale due to an oversupply and a decrease in demand, Mauritius is now looking for alternative sources of revenue and thus relying less on the export of sugar.

Port Louis features a tropical wet and dry climate with a longer wet season than dry season. Its wettest months are from December through April where on average 100 mm (or more) of rain falls during each of these months. The months of September through November forms the dry season, though technically July, with an average of just less than 60 mm of precipitation, could be considered a dry season month. The city also shows a noticeable range of average temperatures, with cool temperatures during the mid-year with average high temperatures of 24°C (MSM 2000). During the height of the wet season, the city sees its highest temperatures averaging around 30°C. The direction of wind is generally from the east, although the cyclones hit the island from the west. Mean monthly relative humidity varies from 86% in March to 80% in October in most places (Anon. 2010).

As a coastal town, Port Louis is exposed to risks and impacts associated with storms, storm-surges, flooding, coastal erosion and direct damage to infrastructure and property. Port Louis has already experienced impacts associated with cyclones. In the past there have been several cyclones, for example, Hollanda (1994) and Dina (2002), which have had impacts on city infrastructure and services.

Cyclone Hollanda lashed Mauritius with wind speeds of 225 km/h followed by torrential rain. This was the worst cyclone since 1975 and Port Louis was particularly hard-hit. Two deaths were reported. Over 50% of the sugar cane crop was severely damaged but not entirely destroyed; however, it caused a 30% reduction in harvest. In addition many vegetable fields were devastated and native vegetation was also damaged or destroyed in many places. The power network was widely damaged, mainly from trees falling on power lines. Damage was estimated at US$ 12.5 million. Telecommunication links (50% out) were severely affected, including damage to satellite dishes. In addition, roads were blocked by trees and landslides. It seems the landslides were caused by lack of maintenance of drains in mountain areas. A total of 290 houses were destroyed and 160 heavily damaged. Shacks of corrugated iron were damaged or destroyed, mostly by falling trees and moderate damage was caused to concrete buildings, some due to poor construction. Estimate of total damage was US$ 84 million, when taking into account production losses, the cost of rehabilitating, crop damage and loss of income in the industrial area (UNDHA 1994).

As the frequency and intensity of storms are projected to increase (IPCC 2007), climate related impacts are likely to increase in severity and this will affect all Mauritians. Key sectors and services that the Port Louis Municipality and the national government provide, such as water and sanitation, health, transport, and energy, are likely to be affected under these projections. The following section will elaborate with case studies how sectoral infrastructure is affected by wind variability associated with cyclones. Some notes on increasing temperature, sea level rise and changes in rainfall and precipitation patterns that will affect the port city will be included but for specific impacts of floods refer to the ***ICLEI Maputo, Mozambique report***, for droughts refer to the ***ICLEI Dar es Salaam, Tanzania report***, for temperature rise refer to the ***ICLEI Cape Town, South Africa report*** and for sea-level rise to the ***ICLEI Walvis Bay, Namibia report***.

5. Sectoral impacts of cyclonic winds in Port Louis

The current global warming trend described in the previous sections is anticipated to give rise to changes in precipitation, which will be accompanied by sea level rise and increased frequency of extreme events, such as sea storm surges, floods, gale force winds and cyclones. Sufficiently warm sea surface temperatures are considered vital to the development of these tropical cyclones.

Changes in wind speed present risks to and impacts upon a multitude of local government sectors and line functions such as: water and sanitation, health, energy, and transport, as well as biodiversity, housing, coastal zones and spatial and town planning.

With the anticipated increase in the frequency and intensity of extreme events, such as storm surges, heavy rainfall, heat waves and flash floods, people whose livelihoods are already under stress will suffer the most as a result of high vulnerability and limited livelihood options. Extreme events may even have disastrous effects such as the destruction of homes, disease outbreaks and loss of human lives (Fairhurst 2009).

Local authorities therefore need to analyse associated and projected impacts and adapt and plan accordingly to strategically build resilience against such climatic variables such as increasing wind speeds. 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.

The risks and impacts upon water and sanitation, energy, transport and health ultimately affect human livelihoods momentarily. For this purpose, sectoral risks and impacts associated with storms will also embody the impacts upon livelihoods. General impacts of increasing wind speeds associated with climate change are highlighted, focussing specifically on impacts to the aforementioned sectors (Table 1 - 5).

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 resources, either natural or derived from natural, 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 investigates 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.

Sugar cane is an excellent example of how impacts of climate change can affect livelihoods. As discussed in Section 4, the cultivation of sugar cane is very important for Port Louis and Mauritius, as it is still the main economic activity of the city and the whole island. But the sugar cane is very sensitive to climate variations and especially extreme events (Figure 8). Strong negative deviations of regional sugar cane yields occur when the crops are seriously affected in all zones of Mauritius (North, South, East, West and Centre) by strong cyclones (for example – 1975, 1980, 1984). A reduction in yield is a reduction to the GDP, the agricultural sectors ability to provide employment and reduces the ability of the sector to grow.

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 cyclonic winds and other impacts of increased cyclone intensity upon the local government services are discussed with the aid of international case studies.

The four sectors are:

- Water and sanitation;
- Transport;
- Health;
- Energy.

In a questionnaire completed by both the Ministry of the Environment and the Mauritius Meteorological Services the following impacts already being felt were of concern were for Mauritius:

- Extreme temperature for people residing in and travelling to and from the city;
- Flash floods occurring more frequently;
- Sea storm surges, particularly of significance for the port; and
- Sea-level rise, particularly for Port Louis.

