Dissertation Topic:

An assessment of the RDP settlements vulnerability to impacts of climate change: A case study of Umlazi Y section, South of Durban.

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This dissertation is submitted in partial fulfilment of the requirements for a Master of Housing in the School of the Built Environment and Development Studies under the Faculty of Humanities

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Declaration

I **Wendy Ntombifuthi Hlatshwayo** hereby declare that this dissertation is my own unaided work except where otherwise acknowledged. It is being submitted to the school of the Built Environment and Development Studies, University of KwaZulu-Natal, Howard College campus, in partial fulfilment of the requirements towards the degree of Masters of Housing. This dissertation has not been submitted before for any examination or degree at any University.

Signature…… …….

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Abstract

Prominences of environmental issues such as climate change have increased the need to achieve environmentally sustainable housing developments. Although effects of climate change are experienced at a global scale, vulnerability of a system is determined by scale and context. The objective of this research study is to understand how RDP dwellings are vulnerable to impacts of climate change and identify climate responsive housing consolidation methods which households can apply to improve the adaptability of RDP settlements. A case study was selected purposively. An Interview was conducted with a housing official and household surveys were conducted from the case study. Research findings indicate that RDP dwellings are vulnerable to impacts of climate change. The following factors contributed to the vulnerability of RDP settlements: lack of information on climate change, lack of resources and housing typology. At a policy level, it was discovered that issues of climate change have not yet been mainstreamed into housing policy. The research therefore, recommends that efforts are made to mainstream issues of climate change into housing policy and that measures are undertaken to strengthen the adaptive capacity of households.

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ACRONYMS/ABBREVIATIONS

AR	Assessment Report
AC	Adaptive Capacity
BESG	Built Environment Support Group
CBD	Centralized Business District
CHES	Coupled Human-Environment Systems
CHDU Sao Paulo	Companhia de Desenvolvimento Habitacional e Urbano do Estado de
DEAT	Department of Environmental Affairs and Tourism
DoHS	Department of Human Settlements
ECCPD	EThekwini Climate Change Protection Department
Enca	eNews Channel Africa
EMD	Environmental Management Department
GBCSA	Green Building Council of South Africa
GHG's	Greenhouse Gases
HE	Hazard Exposure
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LEED	Leadership in Energy and Environmental Design
MCCP	Municipal Climate Protection Programme
TIASA	Thermal Insulation Association of South Africa
RDP	Reconstruction and Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USGBC	United States Green Building Council

Chapter One: Research Introduction

1.1. Background

Prominences of environmental issues such as climate change have increased the need to achieve environmental sustainability within the housing sector. Climate change is the abnormal change in the climate at a global scale. This change is caused by human activities that contribute to the increased concentration of Greenhouse Gases (GHG's) in the atmosphere, making the earth warmer (Hounsome et al, 2006). The abnormal climatic changes can be experienced globally as extreme increase or decrease in temperatures, changes in rainfall patterns and increased in magnitude and frequency of extreme weather events such as hurricanes, flooding, droughts and storms (Iyer and Hounsome, 2006). Effects may include: flooding, soil erosion, wildfires, drought, and heat waves (Wilbanks et al, 2007). The effects and degree of vulnerability of systems vary according to the exposure, sensitivity and ability to adapt (Adger and Kelly 2000).

Ajibade and McBean (2009) affirm that the extreme weather events induced by climate change are having a disastrous impact on human settlements. Although impacted by climate change, settlements in developed countries such as the United States of America and the United Kingdom are more resilient when compared to settlements in developing countries (Ajibade and McBean, 2009). Hurricane Kathrina which occurred in America is one example of an extreme weather event that resulted in the destruction of settlements and loss of life (Wilbanks et al, 2007). In 2003, Europe experienced a severe heatwave which led to lose of lives due to abnormally high indoor temperatures (Wilbanks et al, 2007).

Poor location of settlements on low-laying areas, floodplains and coastal regions is one component which exposes settlements in Africa to effects of climate change (Magazda, 2000). Floods that occurred in 2002, in Rwanda, Kenya, Tanzania, Burundi, Mozambique and Uganda displaced thousands of households and resulted in significant loss of property (Alam et al, 2008). Settlements in African cities located on the coastal regions such as Accra, Lagos and Cape Town have been experiencing increased frequency of coastal erosion (Ajibade and McBean, 2009).

Ajibade and McBean (2009) attest that the physical exposure of settlements particularly in developing countries such as South Africa, to climate change is exacerbated by non-climatic stressors such as diseases, poverty and lack of access to information.

1.2 Introduction to research study

RDP, a socio-economic policy framework formulated by the African National Congress (ANC) identified housing as a basic human right and a high priority basic need (ANC, 1994). However, the democratic government also acknowledged the inability of low-income households to meet their basic housing needs thus, introducing subsidized housing programme (Huchzermeyer, 2001). The RDP housing programme acknowledged the importance of integrating the social, environmental, and economic aspects of housing (The Republic of South Africa, 1994). The ethos was that sustainable housing would improve the quality of household life (ANC, 1994). RDP housing was designed to meet basic housing needs thus; low-income households had to incrementally consolidate the dwelling (Adebayo, 2008). The Housing Act (107 of 1997) defines housing both as a product and a process. This research study will focus more in-depth on the dwelling, the product delivered through the RDP housing development.

RDP housing beneficiaries received a product of standardized services plots with freehold tenure and a core structure (Adebayo and Adebayo, 2010). According to the Housing White Paper, 1994 the product had to provide adequate protection against elements. RDP settlements were first introduced as starter homes and later extended to 30sq m top structures, on a 250sq m plots (Block et al, 2011). The buildings are made of brick and mortar with corrugated iron, asbestos or roof tiles (Block et al, 2011). Adebayo and Adebayo (2000: 8) argue that "*the settlements were built in a linear monotonous pattern with narrow roads and lack aesthetic attributes".* Environmental aspects such as the climate of the area were not considered during construction and design of buildings thus, undermining the responsiveness of buildings to climate change.

According to the UN-HABITAT (20011; 13) environmentally sustainable housing *"is concerned with the impacts of housing on the environment and climate change, as well as the impact of the environment on the housing itself".* Therefore, understanding the climate of a site is crucial when attempting to achieve a sustainable housing development (Conradie, 2012). The climate of the site would include: sun orientation, wind velocity and direction, temperatures, slope, and rainfall patterns (Conradie, 2012). Understanding these environmental factors increases the environmental performance of dwellings thus, decreasing the vulnerability of dwellings to external climate conditions (Ching, 2008). Failure by South African government to deliver environmentally sustainable RDP dwellings suggests that the dwellings are vulnerable to environmental stressors such as climate change.

1.3 Definition of the Problem

The Housing Act (107 of 1997) states that "it is the mission of the Department of Human Settlements (DoHS) to facilitate the creation of sustainable housing developments". However, pressure to deliver at scale, RDP housing demoted environmental concerns such as those of climate change to a lower ranking (Donaldson-sebly, 2007). The DoHS acknowledges that *"despite all the housing policies and strategies formulated since 1994, little has been done to encourage environmentally sound housing developments"* (Republic of South Africa, 2009). This reality has undermined the overall sustainability of RDP settlements thus, making households vulnerable to various social and environmental stressors, including those of climate change. Climate is one of the environmental components of a site that affects the performance of buildings further affecting the comfort levels of households.

This research study will focus mainly on the effects of two climatic elements on the RDP dwelling these include temperature and precipitation. The objective is to understand how the function and materials of the RDP dwelling structure (foundation, floor, walls and roof) responds to these effects of climate change.

Some of the effects of abnormally high temperatures include frequency of heatwaves which affects indoor temperatures (Wilbanks *et al,* 2007). It therefore becomes important that the orientation of the building is considered during the design and construction phase (Ching, 2008). Excessive indoor heating and direct sun radiation

of some rooms in the house compared to others is a result of poor orientation. Greyling (2009) argues that the quality of RDP dwellings was compromised due to failure to consider environmental factors such as building orientation and further recommends the consideration of building orientation requirements in order to ensure high quality future RDP developments.

The Built Environment Support Group (BESG) (2000: 26) identify the foundation and the floor as having the following functions "*for stability, strength, durability, resistance to moisture penetration, fire resistance, and good thermal properties".* Many RDP dwellings have strip foundation and a concrete floor slabs (Greyling, 2009). RDP dwellings do not have concrete perimeters around the dwelling which could help to prevent water seepage in cases of floods. Greyling (2009: 15) argues that "*due to poor quality of land on which RDP dwellings are erected upon, the strip foundation might not be suitable on different locations as some sites are on wet lands or clay soil*".

Thermal Insulation Association of South Africa (TIASA) (2010: 15) defines external walls as the *"the complete walling system, as measured from the outer skin exposed to the environment to the inner skin exposed to the interior of the building"*. RDP dwellings used concrete hollow blocks for both internal and external walls (Greyling, 2009). Kelvin and Meyer (n.d: 1) argue that "*these were of poor quality, with inferior thermal performance characteristics"*. To protect exterior walls from absorbing moisture the walls need to be plastered (BESG, 2000). RDP exterior walls were covered with weak plastering of one coat cemcrete, making it susceptible to interior wall dampness in the cases of intense rainfall (Greyling, 2009).

Charlett (2007: 139) identifies the following as the functions of the roof: strength and stability, weather resistance, thermal insulation, sound insulation, fire resistance, durability and appearance. The RDP dwellings have pitched roofs. The RDP roofing has no gutters to collect water from the roof and a proper drainage system (Greyling, 2009). In cases of intense rainfall buildings become susceptible to flooding due to excessive runoffs. South Africa is identified as water scarce country and thus methods of saving water are crucial so to curb the effects of droughts predicted over South Africa due climate change (du Plessis, Irurah and Scholes, 2003).

Reid, et al (2005; 5) states, *"Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fibre; regulating services that affect climate, floods, disease, waste and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling".* However, the massive clearance of vegetation and topsoil (including the seed bank) prior to construction of RDP settlements has compromised the ability of ecosystems to provide households with these services (Donaldson-sebly et al, 2007).