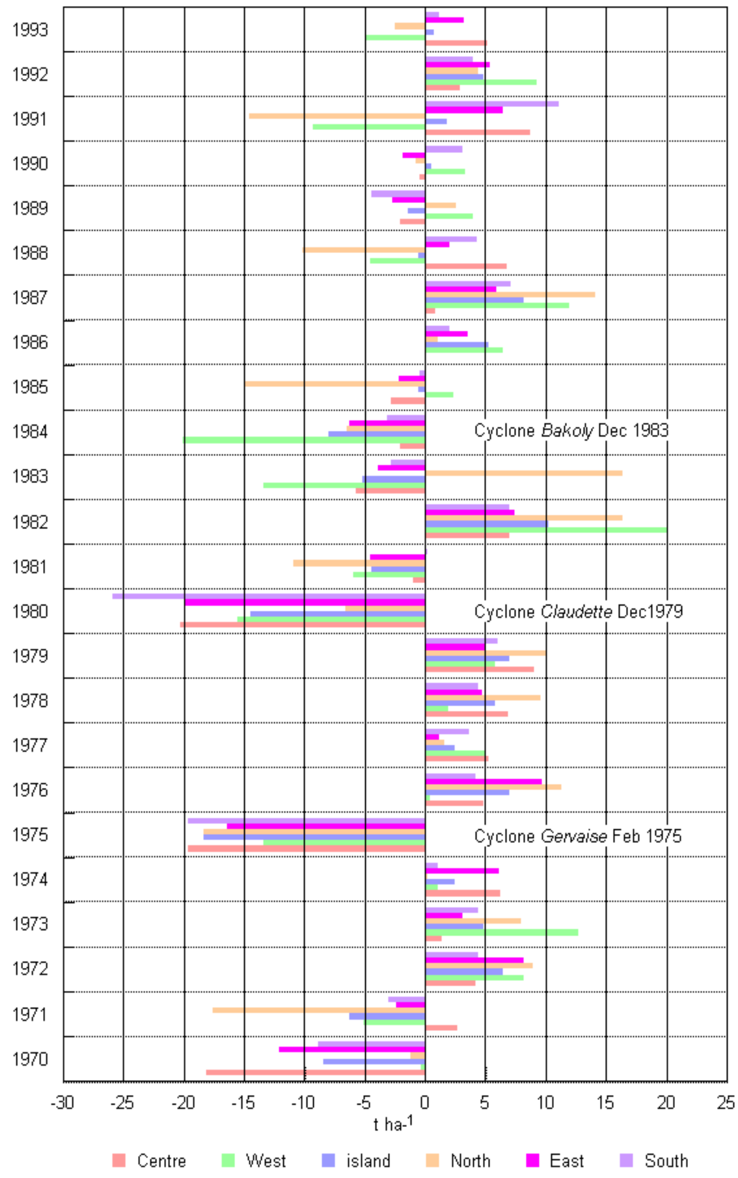

Figure 8. Deviations of sugarcane yields from Regional mean values 1970-1993[11].

[11] Source: AMAS, 1997.

5.2 Water and sanitation

Background

The provision of fresh water supplies to the municipalities and rural areas of Port Louis is managed by the Central Water Authority of Mauritius (CWA). The CWA operates under the aegis of the Ministry of Renewable Energy & Public Utilities. It is a body corporate, established under the provisions of the CWA Act No. 20 of 1971. The CWA is responsible for the mobilisation, treatment, quality control and distribution of potable water on mainland Mauritius. Piped potable water is universal on mainland Mauritius with 98.6% of households having access to piped potable water within their premises, a standard few other African countries can boast. Water is moved through some 3,985 km of distribution pipelines drawing from 106 service reservoirs and a total storage capacity of 237,970 m^3/d. Throughput in the distribution network, currently, averages 545,000 m^3/d. Around half of the water required (51%) is derived from ground water sources, through 112 borehole pumping stations. The balance is from surface sources, mobilised from impounding reservoirs (Mare Aux Vacoas, Piton du Milieu, La Nicoliere, supplemental water from Midlands Dam through La Nicoliere, Port Louis Municipal Dyke Dam and Riviere du Poste).

The CWA operates two slow sand filtration plants and five rapid gravity filtration plants, totalling installed capacity of 315,800 m^3 for the treatment and purification of water from reservoirs. Water from ground water sources is of excellent quality and is only chlorinated prior to joining the distribution network. Potable water has to conform to the standards set by the World Health Organisation (WHO) and the norms specified in the Environmental Protection Act promulgated by the Local Ministry of Environment. The Ministry of Health and Quality of Life conducts independent water quality audits to ensure compliance both direct field analyses, laboratory chemical and biological analysis.

The Port Louis water supply system reaches a service area of 36 km^2. A total of 16 reservoirs and 1 treatment plant are used. On average 94,300 m^3/d moves through the system of which 40% derives from groundwater and 60% from surface water. Potable water demand has been sustainably increasing by an average of 3% yearly over the past twenty five years. The trend is likely to continue up to year 2025. To meet present demand and forecast demand up to 2025, the CWA will have to implement infrastructure development and expansion programmes estimated at US$ 100 million (CWA 2010).

More than half (53%) of Mauritius' water resources are used for irrigation purposes, the remainder is used for hydroelectric power generation (27%) and municipal consumption (20%) (CWA 2010).

Impacts & Vulnerabilities

The supply of water services of any city can be threatened by a number of climate-related affects: low mean annual rainfall, high evaporation rates, pollution of ground water, salt water inundation from sea-level rise (or increased extraction from near-shore aquifers) and flooding from extreme rainfall events.

In Mauritius, increases in the island population, as well as recent droughts (1999, 2010) have forced increased water withdrawals from groundwater reservoirs. In addition, Port Louis faces several problems with respect to aquifer pollution. The use of agrochemicals such as chemical fertilizers is estimated to be three times higher than that of Western Europe and run-off leaches into groundwater sources. Another source of pollution is sugar milling, as most of the nation's 19 sugar mills release the liquid waste from the cane crushing process directly into the environment. Industry is also an important source of pollution. The main industrial zones are concentrated in the metropolitan area and effluent is discharged into the sea where it kills the island's coral reef (which in turn increases the vulnerability of the island as the reefs act as natural buffers to large storm surges), but it has not affected the groundwater supply. However, smaller industrial zones scattered all over the island pose a bigger threat as they are built upon the main aquifers of the island. When they release their untreated effluent into the environment, as most of them do, the effluent can infiltrate the groundwater supplies. The island has four main sewer networks that basically serve the urban population; the rest of the islands' total population (80%) have no access to a sewerage system. They usually dig pits in their back yards and dump used water there. This poses a serious health risk in areas where water tables are high (UGD 2010).

Steps have been taken to remedy the situation. Reforms in current agricultural practices by focusing on water-saving techniques and non-labour intensive techniques; replacing inefficient surface irrigation systems with drip or sprinkler systems, diversifying crops and developing crop combinations that keeps water and nutrients within the farming system. Water uptake by both the agricultural and industrial sectors needs to be monitored as well as quantity and quality of their effluent discharge. In addition, the Mauritius Environmental Sewerage and Sanitation Project has been launched to provide access to sewage treatment facilities for the rural population (UGD 2010).

These measures are important as it is not just burgeoning populations and cyclonic impacts that can affect water supply, a drought in 1999 caused US$ 175 million in damages and lost revenue (PW 2010).

Table 1. Water and Sanitation sector: Impacts and vulnerabilities associated with increasing wind speed.

Impacts upon Water and Sanitation	Impact on livelihoods
• Damage to water supply infrastructure. • Deposition of mud and contaminants in urban freshwater supply and dams. • Increased wave action and flooding along the coast. • Flooding causing strong water flows in aquifers. • Flooding of storm water pipes. • Damage to properties and infrastructure. • Increased sand depositions. • Erosion and landslides which may damage (storm water) infrastructure and assets. • Increase in storm water pollution. • Wind may cause a greater drying effect.	• Increased pressure and need for water supplies for irrigation • Blockages and silting of storm water ways • Increased need for maintenance, upgrades or replacement of infrastructure (e.g. storm water facilities) • Some water supplies / dams offline and thus increasing pressure on remaining water sources and potential water restrictions • Knock on effect on health as a result of increased changes of contamination of fresh water sources • Cases of dehydration • Poor water access • Poor water quality

Case studies

1. Hurricane Ivan had devastating consequences in the **Cayman Islands**[12] and particularly in the Grand Cayman in September 2004. The water supply system suffered little damage owing to the limited rainfall and erosion associated with Ivan. Reservoirs remained intact and the pumping and distribution system appeared to have suffered little damage, as most of the network is underground and protected. However, as the water system is largely dependent on surface water supplies, there was concern that watershed damage may adversely affect water quality over the coming months. While the reservoir system was undamaged, the extensive damage to the watershed promoted erosion affecting water supply. Additionally, watershed loss resulted in an increase in the surface runoff expected during storm events, promoting flooding in streams and catchments areas.

2. The impact of Cyclone Nargis (2008) on the people of **Myanmar** (in the Ayeyarwady Delta and Yangon) was immense. The cyclone killed an estimated 84,530 people, with a further 53,836 reported missing. The damage and losses were on a similar scale of impact to that of the Indian Ocean Tsunami in Indonesia in 2004, especially at the household and community level (Figure 9). The cyclone wiped out the livelihoods of families overnight, flooding over 600,000 ha of agricultural land, killing up to 50% of draught animals, destroying fishing boats and swept away food stocks and agricultural implements. This left households extremely vulnerable and 55% reported to have only one day of food stocks or less, and were relying in part on the steady flow of relief supplies. The total economic losses amount to about 2.7% of the projected 2008 GDP, with the effects of the cyclone

[12] Source: United Nations, 2004.

concentrated on a region important for agriculture and fishing in Myanmar. Recovery needs, which are estimated at just over a total of US$ 1 billion over the next 3 years, include the most urgent priorities of significant food, agriculture, housing, basic services and support to communities for restoring their livelihoods and rebuilding assets (ASEAN 2008).

Prior to the cyclone, water supply for rural communities in the affected areas consisted primarily of household-level rain water harvesting tanks, communal rain water ponds, open wells, tube wells, and rivers. Most households had a roof-rainwater harvesting system that collected rainwater through a gutter into large earthen pots as the main source of water during the rainy season, while in the dry season communal ponds that collected rainwater served as the primary source of water, with most communities having at least one or two ponds. Only a small percentage of communities were connected to piped water supply networks. Ponds and household rainwater harvesting systems were most impacted by the disaster. The cyclone and the flooding that followed, damaged close to 13% of ponds in Yangon and up to 43% of ponds in Ayeyarwady Division. Sanitary facilities, including both pit and open or floating latrines, existed in most communities in both Yangon and Ayeyarwady Divisions. Most latrines that existed prior to the cyclone collapsed or were rendered unsafe for use due to flooding. Open defecation increased, and unsafe excreta disposal with direct drop latrines, without pits, was common. The combination of households using river water as a source for drinking water and the use of floating latrines posed serious health risks in this area.