Ecosystems services as a response to assist households to adapt to predicted changes in eThekwini municipality has the ability to provide households with food (urban agricultural); reduce surface run-off thus preventing flooding and soil erosion; provide windbreakers and rainwater among other things (Reid et al, 2005). However, settlements must be planned and designed to acknowledge these benefits (Landsberg et al, 2011). Failure to consider ecosystems services during environmental assessments increased the vulnerability of dwellings to impacts of climate change (Landsberg et al, 2011).

1.4 Motivation/Justification of the study

In 2011 Durban experienced flooding which claimed the lives of 8 people and destroyed about 700 000 houses (Daily News, November 28, 2011). The South African Weather Bureau reported that Durban received 62.6mm of rain, which had recorded 209.6mm for November 2011, double its average (Daily News, November 28, 2011). Amongst those affected by the flooding were RDP residents whose RDP houses collapsed due to flooding.

On the 6th November 2015, the eNCA news announced the KwaZulu-Natal and Free State province as disaster zones as a result of water scarcity. The South African Weather Services related the water scarcity issue with the heatwave that was causing a decrease in the summer rainfall (eNCA news, 8 November 2015). The increase in magnitude and frequency of extreme weather events such as droughts, floods, and heatwaves are induced by climate change (Wilbanks et al , 2007). The dwelling design should allow for households to participate in water harvesting

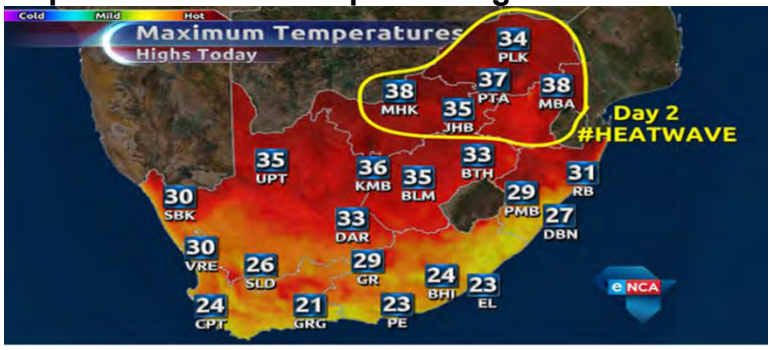
practices. (However, RDP dwellings are unable to provide this function due to lack of gutters and proper water drainage systems (Greyling, 2007).

Figure 1: Flooding experienced in Durban

Sourced from Dr. Debra Roberts' presentation titled 'The Durban Climate Change Adaptation story' EThekwini Municipality

The map below shows the maximum temperatures over South Africa during the presence of a heatwave. The drought was expected to worsen due to the El-Nino effect which was the strongest being experienced in 20 years (South African Weather Services, October 2015). The increase in temperatures has also led to increased frequency of Thunderstorms (South African Weather Services, October 2015). For buildings to protect households from heatwaves environmental factors such sun orientation, window placement and orientation should be considered during the design phase of the construction process.

Map 1: South Africa experiencing heatwaves



Map 1 sourced from: https://www.enca.com/south-africa/no-relief-sight-heatwave-simmers 08 November 2015

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5: 2013) concluded that “warming over land has increased across Africa over the last 50-100 years by 0.5 – 2 degrees Celsius. Durban is likely to experience more days of temperatures over 25 degrees Celsius between Jan-Nov (Hounsome et al, 2006). The Seasonal Climate Watch Report for November 2015 – March 2016 present findings that indicates that South Africa will experience above-normal temperatures over the summer season (South African Weather Services, 2015). Rainfall distribution over Durban is also highly likely to change (Hounsome et al, 2006). It is projected that the number of days without rain will increase and rainfall events will be heavier over short period of time when compared to current condition Schulze, 2005 cited in Hounsome (2006; 61). The Seasonal Climate Watch Report for November 2015 – March 2016 states that there are high probabilities of below-normal rainfall for the mid-late summer season (South African Weather Services, 2015).

The inability of the building elements to resist climate factors makes the dwelling vulnerable and compromises the quality of household life. There are mainly two climate change response mechanisms these include: mitigation and adaptation (Adger and Kelly 2000). The more informed housing developers are about climate change issues the easier it will be to implement either mitigation or adaptation measures to ensure that RDP dwellings are environmentally friendly. This research study seeks to contribute to the expansion of knowledge and understand how climate change affects RDP dwellings and thereafter, recommend environmentally friendly RDP housing consolidation methods.

Figure 2 shows some of the extreme weather events that Britain has experienced as a result of climate change. As South Africa was experiencing droughts in the summer season of 2015, Britain was experiencing server floods. It is the possibility to prevent such disastrous events that further motivates the researcher to undertake this study. Figure 2 below shows the damaged caused by floods in Britain.

Figure 2: Storm Desmond causing floods in Britain

Figure 2 sourced from http://www.theguardian.com/world/2015/dec/06/ on the 07/12/2015.

1.5 Research Aim

The aim of this research study is to understand how RDP dwellings are vulnerable to impacts of climate change and identify climate responsive housing consolidation methods which households can apply in order to improve the adaptability of RDP settlements.

1.5.1 Objectives

1. To explore the extent to which RDP dwellings are affected by impacts of climate change.
2. To identify factors contributing to the vulnerability of RDP dwellings to climate change
3. To assess building standards responses to effects of climate change in RDP settlements in eThekwini Municipality.

1.6 Research questions

- How can RDP dwellings be made more adaptable to climate change induced conditions?

1.6.1 Sub Questions

1. What are the effects of climate change on RDP dwellings in eThekwini municipality?
2. What makes RDP dwellings vulnerable to climate change?
3. What are the existing building standards responses to effects of climate change in RDP settlements?

1.7 Working Hypothesis

This dissertation is based on the assumption that RDP dwellings are vulnerable to impact of climate change. It is thus, assumed that climate responsive housing consolidation methods will improve the adaptability of RDP dwellings thus, decreasing their vulnerability.

1.8 Proposition Statement

This research study seeks to find how RDP settlements are vulnerable to impacts of climate change and assess how future housing consolidation could assist households to build climate responsive dwellings thus, decreasing their vulnerability to climate change.

1.9 Setting of the Scope

Delimitation of Research Problem

The research will only study RDP settlements located at Umlazi, Y section, south of Durban. The study assesses climate change effects on RDP dwellings from 1994 – 2015. The assumption is that, housing should be optimal for twenty years. Therefore, the study will assess past, present and future climate change predictions. The focus will be on the dwelling and immediate environment, and not on the settlement as a whole which will involve more built environment effects apart from that of the dwelling.

1.10 Data Analysis

A multilevel mixed method analysis method was applied to analyse data collected. The research adopted a mixed methods approach which applied both quantitative and qualitative data collection methods and therefore, a mixed method analysis approach was required. Within a multilevel mixed method analysis various qualitative and quantitative techniques are applied to analysis data. The quantitative research findings complemented the qualitative research findings. This process ensured the validity of the research findings. Onwuegbuzie (2011: 4) explains complementary mixed analysis as a process whereby "results from one analysis type [qualitative] are interpreted to enhance, expand, illustrate or clarify findings derived from the other strand [quantitative]". For this research study, the quantitative strand was used to enhance, expand, illustrate and clarify findings derived from qualitative approach.

1.11 Definition of Terms

Climate

Climate: the sum total of the meteorological phenomena that characterise the average condition of the atmosphere at any one place on the earth's surface (Hann, 1903: 1)**.**

Climatic elements: These are temperature, humidity, rain or snow, velocity and direction of the wind (Hann, 1903)**.**

Climate change: The United Convention Forum on Climate Change (UCFCC) report (1992:10) defines climate change as "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time".*

Temperature: when applied in climatology, temperature refers to the total effect of the warmth of the air and also of radiation (Hann, 1903)**.**

Absolute Humidity: The essential features of humidity of any place are described when the quantities of water vapour in the air, and the amount and kind of precipitation are given (Hann, 1903: 58)**.**

El-Nino: The term "El Niño" originally applied to an annual weak warm ocean current that ran southward along the coast of Peru and Ecuador about Christmas time (hence Niño, Spanish for "the boy Christ-child") and only subsequently became associated with the unusually large warmings that occur every few years and change the local and regional ecology (Trenberth, 1997: 2771).

Vulnerability: The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "*The degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes"* (Parry et al, 2007: 20).

Climate change Adaptation: According to Smit and Pilifosova (2007:881) adaptation refers to *"changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change".*

Housing

The Dwelling: the dwelling is the structure of the building and it has three main components: the foundation, walls and the roof (BESG, 2000).

RDP Settlements: RDP settlements are government subsidized low cost housing developments delivered through the capital subsidy scheme to previously disadvantaged households earning no more than R3500.00 per month (The Republic of South Africa, 1994)

Low-income settlements: Government subsidized housing delivered through housing programmes

Environmentally sustainable housing: According to the UN-HABITAT (20011; 13) environmentally sustainable housing *"is concerned with the impacts of housing on the environment and climate change, as well as the impact of the environment on the housing itself".*

Housing consolidation: BESG (2000) refers to housing consolidation as "the improvement of a household's living conditions and circumstances over time"

R-value: The measurement of the thermal resistance of a material which is the effectiveness of the material to resist the flow of heat (TIASA, 2010: 12)

Sustainability

Environmental sustainability: Goodland (1995) states that "*environmental sustainability seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans".*

Bio-climatic building design: building design which emphasizes energy efficiency through passive heating and cooling systems and which is informed by quantitative climatic data and human comfort data for optimization (Conradie, 2012).

Ecosystems Services: Reid, et al (2005; 5) states, *"*Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fibre; regulating services that affect climate, floods, disease, waste and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling"

The Urban Environment: the urban environment is intrinsically linked to the location of the house. It made up of both the physical and social and cultural elements. The urban environment has the following main components: plot size, green space, hard space and access to facilities (BESG, 2000).

1.12 Dissertation Structure

This dissertation is divided into six chapters. Each chapter is further explained below:

- Chapter one: This chapter presents the aims, problem statement and overview of the entire study. It also discusses the research design and research methodology.

- Chapter two: Presents the Conceptual and Theoretical framework. This chapter presents the concepts and theories influencing and supporting the research study.
- Chapter three: This chapter discusses the Literature Review
- Chapter four: This chapter presents the international experience. This chapter explores precedent studies and discuss how countries such as Hong Kong and Brazil have been able to build climate resilient public housing.
- Chapter five: This chapter presents the research findings, discussions and data analysis
- Chapter six is the conclusion. This chapter will conclude the research study and present recommendations.