Figure 9. a) Burmese seeking shelter in the torrential rains that followed Cyclone Nargis[13] and b) a survivor sheltering in the ruins of his destroyed home in Mya Ba Go village, Bogale township, Ayeyarwaddy Division.[14]

[13] www.prosterous.com.
[14] http://report2009.amnesty.org/press-area/en/photos/myanmar.

5.3. Transport

Background

The Public Infrastructure Division of the Ministry of Public Infrastructure, Land Transport & Shipping is responsible for the implementation of road, bridge and government building infrastructural projects in Mauritius. From 2005 to 2008, the number of registered vehicles increased by 13% and the number of cars rose by 23% for the same period. The density of vehicles as at 2008 was 173 vehicles per km of road and there are 285 vehicles per 1,000 inhabitants. Government is currently putting emphasis on expanding road infrastructure, demand management and road safety. In addition sulphur content of automotive and industrial diesel oil would be lowered to 500 ppm as from August 2010 to make substantial air quality improvement. Diversification of fuel supplies with biodiesel manufacture or import and the promotion of fuel saving techniques through education and information programmes are being investigated. The promotion of hybrid and electric vehicles through fiscal incentives is also a priority.

Conscious that an efficient air transport system is fundamental for sustained development and in line with its target of 2 million tourists by 2015, the Mauritian Government has adopted a gradual air access liberalisation policy since 2005. The Sir Seewoosagur Ramgoolam International Airport (SSRIA) is being expanded and modernised to cater for a 4 million passengers per year capacity.

Impacts & Vulnerabilities

Mauritius is a trading nation. Owing to its remoteness from major markets, it depends heavily on transportation to ensure sourcing of raw materials and delivery of its exports. Being so far from its markets and with the advent of new tax regimes with regard to climate change, Mauritius will also be at a disadvantage as it may be subject to carbon taxes (NAR 2010).

The **air** transportation sector is vulnerable to rising fuel prices and has a consequential impact on the national carrier. In 2009 Air Mauritius incurred a loss for the year of Euro 85.4 million as a result of fuel hedging losses. Additionally, extreme weather events arising from climate change may also impact on the air transport sector with more and more flights being diverted to other regional airports. As a result, the national industry is likely to incur significant losses (SIDS 2010).

Similar to all island states, **ports** are critical links in the supply chain and to promote economic growth. Since the past five years, the port and maritime sectors have moved from a situation of boom and severe congestion to one of uncertainty and loss of business associated with the effects of the world economic crisis (SIDS 2010).

Traffic congestion, along the major roads leading to the capital city, accounts for losses of approximately US$ 100 million/year in economic activity. At present, the challenge lies in alleviating the congestion problem, through investing in more sustainable modes of travel and the adoption of complementary land use and transport strategies to sustain urban and coastal tourism growths. Yet another challenge is the shift from private to public transportation (SIDS 2010).

Mean sea level rise and sea storm surges impacts on transport commuters along a coastline, delays transport in the case of damaged or flooded roads and causes long term erosion to roads, railway lines and bridges in the close vicinity of the sea (Table 2).

Table 2. Rise in mean sea level, sea storm surge and increasing wind speeds impacts on Transport.

Type	Impacts upon Transport	Impact on livelihoods
Road	• Damage of infrastructure • Blockage of roads (fallen trees, debris) • Flooding causes diversions • Accidents • Inundation of roads • Road closures on bridges and mountain passes • Damage to signage and overhead cables • Erosion of bridges	• Traffic jam and increased waiting time • Limits access routes • Delays to the work place and markets • Work hours lost– reducing income • Risk to public safety
Rail	• Damage of infrastructure • Blockage of railway tracks (fallen trees, debris) • Erosion of railway infrastructure • Inundation of railways • Disruption of electronic transport infrastructure (e.g. train signals) • Expense of maintenance	• Causes delays and cancellations of trains • Unable to reach destination • Work hours lost– reducing income
Air	• Damage of infrastructure • Accidents and air crashes • Reduction in GDP • Airport closes for safety during cyclones • Increased insurance required by operators	• Reduces accessibility to airports • Delay in exports/imports • Decreased safety
Port	• Damage of infrastructure • Erosion to coastal infrastructure and equipment • Damage of boats • Erosion to harbour wall • Damage to anchored boats	• Days at sea lost • Work hours lost – reducing income, if the port is rendered unworkable then there is no income stream until the damage has been cleared • Delay in exports/imports • Increased insurance premiums

Increasing wind speed may impact on transport routes causing damage to infrastructure, and may impact on the economy of the transport sector if increased wind speeds directly impact on fuel usage.

Case studies

1. **Guatemala** was badly affected by tropical storm Agatha in May 2010. The first named storm of the 2010 Pacific hurricane season formed off the west coast of El Salvador.

Figure 10. Giant sinkhole caused by the rains of Tropical Storm Agatha in Guatemala City[15].

The storm made landfall near the Guatemala-Mexico border and was one of the deadliest Pacific tropical cyclones on record, at least 184 people were killed in Guatemala, El Salvador and Honduras and more that 165,000 were evacuated from their homes. A large sinkhole (Figure 10) more than 18 m wide and 60 m deep formed in the middle of Guatemala City, swallowing a street intersection and a three-story clothing factory (Global Greenhouse Warming 2010).

2. The Cyclone Giri made landfall in the west coast of **Myanmar** causing large scale damage in October 2010. The cyclone struck the coast near the town of Kyaukphyu, with winds reaching 160 km/h and triggering a tidal surge of up to 12 feet in some areas on the Bay of Bengal coast. Delivery of foreign aid food and relief was hampered by destroyed bridges, in addition roads were inaccessible and waterways had to be used instead (DREF 2011) even though many boats were also destroyed (Figure 11).

[15] Source: http://news.nationalgeographic.com/news/2010/06/100601-sinkhole-in-guatemala-2010-world-science/.

Figure 11. Boats destroyed during cyclone Giri [16].

5.4. Health

Background

The number of reported weather-related natural disasters has more than tripled since the 1960s, globally. Some of this can likely be attributed to better reporting and a greater ability to get to remote areas that are affected by these disasters, but the trend holds. Every year, these disasters result in over 60,000 deaths, mainly in developing countries (WHO 2010). Rising sea level and increasingly extreme weather events like cyclones are likely to destroy homes, medical facilities and other essential services. More than half of the world's population lives within 60 km of the sea. People may be forced to move, which in turn heightens the risk of a range of health effects, from mental stress and disorders to communicable diseases (NAR 2010). In addition to the public health and medical consequences of these disasters, the social, cultural and psychological impact of cyclones have an enormous and long-lasting impact throughout the world, and a direct effect upon human development in general. Whenever there is a disruption of routine public health services (in an event of a cyclone) there is the potential for secondary adverse health effects to develop among the disaster-affected population (Keim 2006).

Increasing mean sea levels and extreme events such as sea storm surges associated with cyclones affects populations living in small island developing states and other coastal regions. Some communities are more vulnerable and prone to impacts and risks than others in these regions; however, cyclone events impact on people's well-being and health directly and/or indirectly. People's health is more likely to be impacted by indirect impacts relating to this climatic occurrence. For example people who rely on water supplies from estuaries and aquifers may become ill if the

[16] www.allvoices.com

fresh water source becomes inundated by saline water or and contaminated by debris. Inundation of sea water may create areas of stagnant water in places which could cause the spread of diseases - "*climatic conditions strongly affect water-borne diseases and diseases transmitted through insects, snails or other cold blooded animals. Changes in climate are likely to lengthen the transmission seasons of important vector-borne diseases and alter their geographic range*" (WHO 2010). In addition storm water can inundate sewerage treatment ponds which can lead to raw effluent entering surface ground water systems.

A rise in mean sea level and sea storm surges is likely to impact upon coastal infrastructure, transport networks and even medical facilities in close proximity to the shoreline which is likely to cause indirect impacts on health and the accessibility to health care. Agricultural production along the coast is likely to be inundated reducing food security which may lead to famine.

The most frequently reported cyclone-related injuries are lacerations, blunt trauma, and puncture wounds. An increased incidence of animal and insect bites following tropical cyclones has also been noted and chronic diseases are known to be exacerbated after cyclones (Keim 2006).

Like most small island developing countries Mauritius also faces daunting challenges in its endeavour to attain its Millennium Development Goals; these include HIV/AIDS, cardiovascular-related diseases, diabetes and other non-communicable diseases, and preparedness to respond effectively to national, regional and international outbreaks. In 2008, diabetes and cardiovascular diseases taken together, accounted for 57.8% of all deaths. The prevalence of diabetes in Mauritius, one of the highest in the world; has increased from 19.5% in 1998 to 23.7% in 2009. On the other hand population growth, a vital factor in the sustainable development equation, has been quite successfully tackled. The total fertility rate, which dropped sharply from about six children per woman in the 1960's to about three in the 1970ss, stood at 1.5 in 2009 (NAR 2010).

In2009, an efficient Epidemic Alert and Response system to control the resurgence of communicable diseases was set up. The first wave of the AH1N1 pandemic was successfully contained as are outbreaks of dengue fever. They undertake the control of malaria and chikungunya too.

In Mauritius, in 2008, the total number of beds in government institutions was 3,500 as compared to 3,819 in 2000. In the private sector there were, in 2008, seventeen private clinics, with a total of 582 beds. The total number of beds in the public and private sectors as at the end of 2008 was 3.3 beds for 1 000 inhabitants. Out-patient care is also provided in the private sector, including several clinics and dispensaries on sugar estates. In-patient service is provided in 19 private clinics.

Mauritius has years of cyclone experience and as a result knows the risks and response measures necessary. However, if the intensity and/or frequency of these events increase they will need to be better prepared. In 2008, the existing arrangements as regards to the running of hospitals during cyclonic periods, torrential rains, tsunamis and other natural disasters were reviewed and updated.

There is an urgent need to address the issue of preparedness in Mauritius as a result of recent meteorological observations and forecasts. Improved planning and preparation are therefore necessary to safeguard health facilities and to ensure that they continue to provide health care during and after emergencies (NAR 2010).

Impacts and Vulnerabilities

Climate change is expected to have a negative impact on human health in Mauritius. A 2°C increase in the average temperature when added to the already humid conditions prevailing during summer in the capital city and the other coastal areas will be detrimental to the health of elderly persons, small children and chronic invalids. Furthermore, a combination of such temperatures with high values of relative humidity is bound to be catastrophic to human health.

Urbanization is relatively dense and large areas are being covered by concrete structures with few parks and gardens. Residential buildings have been erected to serve more as shelters from strong cyclonic winds than as efficient energy-consuming units. During summer these get heated up by solar radiation and emit the stored heat at night thus considerably increasing indoor and local ambient temperatures.

Air conditioning facilities are becoming an important household item and as the lower income group will not be able to afford such facilities; excess heat will become a major health problem. A nation that cannot rest and recover will not be productive and is most likely to suffer from cumulative distress (INC 1999).