1.13. Research methodology

1.13.1 Introduction

The research methodology orientates the reader on the research design frameworks applied to select the research methodology. The section will discuss in-depth the strategies of inquiry, type of methods used to collect data, how the sample was selected and the provide information on the study area.

1.13.2 Research design

Research designs are procedures for collecting, analysing, interpreting and reporting data in research studies (Creswell, 2003). Creswell (2003: 4) identifies three elements that should influence the researcher when developing their research design framework these include; philosophical assumptions (Knowledge claims), strategies of enquiry (qualitative, quantitative or mixed methods approach) and methods of data collection. Chapter two on contextual and theoretical framework will discuss in detail the meaning of philosophical assumption and present those that influence this research study. This section will focus on the strategies of enquiry and methods of collecting data. The table below shows a tabulated summary of the selected research design framework.

Table 1: Research Design Framework

Philosophical Assumptions	Strategies of inquiry	Data collection methods
Pragmatism – Consequences of actions Problem-centred Pluralistic Real-world practice	Vulnerability Assessment Mixed methods approach- Transformative Case study	Observations Both open-and-closed ended questionnaires Use of instruments for statistical data (thermometer, compass)

Table 1 adopted from Creswell (2003) and modified by the author.

Creswell (2003: 5) defines methodology as *"a strategy or plan of action that links methods to outcomes – governs our choice and use of methods".* Research

methodology therefore, plays an intrinsic role in determining the strategies of enquiry and methods of collection data. According to Creswell (2003: 13) “strategies of inquiry or methodologies provide specific direction for procedures in a research design”. There are three types of research methods applied in research to enquire/study a subject. These include: qualitative research methods, quantitative research methods and mixed methods approach.

This research study applied the mixed method approach. Johnson and Onwuegbuzie (2004:17) define mixed method research as *“the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study”.* Some of the research questions require quantitative data collection methods and others require the application of qualitative methods. To understand the effects of climate change a case study approach was adopted so to capture household’s experience however, to verify the responses quantitative methods were used such as using thermometers to capture indoor temperatures and a compass to capture house orientation. The quantitative findings are used to complement qualitative research findings. This exercise strengthened the validity of the research findings.

Moret (2014) recommends that when undertaking vulnerability assessments both qualitative and quantitative research methods should be applied to achieve accuracy of findings. The most fundamental determinant of the research method is the research questions (Johnson and Onwuegbuzie 2004). To answer the research questions the researcher will have to apply both quantitative and qualitative data collection methods. The data will be collected concurrently and both research methods will be given equal status. The First Assessment Report of the Urban Climate Change Research Network (2011) presents the Urban Climate Change Vulnerability and risk assessment Framework. The researcher has selected the strategies of inquiry for this study based of this framework.

Figure 3: Urban Climate Change Vulnerability and risk assessment Framework.

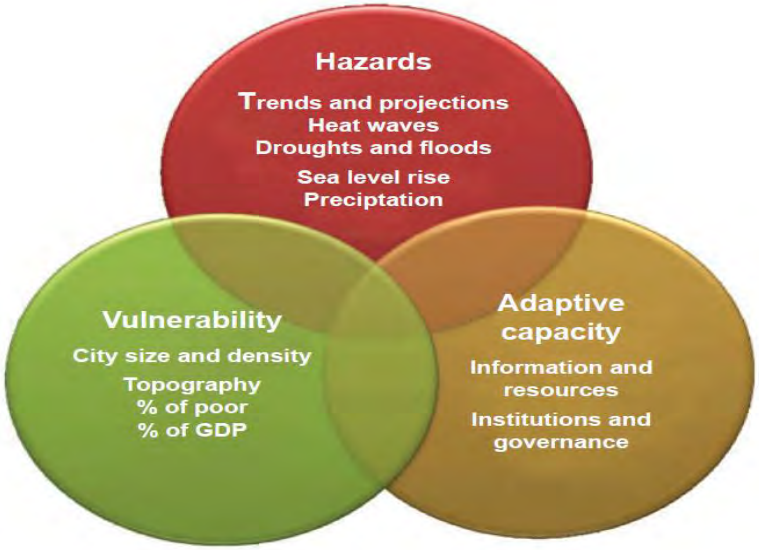


Figure 3 sourced from Urban Climate Change Research Network (2011: 20)

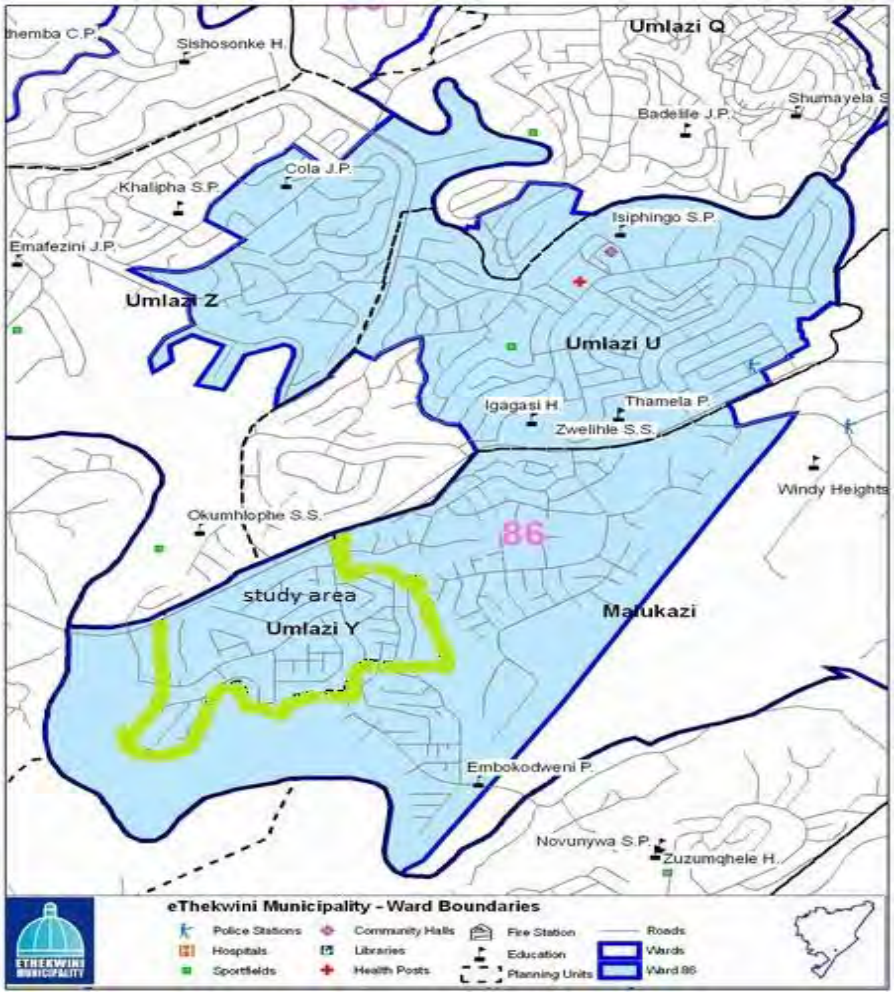
1.13.3 Study area

The community profile enables one to understand the socio-economic status of the study population and further understand its ability to deal with environmental stressors such as those of climate change. Smit and Pilifosova (2007:30) identify limited economic resources, poor information and skills and poor infrastructure as some of the reasons influencing the inability of households to adapt to changes of climate.

Umlazi Y section is a township located South of Durban, KwaZulu-Natal. It is the area outlined in green on the locality map above. Umlazi is located 17 kilometres from the Durban Central Business District (CBD) (Umlazi Economic Development Plan, 2008). The second largest township, Umlazi forms part of EThekwini Municipality. It falls under ward 86 of the EThekwini Municipality ward demarcation system (www.durban.gov.za). The RDP Houses located at Kwampisi Drive were built in the year 1998 and 2000. The Umlazi Economic Development Plan (2008:5) maintains that "*Umlazi inherited the dismal effects of apartheid planning policies characterized by spatial and economic isolation".* The researcher selected Umlazi Y section because it accessible and it amongst the first areas that RDP housing projects were implemented after 1994 thus, the building lifespan is mature enough to

have experienced climatic changes. The RDP houses are attached thus, one site hosting two households. This will enable the researcher to understand how orientation of each side affects the quality of household life. Also, the area is surrounded by the EZimbokodweni River. The researcher is interested in finding out if the river affects the climate of the area and if the community does use the river for adaptation purposes.

Map 2: Municipal Unit Boundary Map



Map 2 of the study area sourced from:
http://www.durban.gov.za/Online_Tools/Pages/Community_Profiles.aspx

1.13.4 Study population

Data on the Umlazi Y section community profile (2005-2010) was sourced from http://www.durban.gov.za/Online_Tools/Pages/Community_Profiles.aspx. Umlazi Y

section has a total population of 4036 residents. Majority of the population is made of Africans. There are a total of 48 per cent males and 52 per cent females. Most of the population is between the economically active age group of 18 – 64 years. A significant portion of the population is unemployed and 10 per cent of the population has no household income.

Regarding delivery of basic household services, 96 per cent of the households receive refuse disposal services and water in their dwellings. There is a primary school in the area. 927 represent the number of households in the area. Majority of the households live in formal dwellings

1.13.5 Sources of Data

The researcher will collect data from two types of data sources; primary and secondary sources of data.

1.13.5.1 Primary and secondary sources

Primary sources of data include the research sample. Creswell and Miller (2000) identify this type of sourcing to be more accurate when compared to other sources because the researcher collects primary data from the original sources. Primary sources of data for this study include: the RDP dwelling, RDP housing beneficiaries and an official from the eThekwini Human Settlements Unit. Secondary data will be collected from existing relevant literature data sources which include; journals, books from the library, reports, electronic data and dissertations. The Official from the Department of Human Settlements will be the key informant.

1.13.5.2 Sampling Method

Bless (2013: 162) defines a sample " *as a subset of the whole population, which is actually investigated by the researcher and in the case of quantitative research whose characteristics will be generalized to the entire population".* The advantages of sampling include its ability to save time and cost implications (Bless et al, 2013). The researcher selected probability sampling methods to select an official and households which will participate in the study.