- The following health risks were listed as applicable to Mauritius in the light of climate change in a recent report (Commonwealth 2009):Health effects due to extremes of temperature and more a heat related health effects.
- Health effects due to natural disasters such as cyclones, flooding and tsunamis and including the following: injuries and loss of life; increase in communicable diseases such as food-borne and vector-borne diseases; mental stress; health effects due to air pollution. Other indirect health effects such as harm from ultraviolet rays when residents have insufficient shelter from the elements.

The report pointed out that no specific climate change and health policies being developed yet and there was little mutualism between government departments on the issue, or partnering at an international level.

Table 3: Increasing wind speeds and cyclones and their impacts on health

Impacts upon Health	Impact on livelihoods
• Damage to clinics, hospitals and other infrastructure and	• increased deaths from:

services. • Increased pressure on emergency services. • Service delivery backlogs in clinics and hospitals. • Chemical Hazards: contamination of flood water with oil, diesel, pesticides, fertilisers etc. • Spread of infectious diseases: skin and respiratory diseases and stomach ailments. • Worsening of existing chronic illnesses. • Long-lasting psychological impacts. • Higher wind speeds and changes in air pressure cause people to feel unwell (i.e. headaches). • Increased drying effect. • Increased health threats through heat stress. • Disruption of solid waste management. • Loss of hygiene and sanitation – increased pests and vectors.	– Drowning – Electrocution – Injuries caused by trees and other debris becoming airborne • Increased casualties • Hours of work lost • Medical bills to pay • Poor and limited water supply to residents • Dehydration • Loss of shelter • Likely to affect vulnerable communities (young, woman and elderly) most at risk to infection and heal risks and impacts associated with severe extreme events • Food scarcity

Case studies

1. Cyclone Aila hit the city of Gabura in **Bangladesh** on 23 May 2009. A year after this event the suffering of climate victims is still continuing. Lack of accessibility of clean drinking water was major issues as many people had no choice but to drink contaminated water and were suffering from water borne diseases (Figure 12). After the cyclone, people were moving up to 10 km away to get a jar of pure drinking water. The cyclone caused 190 immediate deaths, injuries to 7,103 people, damage to 6,000 km of roads, more than 1,700 km of embankments collapsed and more than 500,000 people were left homeless (Islam 2010).

While the cyclone was not as strong as Cyclone Sidr, and the initial death toll was considerably lower, it is estimated that about 4 million people were affected during and after Cyclone Aila. The cyclone has had a devastating long-term impact, particularly because embankments which were breached during the storm remain unrepaired. This means that some homes and schools still flood at high tide. People continue to live on embankments, the only place above water level, without sufficient food, water, shelter or protection. Livelihood options were severely affected by the cyclone as livestock, shrimp ponds and cropland were washed away or destroyed.

Figure 12. A child suffering from a skin diseases caused by consuming contaminated water[17].

One serious implication of this to the health of the survivors comes in the form of salinity. The areas flooded during the cyclone left highly saline soils, 2.8 million ha in all, about one fifth of the total area of Bangladesh. The adverse effects of salinity on ecosystem and crop productivity are well documented but now health effects are also emerging too such as pre-eclampsia, eclampsia (seizures or convulsions in pregnant women that are not related to a pre-existing brain condition) and hypertension (Islam 2010). Records from an antenatal clinic located in a port region in Bangladesh reveal that 21% of women between the age of 16-40 years have been diagnosed with at least one hypertensive disorder. This rate is strikingly higher than the figure of 2.65%, 6.8% and 5.4% seen in non-coastal rural communities in Bangladesh (Khan *et al*. 2008).

5.5. Energy

Background

Local energy resources of Mauritius are limited as there are no known reserves of oil, gas or coal and no refinery. The country depends mainly on imported energy. During the last ten years, the energy sector has witnessed a sustained increase in primary energy, used mainly for industrial, transport, commercial and domestic sectors. The total primary energy requirements of Mauritius vary significantly and depend on the volume of ***bagasse***, a by-product of the sugar industry, available for power generation by sugar factories (INC 1999).

The Central Electricity Board (CEB) of Mauritius is the parastatal body that is empowered by the Central Electricity Board Act of 25 January 1964 to "*prepare and carry out development schemes with the general object of promoting, coordinating and improving the generation, transmission, distribution and sale of electricity*". The CEB produces around 40% of the country's total power requirements from its four thermal power stations (three heavy fuel power plants and one kerosene fired gas turbine power station) and eight hydroelectric plants; the remaining 60% being purchased

[17] Islam 2010.

from Independent Power Producers (CEB 2011). The thermal power stations using imported fuel oil produce about 75% of energy generated, hydro-power plants accounting for 13% and sugar factories the final 12% (INC 1999).

Only about 18%of energy is produced from renewable energy sources, including bagasse, hydro, solar and wind energy. The most plentiful indigenous source of energy is bagasse. The seasonality and variability in sugar production require power plants at sugar mills to use the dual fuel system of bagasse and coal to supply power to their grid at guaranteed levels all year round.