A geographical cluster sampling method was applied to determine households from which to collect data. 10 per cent of the total population from the households will be selected to participate from the selected geographic area within Umlazi Y section. The study will apply a geographical cluster sampling which will target only RDP houses located within the selected geographical location. Umlazi Y section has a total of 927 households however; only 700 of these households live in the selected geographic area which is located on the upper Kwampisi Drive area in Umlazi Y section. This means the researcher will select 10 per cent of households from the selected geographic sample. The researcher will therefore, select 70 RDP households from which to collect data.

Map 3: Aerial view of Study Area

1.13.6 Research Methodology/Strategies of enquiry

The research study will apply the *vulnerability assessment methodology* as a strategy of inquiry. The vulnerability assessment methodology was determined by the overarching assessment framework identified above. The study will apply a vulnerability assessment based on the analysis provided by the United Nations Development Programme (2010) which posits that climate change vulnerability is an outcome of the interrelationships between hazard exposure, sensitivity and adaptive capacity (Department of Rural Development and Reform, 2012: 5). The equation

below depicts this analysis of vulnerability to climate change and will be applied to undertake a vulnerability assessment for this research study.

Climate Vulnerability =

Exposure to climate hazards and perturbations x sensitivity – adaptive capacity (UNDP, 2010: 20) HE+ P * S – AC = CV

Bubeck et al (2014: 21) identifies hazard exposure **(HE)** as "*typical exposure factors include temperature, precipitation, evapotranspiration and climatic water balance, as well as extreme events such as heavy rain and meteorological drought".* The indicators for hazard exposure of RDP dwellings were focused on extreme weather events in relation to temperature and precipitation. These indicators included: droughts, floods, and heatwaves. Data collection instruments such as thermometer and compass were used to measure hazard exposure. Information on observed and projected changes in temperature and precipitation will also play a huge role in assessing hazard exposure. Perturbations **(P)** are defined as follows *"small variations from the norm in the physical system, typically of lesser magnitude than a hazard, but of possibly longer duration"* (United Nations Development Programme, 2010: 10).

Bubeck et al (2014: 21) posit that *"sensitivity* **(S)** *determines the degree to which a system is adversely or beneficially affected by a given climate change exposure".* 'The system' in the context of this study refers to the RDP dwelling and its intermediate environment. Therefore, to determine the natural/physical environment and societal environment and thus, sensitivity of the RDP dwelling, the researcher will conduct observations and capture measurements. The researcher will undertake a site visit and assess the components of the RDP dwelling in relation to its sensitivity to potential impacts of climate change. (Bubeck et al, 2014: 21) defines potential impacts as follows *"exposure and sensitivity in combination determine the potential impact of climate change"*

According to Fussel and Klien (2006: 319) adaptive capacity **(AC)** of a system or society refers to "*the ability to modify its characteristics or behaviour so as to better*

cope with changes in external conditions". These include social stressors such as poverty, lack of information, lack of access to job opportunities, poor institutional framework, and demography (Fussel and Klien, 2006). These are referred to as non-climatic drivers of vulnerability (Fussel and Klien, 2006). To collect information that will respond to this indicator of the equation, the researcher conducted a semi-structured interview with an official from the eThekwini Municipality Human Settlements unit.

To quantify the outcomes of these indicators the researchers has placed a numerical value on each. Below is a toolkit developed by the author to calculate climate vulnerability.

Table 2: Toolkit for calculate climate vulnerability

Exposure to climate hazards and perturbations	**Sensitivity**	**Adaptive Capacity**	**Climate Vulnerability**
Heatwaves = 3.5 Flooding = 2.5 Drought = 3 Soil erosion= 1	Physical environment = 6 Societal environment = 4	Access to information on climate change = 4 Access to financial resources = 5 Policy framework = 1	**= X the higher the x value the greater the vulnerability** **1 – 10 = Vulnerable** **10 – 20 = Highly vulnerable** **>20 = Extremely vulnerable**

(Author, 2016)

Figure four is identified as an '*impact chain'* Bubeck et al (2014). Bubeck et al (2014: 58) define impact chains as "*an analytical tool that helps you better understand, systemise and prioritise the factors that drive vulnerability in the system under*

review". In attempts to determine vulnerability of RDP dwellings to climate change the researcher has applied this analytic tool.

Figure 4: Analytic tool applied in climate vulnerability studies

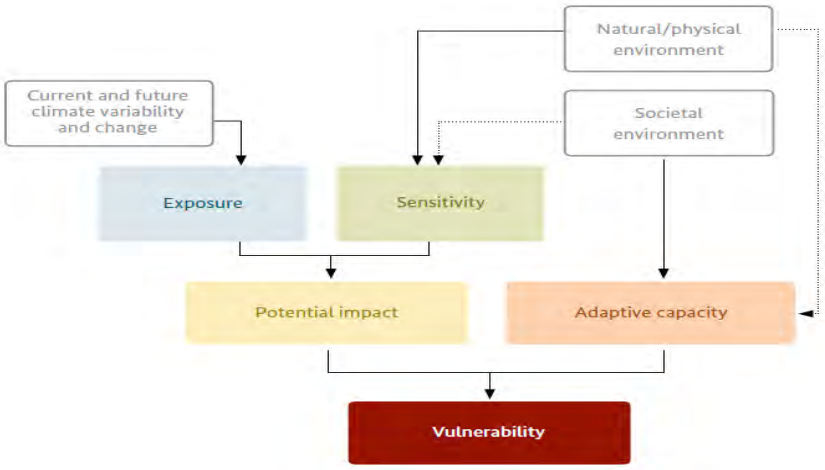


Figure 4 sourced from the Vulnerability Sourcebook

1.13.7 Data collection

Bubeck et al (2014) identifies two primary methods of collecting data for vulnerability assessments these include: measurements and census and surveys. These are used to quantity both exposure indicators and adaptive capacity indicators. Bubeck et al (2014:77) as *"parameters which provide information about specific states or conditions which are not directly measurable".* The researcher will carry out measurements to determine the following indicator: temperature. To measure indoor temperature a thermometer will be used. To determine outdoor temperature and precipitation reference will be made to the findings of the South Africa Weather Services. A compass will be used to determine the orientation of the building. The findings for this type of data collection method will yield quantitative findings. Observations, and interviews will be undertaken to determine sensitivity of the system in this case 'the RDP dwelling' and furthermore the households. Pictures will be taken to support observations. Two sets of questionnaires were constructed for data collection. The interviews were conducted using open-close-ended questionnaires. Households were requested to participate by responding to the questionnaires. Semi-structured interviews will be carried out with officials from the

KwaZulu-Natal Department of Human Settlements. The findings from these data collection methods provided qualitative research findings. Findings from the qualitative data collection methods will be complemented by findings from quantitative findings.

1.13.8 Chapter summary

This Chapter presented section one which discussed the research background, research problem statement and research aims, questions and objectives. And, section two which presented the research methodology. This section discussed in depth the applied research design framework, data collection methods and the study population. Chapter two which follows after this chapter will focus on the theoretical and conceptual frameworks influencing this research study.

Chapter Two: Conceptual and Theoretical Framework

2.1 Introduction

Chapter one introduced the research study, the problem statement, aims and objectives and research methodology. The study adopted Creswell's (2013) research design framework. The framework identifies a research design framework as having three elements of enquiry: philosophical assumptions, strategies of enquiry and data collection methods (2013: 3). The philosophical assumption consists of elements that constitute knowledge claims about a particular discipline (Creswell, 2013). According to Creswell (2013: 4) "philosophical researchers make claims about, what is knowledge (ontology), how we know it (epistemology), what values go into it (axiology), how we write about it (rhetoric), and the processes for studying it (methodology)". Chapter two of this research study is based on the conceptual and theoretical framework influencing the study therefore, it will be presenting the philosophical assumptions as defined by Creswell early on.

Depending on the nature of the research study, Creswell presents four schools of philosophical assumptions: post positivism, constructivism, advocacy participatory and pragmatism (2013:11). This research applied the pragmatism form of philosophical assumptions which are based on consequences of actions; problem-cantered; plurastic in nature and real-world practice orientated (Creswell, 2013). Anthropogenic climate change is based on consequences of actions, impacts of climate change are problem-cantered and the vulnerability of systems to impacts of climate change is real-world orientated and requires global solutions. This section will discuss in-depth the following philosophical assumptions influencing the research study: climate change, vulnerability frameworks, sustainable housing, ecosystems services and policy responses.

2.2. Climate change

2.2.1 Defining climate change

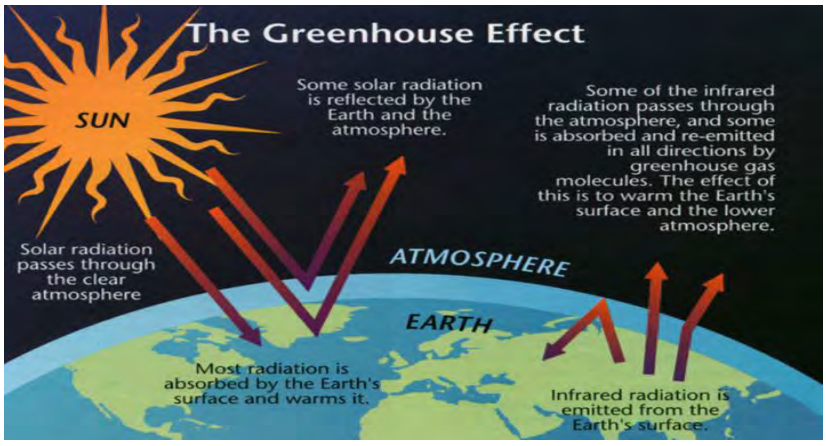
Climate has been changing for decades however; there has been growing concerns with the current speed at which climate is changing and the extreme weather events

associated with this change (Lashen et al, 2010). This unprecedented change in climate has been associated with human activities that have contributed to increased concentration of Greenhouse Gases (GHG's) in the atmosphere thus, trapping more heat and making the earth warmer (Hounsome et al, 2006). Human-induced climate change is associated with more frequent and extreme weather patterns resulting in disastrous outcomes thus, posing threats on various human systems (Daroudi et al, 2009). Understanding climate change and its potential impacts allows one to determine what type of hazards and perturbations a system is exposed or likely to be exposed to. Increased exposure to hazards and perturbations increases the sensitivity of system and if the system has a decreased adaptive capacity vulnerability to climate change is increased.