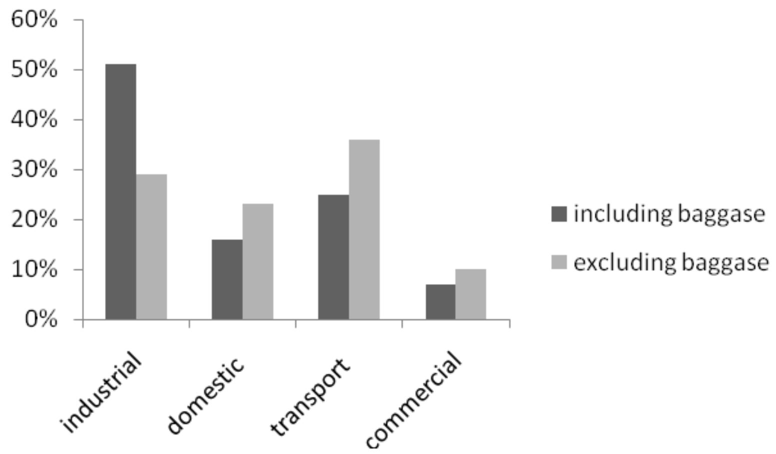

Figure 13. The final energy consumption for each sector, both with and without bagasse[18].

The shift in the structure of final energy use from commercial and domestic sectors to industry and transport is noteworthy (Figure 13).

The hydroelectric potential of the country has largely been developed but during the past ten years, output has been uneven, varying between 75 GWh and 148 GWh but with an annual average of 108 GWh which is equivalent to about 24,000 tons of oil.

Energy conversion consists of four transformation segments; generation of electricity in oil-based power stations, production of steam and generation of electricity from bagasse, transformation of coal into electricity and production of small amounts of charcoal from fuel wood.

In December 2010 Mauritius launched an initiative asking the population to produce electricity from renewable sources. The Grid Code, produced by the Central Electricity Board (CEB), establishes the standards of performance, reliability and safety for the planning and operation of the power system

[18] INC 1999.

in which clients can produce electricity from photovoltaic, wind or hydrological sources for their own use and sell any surplus to the national network. The code is restricted to plants up to a maximum capacity of 50 kilowatts and the total installed capacity is for now limited to a maximum of 200 plants island-wide.

The total supply of forest products and waste wood was estimated at 22,000 t of which 9,900 t qualified as fuel wood. The contribution of other renewable sources of energy such as solar radiation was very low and restricted to the use of water heating devices.

Wind and solar are two of the most established renewable energy resources that can benefit economies, and are suited for local climatic conditions. Mauritius is developing Renewable Energy Policy once the potential of renewable energies can be calculated. The Mauritius Research Council (MRC 2008), together with other stakeholders, has taken the lead to develop wind roses[19] and solar energy resources for Mauritius (MRC 2008).

An 18 MW wind turbine project near the village of Plaine des Roches will reach completion first. Construction is set to begin in early 2011 and be complete within a year. The company responsible for these projects, Aerowatt, sold 210,000 carbon credits generated from the project to the Swedish government. The sale of the credits will help finance the wind farm. The second wind energy project will be near Britannia, 25 km south of Port Louis. The 22 MW wind farm is being developed in collaboration with the Mauritian sugarcane and ethanol producer Omnicane Limited. The project is close to finalization and should reach completion in early 2012 (Reve 2010).

Impacts and Vulnerabilities

Climate change affects energy supply and demand such as prolonged drought occurrences reducing hydropower supply, floods and strong winds damaging network cables, cutting off energy supply; and extreme high and low temperatures increasing the demand of energy. Extreme wind events are likely to cause damages to power stations, power lines and other facilities of electricity.

Table 4. Increasing wind speeds impacts on energy.

Impacts upon Energy	Impact on livelihoods
• Erosion of coastal power lines. • Damage and losses to energy production facilities and infrastructure (power stations, high voltage lines etc). • May cause an increased demand for energy.	• Chances of electrocution by livewires being submerged in floodwater • Limited fresh produce for

[19] A wind rose is a meteorological diagram depicting the distribution of wind direction and speed at a location over a period of time.

• Extreme temperatures increase the demand of energy as cooling facilities are employed. • Power outages due to floods destroying power lines. • Energy supply cut for borehole water pumping. • Loss of economic activity unless alternate energy supplies are in position.	consumption • Limited water supply if water sector does not have backup generators causing dehydration • Inability to boil water to ensure water is potable and to prevent the spread of cholera and other water-borne diseases

Case studies

1. The tropical cyclone which struck the Gujarat state, **India,** in June 1998 left thousands dead. The thriving industrial complexes of Kandla, Porbandar and Jamnagar were devastated when the cyclone made two landfalls, the first 35 km north of Porbandar and the second closer to Kandla port. Damages near the first landfall were attributed to gusts and those at Kandla to the combined effect of gusts and surge. Transmission lines, communication lines, roads and railway installations suffered moderate to high damages. High-tension transmission towers were damaged the most. Almost no tower was left intact along the cyclone track between the two landfalls. Some of the towers failed right at the ground level. In the wind energy sector, majority of the wind mill towers were damaged by twisting their blades. Construction quality severely affected the damage pattern of the pre-cast concrete distribution poles. Many of the poles were twisted above the ground level (Raju and Sinha 1998).

2. Cyclone Yasi (January 2011), a Category 5 storm with winds of up to 285 kph, hit north Queensland, **Australia**, smashing buildings and infrastructure, and knocking out power in coastal towns and cities (Figure 14). Despite the damage no fatalities were reported. At least 154,500 Ergon Energy customers in North Queensland were without power. In addition to "substantial damage" to the Ergon Energy network, there was also damage to Powerlink Queensland's electricity transmission network, affecting electricity supply to the coastal communities of Mission Beach, Cardwell, Tully and Ingham. Powerlink Queensland is the company responsible for the state's high voltage network and provides electricity to Ergon Energy to distribute to customers. As the power restoration effort began many areas were still inaccessible to crews with roads blocked by fallen trees and branches (ENS 2011).

Figure 14. a) Damage to both the standard electricity network [20] & b) a wind turbine on 'Strand' in Townsville[21].

Lessons learned: Provisions need to be reviewed in terms of wind gusts and energy infrastructure. Frequent failures of steel latticed towers indicate probable reason to be of insufficient design for the wind speeds or the unknown behaviour of such structures under the dynamics of a cyclone. Furthermore, design provisions for torsional resistance of these towers under the worst case of swapping of wires should also be reviewed. Construction quality should be strictly maintained in concrete distribution poles. Design practices have to be reviewed to provide adequate strength to resist torsional forces as discussed in the case of transmission towers (Raju and Sinha 1998).

[20] http://www.businessday.com.au/photogallery/environment/weather/yasi-hits-north-queensland/20110202-1acrd.html?selectedImage=54.
[21] http://au.news.yahoo.com.

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).

Mauritius is no exception and Port Louis, home to a large proportion of the main islands population, will be the city most affected by the impacts associated with increased intensities of cyclones, sea level rise and other projected climate changes. Port Louis is already prepared for cyclones but the intensity and frequency of projected cyclones is likely to strain current adaptation. This coupled with rising sea-levels will affect all local government sectors (see section 5 and Table 5 for a summary). If the city is unable to adequately meet its mandate of basic service provision, these impacts are likely to mean, that for an average resident of Port Louis, a decrease in quality of life and ability to make a living is inevitable. 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 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. Port Louis 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 report (Moser, C. and D. Satterthwaite, 2008) 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 Port Louis focused specifically on impacts and vulnerabilities associated with cyclones and associated winds and torrential rains and is one of a suite of five reports. The other reports deal with extreme temperature (Cape Town), drought (Dar es Salaam), flooding (Maputo) and rising sea-levels (Walvis Bay). 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 Port Louis can lead the way for Mauritius.

Table 5. General Impacts of increasing wind speeds associated with climate change upon municipal sectors.

Water and sanitation	• Drying effect and erosion. • Damage to water supply infrastructure and properties. • Deposition of sand, mud and contaminants in urban freshwater supply and dams. • Increased wave action and flooding along the coast, causing: ○ Damage of storm water pipes; ○ Increase in storm water pollution. • Salt water intrusions into freshwater systems in coastal zones are anticipated to increase. • Decreased availability of freshwater for domestic and industrial use: ○ Increased pressure and stress on fresh water supply; ○ Water treatment capacity will increase; ○ Water sanitation in the poorer, vulnerable areas will be affected; ○ Knock on effect on health as a result of increased changes of contamination of fresh water sources.
Transport	• Destruction, damage and disturbance to harbours, jetties, boat ramps and other infrastructure such as roads, storm water outlet, electrical substations, main water pipes, beachfront promenades. • Coastal flooding is likely to cause diversion, delays and even suspension of transport services for the public, businesses and transfer of commodities. • Accidents, waiting time, risk to public safety.
Health	• Increasing wind speeds will impact upon the heath sector as a result of increased deaths from: ○ Drowning;

	○ Electrocution; ○ Carbon monoxide poisoning in the clean up stages after flood events; ○ Trees and other debris which are flying around. • Illnesses, such as infectious diseases (skin and respiratory diseases and stomach ailments), worsening of chronic illnesses, long-lasting psychological impacts, increased health threats through heat stress, headaches caused by high wind speeds and changes in air pressure. • Damage to clinics, hospitals and other infrastructure and services. • Increased pressure on emergency services. • Service delivery backlogs in clinics and hospitals. • Chemical Hazards: contamination of flood water with oil, diesel, pesticides, fertilisers etc. • Increased drying effect. • Disruption of solid waste management. • Loss of hygiene and sanitation – increased pests and vectors.
Energy	• Damage and losses to energy production facilities and infrastructure (power stations, high voltage lines etc). • May cause an increased demand for energy for upgrades and adaptation: • Clean up operations; • Rebuilding of infrastructure and housing; • Erosion of coastal power lines.
Livelihoods	• Threat to homes, infrastructure, transport, safety and basic services. • Further exacerbate the anticipated rainfall and erosion impacts on informal settlements. • Inundation of salt water reducing freshwater resources supply. • After sea storm surge events or heavy rainfall water may not be able to disperse / run-off and water may become stagnant leading to disease outbreaks. • Cyclones may also reduce natural resource capital on which the local inhabitants are heavily dependent.

7. Glossary

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: 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.

Anthropogenic changes: Human activities that change the environment.

El Niño-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 telecom-nections. The cold phase of ENSO is called La Niña.

Intense tropical cyclone: A tropical storm in which the estimated wind gusts range from 234 to 299 km per hour.

Moderate tropical storm: A non-frontal synoptic scale low-pressure system originating over tropical waters with organized convection and definite cyclonic wind circulation. Estimated gusts associated with moderate tropical storms range from 89 to 124 km per hour.

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.

Severe tropical storm: A tropical storm in which the estimated wind gusts range from 125 to 165 km per hour.

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

Tropical cyclone: A tropical storm in which the estimated wind gusts range from 166 to 233 km per hour.

Tropical depression: A non-frontal synoptic scale low-pressure system originating over tropical waters with enhanced convection and/or some indications of cyclonic wind circulation. Winds circulate clockwise around low-pressure and cyclone systems in the southern hemisphere. Gusts associated with tropical depression are generally less than 89 kilometres (km) per hour.

Very intense tropical cyclone: A tropical storm in which estimated gusts exceed 300 km per hour.

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.

Zone of disturbed weather (or tropical disturbance): an area of low pressure relative to the surrounding region; the associated cloud masses are usually not well-organized.

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