Climate vulnerability **(CV)** is the result of interaction between Hazard Exposure **(HE),** Perturbations **(P),** Sensitivity **(S)** and Adaptive Capacity **(AC).** It is in understanding these variables that one can determine climate vulnerability of a system. Below is an equation showing interactions between the various indicators determining climate vulnerability of a system.

↑HE + P * ↑S – ↓AC = CV ↑

Figure 5: Schematic Diagram of the Greenhouse effect



[Sourced from Hounsome et al, (2006:39)]

The global atmosphere is made up of Greenhouse Gases, such as carbon dioxide, methane, chlorofluorocarbons and nitrous oxide (Hounsome et al, 2006). The

greenhouse effect is a natural process that maintains an average temperature on earth (Hounsome et al, 2006). In the absence of greenhouse gases, earths' average temperature would be -18 degrees Celsius making the earth unsuitable for human habitation (Yohe et al, 2007). GHG's act like the earth blanket retaining heat in the atmosphere (eThekwini Municipality, 2011). The sun intercepts energy through the earth atmosphere as short wavelength energy (Hounsome et al, 2006). The water vapour, gases, and dust absorb some of the radiation (Hounsome et al, 2006). Some radiation passes through to reach the earth surface (Hounsome et al, 2006). About one third of the radiation is emitted back into space as longer wavelength energy (Hounsome et al, 2006). The emitted energy is trapped or absorbed by greenhouse gases (Hounsome et al, 2006). The effect of this is to warm the earth's surface.

Changes in rainfall are also influenced by changes in temperatures (Hounsome et al, 2006). According Hounsome et al (2006: 37) "annual land precipitation has continued to increase in the middle and high latitudes of the Northern Hemisphere by 0.5 – 1 %; however, over the sub-tropics there is a decrease of precipitation approximately 0.3% per decade. South Africa is located in the sub-tropics and has been experiencing decrease in rainfall volumes. These rainfall patterns will result in environmental hazards such as droughts, flooding, soil erosion, and water scarcity (Hounsome, 2006).

The climate of Southern Africa can be classified as having three main climatic regions: the west which is mostly arid; the subtropical north east humid region and the semi-arid region found on the central part of Southern Africa (Daron, 2014). Daron (2014:7) identifies the following factors as affecting the climate of the Southern African region: the altitude, the warm Indian and cool South Atlantic Ocean, the migration of the Inter-Tropical Convergence Zone (ITCZ), and the location of dominant atmospheric high and low pressure system. South Africa is located between 22 and 34 degrees Southern Latitude on the sub-tropical zone (Daron, 2014).

The IPCC Fourth Assessment Report (AR4) showed that Durban is likely to experience an increase in monthly maximum temperatures by between 2-3 degrees Celsius (Hounsome et al, 2006). Durban is likely to experience more days of temperatures over 25 degrees Celsius between Jan-Nov (Hounsome et al, 2006).

Increased mean maximum temperatures will have direct and indirect impacts on natural and human systems including dwellings (Hounsome et al, 2006). Heatwaves and wildfires are highly likely to be frequent in a warmer climate (Hulme et al, 2007). Increased health problems and increased energy demand for cooling systems, and droughts are some of the effects induced by abnormally high temperatures (Hounsome et al, 2006)

2. 3. Vulnerability Frameworks

Many definitions have been formulated in attempts to conceptualize vulnerability within the climate change context Birkmann (2006: 11) posited that climate change scholars *are still dealing with a paradox: we aim to measure vulnerability, yet we cannot define it precisely*. Fussel (2005) believes that the existing confusion when attempting to conceptualize vulnerability within climate change studies is a result of failure to distinguish between two greatly independent dimensions of vulnerability factors; scale and disciplinary domain.

Figure 6: Example of time, scale and context when assessing vulnerability of a system

Domain / Scale	Socioeconomic	Biophysical
Internal	**Response capacity** *e.g.*, household income, social networks, access to information	**Sensitivity** *e.g.*, topography, environmental conditions, current climate
External	**"External social factors"** *e.g.*, national policies, international aid, economic globalization	**Exposure** *e.g.*, severe storms, earthquakes, sea-level change

Figure 6 sourced from (Birkmann, 2006).

2.3.2 Vulnerability to climate Change

The study of climate change vulnerability is deeply entrenched in the hazards literature or geography and natural hazards research (Doherty, 2012; Fussel, 2006). However, other research disciplines such as human ecology, political economy, political ecology, and food security and development studies have also influenced the conceptualisation of vulnerability within the climate change literature (Doherty et

al, 2011; Fussel, 2006). Stemming from these two influence disciplines a dichotomy has emerged within which the study of climate change vulnerability is examined.

2.3.3 Conceptual frameworks of vulnerability assessments

The climate change literature provides three broad conceptual perspectives from which to interpret vulnerability. These consist of the biophysical, social and the integrated perspective (Doherty et al, 2012). From these perspectives methodologies such as the Climate Change Assessments (CIA), Vulnerability Assessments (VA) and the Adaptation Assessments (AA) have been developed (Doherty et al, 2012). Climate change research inspired by the hazards literature tends to interpret vulnerability as a biophysical condition whilst studies inspired by the human ecology and political ecology interpret vulnerability as socio-economic condition. The third conceptualisation of vulnerability is relatively young in the climate change literature. Vulnerability as a biophysical condition *"addresses the vulnerability and degradation of environmental conditions and extrapolates these in terms of potential impacts on humans"* (Liverman, 1990) cited in Doherty et al.

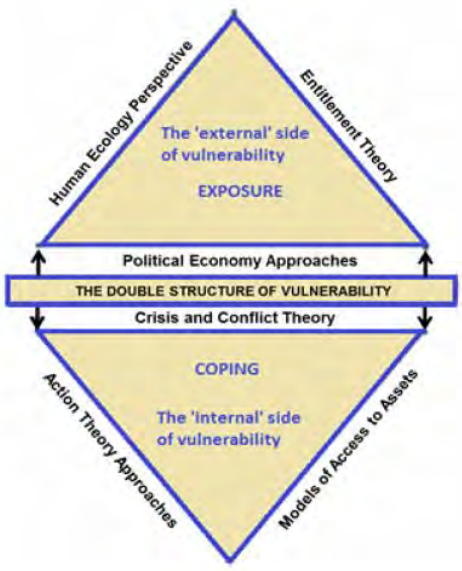
(2012). Doherty et al. (2012: 7) refers to this dimension of vulnerability as the 'physical-environmental dimension' and defines as "*the harm caused by climate on a system*". The biophysical perspective is also known as the risk-hazard approach (Doherty et al, 2012). The biophysical approach is more science driven and it focuses on quantifying projected climatic changes and impact on the system but does not consider the adaptive capacity of that system. These form of studies provided valued information on mitigation measures as a response mechanism for reducing actions of climate change. The biophysical approach would also be used more aggressively when undertaking Climate Change Assessments (CIA) (Doherty et al, 2012). Biophysical approaches are seen as conventional methods however; as the need grew to understand the adaptive capacity of affected systems other perspectives to climate change vulnerability emerged (Doherty et al, 2012).

The social perspective is one approach which emerged in the 1960s and 1970s as a response to the need for assessments that consider not only impacts, but vulnerability and adaptive capacity of affected systems (Doherty et al, 2012). It is inspired by the human ecology, political ecology and development studies (Doherty

et al, 2012). From the social perspective vulnerability is viewed as "*a socially constructed phenomenon resulting from particular social, political, historical and economic processes and structures impacting on individuals/groups which can lead them to vulnerability"* (Doherty et al, 2012: 9).

The 'double structure of vulnerability' model views to this condition as the 'entitlement' because it is an inherent vulnerability and it pre-existed before the hazardous event (Ciurean et al, 2013). From this perspective, impacts of climate change are seen as further aggravating the vulnerability of a system that is already challenged by non-climatic issues. Vulnerability is thus, perceived as a starting point (Fussel. 2006).

Figure 7: Bohle's conceptual framework for vulnerability analysis



Sourced from: (Ciurean et al, 2013: 8)

Bohle's double structure of vulnerability identifies the system at risk as having two sides the external side being made up of political economy approaches (human ecology approach and entitlement theory) and the internal side made up of the crisis and conflict theory and the action theory approaches (Ciurean et al, 2013). The institutional framework within which a system exists determines the external side. For example RDP housing exists within policy framework founded on the neoliberal political economy which thus, influences the nature of settlements and its ability to respond to changes (Ciurean et al, 2013). Entitlement theory relates vulnerability of a

system and its inability to access or manage assets (Birkmann, 2006). RDP are thus, vulnerable due to the inability of households to access resources required to consolidate the house and hence achieve adequate housing. The internal side or elements relate mostly to the ability of households to cope with changes and how people react to hazards (Birkmann, 2006).

Bohle's perspective is widely applied for Vulnerability Assessment (VA) studies as it seeks to understand climate change from a vulnerability perspective and not from an impact perspective only. To fully understand the vulnerability of households/communities of developing countries one would have to consider both the biophysical conditions and the social or contextual conditions of the system. To understand the factors contributing to vulnerability of low-income settlements one needs to consider both the above mentioned approaches. The method of combining both the biophysical and the social approach when assessing climate change vulnerability is known as the integrated perspective (Doherty et al, 2012). Birkmann (2006) also emphasizes the need for a shift from measuring hazard analysis to assessing vulnerability of systems in order to achieve sustainable development.

The integrated perspective seeks to address both the biophysical and social dimensions of vulnerability (Doherty et al, 2012). This perspective is relatively new when compared to the other views of climate change vulnerability. The integrated perspective is particularly helpful when undertaking assessments which are to inform policy development and applied most effectively when undertaking Adaptation Assessments (AA) (Doherty et al, 2012). The system of analysis is focused on Coupled Human-Environment systems (CHES). Below is a table illustrates the varying dimensions of perspectives discussed above.

Figure 8: Perspectives on Vulnerability

	Perspectives on vulnerability		
	Biophysical	Social	Integrated
Focal point of analysis	Biophysical conditions and the hazard	Social systems and social conditions	Both biophysical and social systems (i.e. the CHES)
Type of analytical questions	What are the hazards and impacts?	How are people affected? How are they capable to cope with climate change?	How and why do coupled systems change? What is their capacity to adapt?
System of analysis	Sectors, regions, activities, places	Social groups, e.g. communities, individuals	Coupled human-environment system, ecosystems
Time period of interest	Future climate change	Current climate variability	Current and future climate change

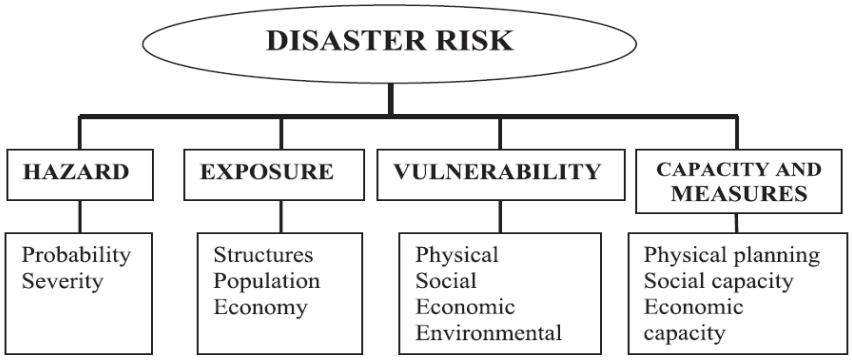
Figure 8 sourced from Doherty et al (2012: 8)

Various conceptual frameworks of vulnerability analysis have been developed over the past years. These include: the sustainable livelihood framework, UNISDR framework, framework of hazard and risk and the Onion framework (Birkmann, 2006). However, for the benefit of this research study only the risk-hazard framework will be discussed in detail. This framework will assist the researcher to understand factors contributing the vulnerability of low-income settlements to impacts of climate change, second objective of the study. Fussel identifies vulnerability assessments as having four dimensions (a) temporal reference; (b) scale; (c) vulnerable system and (d) valued attribute and hazards (Cueva, 2011).

The risk-hazard framework

The risk-hazard framework was developed for risk and disaster management (Doherty et al, 2012). The biophysical dimension of vulnerability influenced the emergence of this framework. Kasperson et al (2005) citied in (Doherty et al, 2012) argued that the risk-hazard is helpful when assessing the risks to certain valued elements (exposure unit) that arise from their exposure to hazards of a particular type and magnitude. Fussel (2005) identifies the risk-hazard framework as being amongst the classical approaches present in the vulnerability research literature. Risk-hazard frameworks are mostly applied to undertake Climate Impact Assessments (CIA) and were popular in the early nineties.

Figure 9 shows the conceptual framework of the disaster risk



Sourced from: Birkmann (2006: 23)

The risk-hazard framework defines vulnerability *as "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor"* (Fussel and Klien, 2006: 306). The primary aim of risk-hazard is to comprehend the impact of a hazard as a function of exposure of the hazard event and the sensitivity of the exposed system (Turner, 2003). The risk-hazard framework identifies two factors fundamental when assessing vulnerability; (1) the 'hazard' "*which is a potentially damaging physical event, phenomenon or human activity characterised by its location, intensity, frequency, and probability"* (2) 'vulnerability' which refers to the "*relationship between the severity of hazard and the degree of damage"* (Doherty et al, 2012). The risk-hazard approach views 'hazard' and 'vulnerability' as two fundamental and independent determinants of 'risk' (Fussel, 2005). However, writers have in the past used the term 'vulnerability' interchangeable with 'risk' and some even argue that vulnerability is a determinant of risk.

However, Turner (2003) citied in Doherty et al. (2012) argues that risk-hazard framework is not capable of successfully assessing the vulnerability of a given system because it does not treat the following fundamental issues: (a) the ways in which the systems in questions amplify or attenuate the impacts of the hazard; (b) the distinction among exposed sub-systems and components that lead to significant variations in the consequences of hazards; and (c) the role of political economy, especially social structures and institutions, in shaping differential exposure and consequences.

2.4 Ideal dwelling structure

2.4.1 Introduction to Sustainable housing

After the World War II increased demand for affordable housing resulted in the mass production of low-income housing in most developed countries (Stone, 2003). However, in Russia and United States and later in developing countries such as South Africa, mass housing production has led to sterile environments and poor quality of buildings (Koebel, 1999). The Brundtland Report defines sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs (*World Commission on Environment and Development, 1987*).* Choguill (2007: 145) concludes that for housing to be sustainable "*housing initiatives must be economically viable, socially acceptable, technically feasible and environmentally compatible*".

2.4.2 The building

Charlett (2007: 2) states "a building consists of an assembly of materials and components, joined to shelter to its occupants". He further goes on to identify to basic functions of buildings which are to act as an enclosure for activities housed within and protect the occupants and contents from the vagaries of the external climate (2007). The latter function is particularly important to this study becomes it links the dwelling or (the RDP dwelling) to the external climate which now due to climate change poses threats on the building itself. Figure 10 below shows an overview of the functions of the building envelope and the different building elements that fulfil each function. These include the wall, floor, foundation and roof of the building (TIASA, 2010: 9).

Figure 10: Functions of building envelope

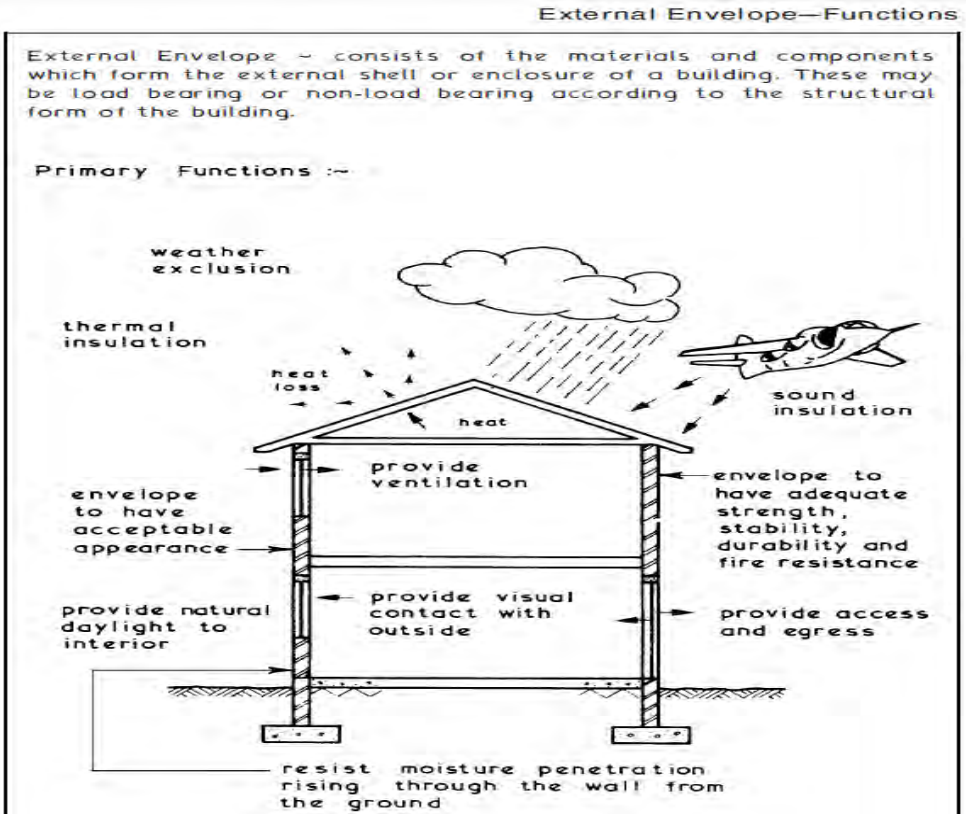
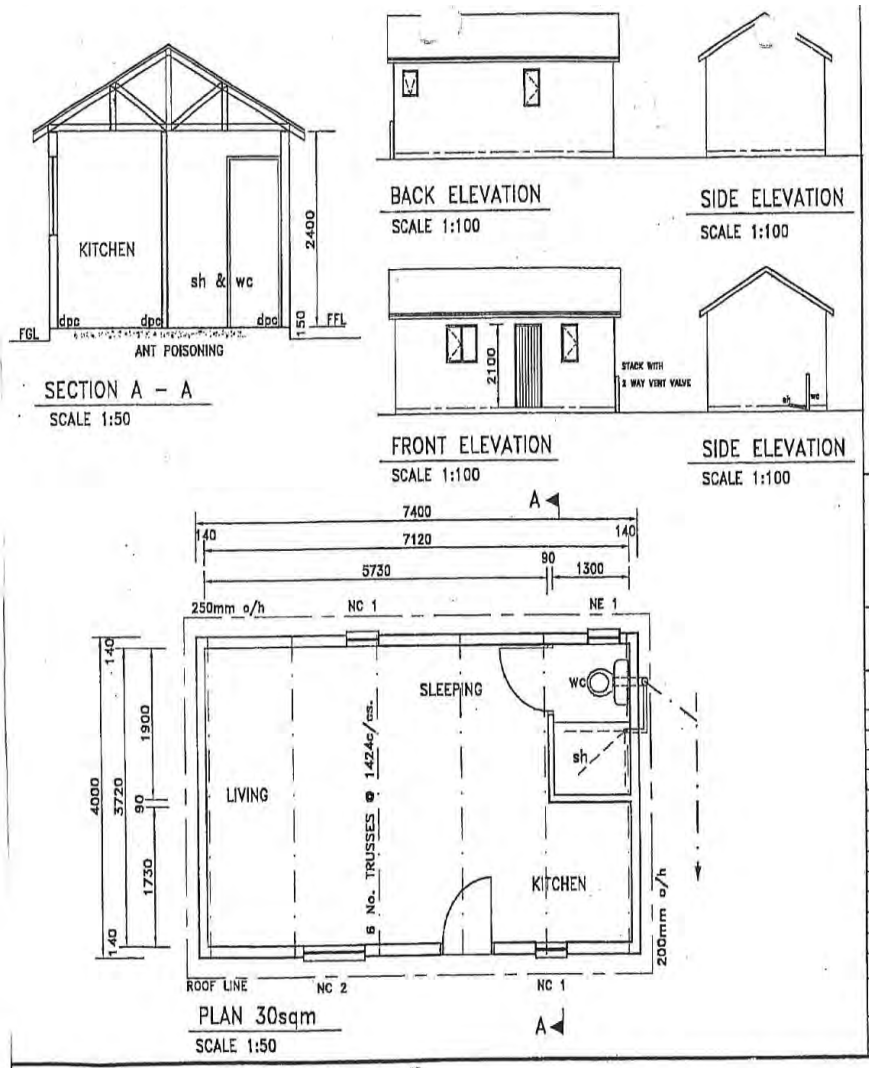


Figure 10 sourced from Chudley and Greeno (2008: 17)

The National housing code (2009: 27) provides norms and standards in respect to stand-alone permanent residential structure. RDP dwellings fall under this category. Contractors are required to comply with these specifications. The dwelling has to be 40 square meters. The dwelling should have the following rooms: two bedrooms, a separate bathroom with a toilet, shower and hand basin; a combined living area and kitchen with wash basin; and a ready board electricity installation where electricity supply is available. The technical specification of the foundation, floor, walls and roof is further discussed under section 2.4.3 ‘Building elements’.

Figure 11: Typical plan of a RDP house



Sourced from: EThekwini Municipality Housing

The layout presented above was one of the proved low-income developments identified for the Waterloo area in Durban. The development complied to the following construction specifications: Ground to be shaped with fall away from dwelling; external walls: 140mm concrete hollow blocks; internal walls: 90mm concrete hollow blocks; provide brickforce every 2nd course and over all doors and windows; Lafarge Marulelo roof system with steel support structure including six trusses at 1424; roof pitch at 26 degrees; Mortar filling to eaves; standard steel windows and door frames as shown with lintels over; and one coat cemcrete to external walls. These low-income housing development specifications are not generic as contractors' preference may differ per project. However, the above layout

and specifications resemble most of low-income settlements including those in Umlazi Y section.

2.4.3 Building elements

2.4.3.1 Walls

TIASA (2010: 15) defines external walls as the *"the complete walling system, as measured from the outer skin exposed to the environment to the inner skin exposed to the interior of the building"*. (BESG, 2000: 26) argue that "*the requirements of walls are to provide stability, strength, durability and fire resistance, to have adequate thermal properties and resistance to sound transmission, and to exclude rain"*. The most widely used materials for walls are bricks, blocks and stones (Charlett, 2007). Kelvin and Meyer identify cavity and double skin walls as the most energy efficient types (n.d). RDP dwellings used bricks for the walls and these were single walls with no insulation (Greyling, 2009). Kelvin and Meyer (n.d: 1) argue that "*these were of poor quality, with inferior thermal performance characteristics"*. To protect exterior walls from absorbing moisture the walls need to be plastered (BESG, 2000). RDP exterior walls were covered with weak plastering making it susceptible to interior wall dampness.

2.4.3.2 Foundation and floor

BESG (2000: 26) identify the functions of the foundation and the floor as "*for stability, strength, durability, resistance to moisture penetration, fire resistance, and good thermal properties, all of which are met by conventional concrete foundations and floor slabs"* Many RDP dwellings have strip foundation and a concrete floor slabs (Greyling, 2009). This type of foundation is the cheapest and thus, widely used in mass low-income housing (Charlet, 2007). Greyling argues that due to poor quality of land on which RDP dwellings are erected upon, the strip foundation might not be suitable on different locations as some sites are on wet land or clay soil (2009: 15).
The South African Norms and Standards of stand-alone residential structures which includes RDP dwellings state that *"the foundation of any building must be designed to safely transmit all the loads from the building to the ground without causing or being subjected to excessive movements*" (Department of Human Settlements,

2009: 28). The South African Norms and Standards provide the following minimum specifications for foundations; External: 500 x200mm (10Mpa) concrete strip footings; Internal: 400 x 200mm (10Mpa); and c) Founding depth: 400mm (Department of Human Settlements, 2009: 28). The strip foundations used for RDP dwellings form part of the shallow foundation types. This type of foundation requires strong sub-soil as it transfers the building load to the sub-soil if the sub-soils are not strong the building becomes susceptible to cracking of the walls and even collapsing (Charlett, 2007).

Charlett (2007: 121) state that "*the primary function of all floors in a building is to provide support to the occupants of the building, along with any furniture and equipment".* The RDP dwellings have concrete floor slabs with a plastic waterproofing material (Greyling, 2009). To keep the floors warm during winter, households had to cover the floor with plastic mats or carpets (Greyling, 2009). The prominence of climate change places more stress of these building elements as flooding is expected to occur more frequently as a result of climatic change.

2.4.3.3 The roof

Figure 12: Functions of Roof

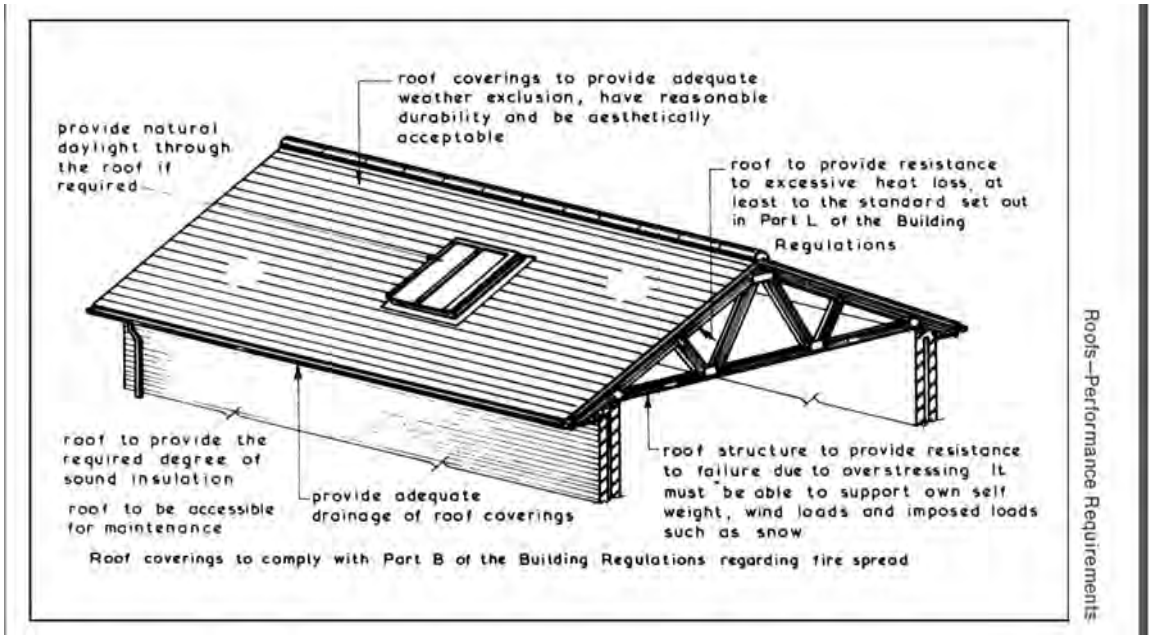


Figure 12 sourced from Chudley and Greeno (2008: 391)

Chudley and Greeno (2008: 391) provide a illustrate diagram presenting the roof and its functions in relation to it internal and external environment. Charlett (2007: 139) identifies the following as the functions of the roof: strength and stability, weather resistance, thermal insulation, sound insulation, fire resistance, durability and appearance. Corrugated iron roof sheet are commonly used inn RDP dwellings with some using clay roof tiles (Greyling, 2009). There are two types of roofing: the flat and the pitched roof (Charlett, 2007). Most RDP dwellings have a pitched roof. Charlett (2007: 156) states that pitched roofs have "*their surfaces sloping at an angle greater than 10 degrees to provide a run off for rainwater at the eaves*". The roof has no gutters to collect water from the roof (Greyling, 2009). In cases of intense rainfall buildings become susceptible to flooding due to excessive runoffs. South Africa is identified as water scarce country and thus methods of saving water are crucial so to curb the effects of droughts predicted over South Africa due climate change (du Plessis, Irurah and Scholes, 2003).

2.4.4 Environmentally sustainable dwellings

2.4.4.1 Building Orientation

Conradie (2012: 2) state that "it is important to understand the climatic conditions of the site and their impact on the building". In many climates the optimum orientation would be a north-south orientation with the long façade facing towards the equator minimizing the façade areas facing east and west (SANS204, 2011).

The TIASA states that "a building should be designed to respond to the site conditions to maximize free solar access and energy (2010:21). The diagram below shows the preferred building orientation. Due to mass production, RDP houses were not orientated according to the site characteristics and thus, related in some RDP dwellings having poor thermal performance. The attached RDP dwellings at Y Umlazi were positioned as the diagram showing poor orientation below.

Figure 13: Building Orientation

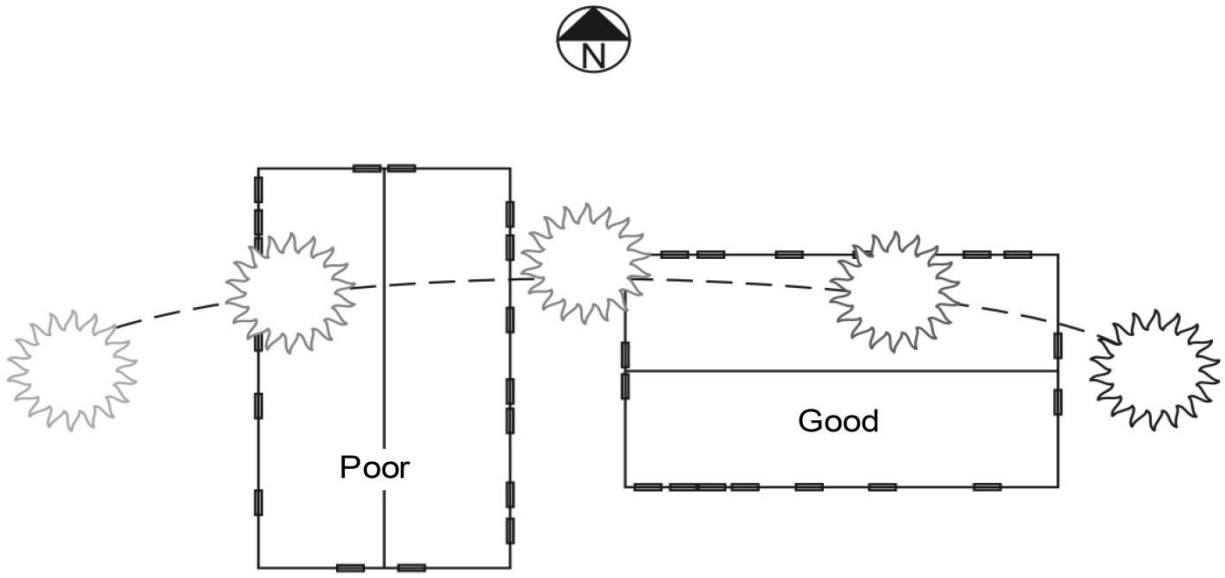


Figure 13 sourced from google

2.4.5 Energy Efficient buildings

Energy efficiency is an important subject in the sustainable housing discourse. This is partly because it holds the potential to reduce GHG emissions and thus, mitigate climate change and also, able to assist households to adapt to climatic changes hence, strengthen their resilience. The Leadership in Energy and Environmental Design LEED which is an United States America, green building rating system pioneered by the US Green Building Council (USGBC) has created a globally applied credit system which awards developers on each aspect of the sustainable housing and optimizing energy performance is one of the aspects of buildings credited for, when achieved (Cidell, 2009). Ching (2008: 24) states that *"the siting, orientation and construction assemblies of a building should minimize heat loss to the outside in cold weather and minimize heat gain in hot weather".* TIASA attests that "*energy smart homes can be up to 5 degrees warmer in winter and up to 10 degrees cooler in summer, making the home brighter and more comfortable to live in throughout the year*".

2.4.6 Passive buildings

According to TIASA (2010: 20) passive buildings have a *"design that does not require mechanical heating or cooling".* Kelvin and Meyer (n.d: 1) argues that *"The thermal efficiency of a building is primarily affected by the meteorological factors surrounding the building"*. Kelvin and Meyer (n.d) findings indicated that due to the low quality of the walls (bricks and concrete) materials used during the construction of RDP houses, the buildings have a low R-value thus, highly affected by the outdoor weather. R-value refers to the thermal resistance of a component (TIASA, 2010). Ching assess passive solar building design and concludes that *"passive solar heating refers to using solar energy to heat the interior spaces of a building without relying on mechanical devices that require additional energy*" (2008: 234). The Norms and Standards (2009: 35) identify the following as the most basic principles to achieve thermal efficiency in RDP dwellings. These include:

a) The longer axis of the dwelling should be orientated so that it runs as near east/west as possible;

b) The dwelling should be compact in plan with the rooms that are used most and the major areas of glazing placed on the northern side of the building to allow solar heat to penetrate the glazing during the winter months;

c) The roof overhang to the northern wall should be sufficient to shade the windows from midday summer sunshine; and

d) Windows facing east and west should be limited in number and confined in area to the minimum required for daylight and ventilation.

2. 5 Ecosystems services

Environmental degradation caused by growing economic growth after the Second World War became a major concern in developed countries (United Nations, 1987). Environmental concerns led to the United Conference on Human and Environment in Stockholm in 1972 which was preceded by the Brundtland Conference in 1987. The meetings resulted in the formulation of a more environmental conscious development framework 'sustainable development'.

The environment refers to both the natural and built environment while sustainability according to the Penguin English Dictionary (2003; 1418) defines sustainable as "*able to be maintained at a fixed level without exhausting natural resources".* Goodland (1995:3) states that "*environmental sustainability seeks to improve human*

welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans". Ekins (2011:64) defines environmental sustainability *"as the maintenance of important environmental functions and hence the maintenance of the capacity of the capital stock to provide those functions".* This implies that environmental sustainability can only be achieved if the production (source) and consumption (sinks) are kept within sustainable limits (Goodland, 1995).

Ecosystem services determine the sensitivity of the RDP dwellings and its ability to adapt. Undermined ecosystem services will increase the sensitivity of the system and decrease the adaptive capacity thus, resulting in increased climate vulnerability. Ecosystem services represent the biophysical environment of the RDP dwellings. It is important therefore, to ensure that sensitivity is kept low whilst adaptive capacity is heightened to ensure that climate vulnerability is reduced.

The primary objective of environmental sustainability is to sustain global life-support systems Goodland, 1995). Life-support systems can also be referred to as ecosystem services or the natural capital these include; provisioning services, regulating, cultural and support (Ekins, 2011). Life-supporting services ensure the well-being of humans (Landsberg et al, 2011). De Groot in Ekins (2011: 631) defines environmental functions also referred to as ecosystem services as "*the capital of natural processes and components to provide goods and services that satisfy human needs*". Reid, et al (2005; 5) states, *"Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fibre; regulating services that affect climate, floods, disease, waste and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling".*

Origins of environmental sustainability were rooted in, the general concern for the natural environment attempts to achieve environmentally sustainable development has thus, focused on environmental protection and thus has tended to overlook the social and economic pillars of sustainable development (Prochorskaite and Maliene, 2013). Environmentally sustainable housing is housing which in harmony with the natural environment (Ross, 2010). Environmentally sustainable housing must ensure

that the source and consumption levels for settlements development and maintenance are kept within sustainable limits.

2.7 Chapter Summary

This Chapter presented the conceptual and theoretical framework influencing this research study. The main concepts and theories that were discussed include: climate change, vulnerability, and sustainable housing and ecosystem services. The research adopted Creswell's' research design framework and selected the pragmatic philosophical assumptions. These are concepts and theories based on real-world orientated practice, problem cantered and they are based on consequences of action. Climate change is a result of human interference with nature and thus, is a theory formulated to first, understand the nature of the problem and secondly, develop response measures.

Sustainable housing is a theory developed to deal effectively with climate change hence is an action of consequence. Vulnerability also is a problem that, in this particular case has been enhanced by the existence of change and thus, real-world solutions are required to deal appropriately with the problem. Dowing and Patwardhan (2003) identify similarities existing within current definitions of climate change vulnerability of systems these include threat, region, the sector, the population group, the consequence and time period.

The term vulnerability has a very broad meaning and thus, sometimes difficult to define. Within the climate change discourse, the Intergovernmental Panel on Climate Change (IPCC) formulated a definition of vulnerability which would be suited for application of this term in the Climate Change discipline. Vulnerability has varying frameworks including: the risk-hazard and the double structure of vulnerability. Climate Change vulnerability is entrenched in the risk-hazard framework. To assess the vulnerability of a system to climate change vulnerability assessments such as the Climate Change Assessments (CIA), Vulnerability Assessments (VA), and the Adaptation Assessments (AA). It is important to understand the system at threat to impacts of climate hence; the following heading discusses RDP housing.

Chapter Three: Literature Review

3.1 Introduction

The literature review discusses the works of various authors that have contributed to the body of literature within this specific field of study. To explore the research topic one was required to examine literature on settlements, climate change and vulnerability. The purpose of reviewing literature was to compare and contrast different views on issues of settlements, vulnerability and climate change. The researcher argues that RDP settlements are vulnerable to climate change and that climate responsive consolidation methods would improve the adaptability of RDP settlements, thus decreasing their vulnerability to impacts of climate change. The researcher thus, explored literature that supported or refuted this argument. The chapter will first discuss the various definitions of climate change, vulnerability and settlements. Secondly, various arguments relating to this study will be assessed, and lastly, a conclusion providing a summary of the work discussed in this chapter is presented.

3.2 Definitions of terms

The broad application of the term 'vulnerability' by various scholarly communities led to the emergence of various definitions of the term (Fussel, 2005). This created a difficultly and confusion when attempts were made to apply the term within climate change literature (Fussel, 2006; Birkmann, 2006). Timmerman (1981) citied in Fussel (2007:155) argued that *"vulnerability is a term of such broad use as to be almost useless for careful description at the present, except as a rhetorical indicator of areas of greatest concern*". In defining vulnerability, Smit *et al* (2000) and Turner *et al* (2003) identify harm and exposure of system to impacts of climate change as the key component determining vulnerability of a system. Whilst Adger and Kelly (2000); Parry et al (2007) and Blaikie et al (1994) do mention these components, they go further to reiterate the importance of a system's ability to cope with impacts, resist and recover from an impact. Fussel (2005) and Parry (2007) group these components of vulnerability into the following categories:

Exposure is a measure of the magnitude and extent (i.e., spatial and temporal scales) of exposure to climate change impacts.

• Sensitivity is a measure how a system is likely to respond when exposed to a climate-induced stress.

• Adaptive capacity is a measure of the potential, ability, or opportunities available to decrease exposure or sensitivity of a system to a climate induced stress (i.e., adapt).

The Climate Change North, 2004 cited in Hounsome et al (2006:6) define climate change as "*changes in the average climate of the earth as a whole, including temperature increases (global warming) or decreases, and shifts in wind patterns and precipitation. These global impacts will in turn impact the average weather that a particular region will experience".* Hounsome (2006); Magadza (2000); Smit and Pilifosova (2007) all concur on that observed changes brought about climate change include: changes in temperature, precipitation, changes in snow and land, changes in sea level, changes in atmospheric and oceanic circulation patterns and changes in climate variability and extreme weather events.

Housing in the South African Housing White Paper (1994: 18) is defined as "*a variety of processes through which habitable, stable, and sustainable residential environments are created for viable households and communities"*. Many definitions of housing/settlements attach the element of UN-HABITAT (2012). The Housing White paper (1994) and Golubchikov Badyina (2012) agree that the primary function of a house should be to protect the households and house contents from external factors including climate.

3.3 Impacts of Climate Change

Scott et al (2007) and Hounsome (2006) concur that climate change has both direct and indirect impacts on settlements. Ajibade and McBean (2009); Magadza (2000); Roberts (2008) recognize the following climate change induced effects as those affecting settlements: sea level rise, impacts on water resources, floods and droughts, food security, increase in health risks from vector borne diseases and increased temperatures. Extreme weather events such as floods, hurricanes and heatwaves would form part of direct impacts whilst food security and increase in diseases forms part of indirect impacts.

3.4 Settlements' vulnerability to impacts of climate change

Ajibade and McBean (2009) and Magadza (2000) firstly, identify settlements as one of the sectors exposed to impacts of climate change and secondly, the authors agree that settlements located in Africa and other developing countries are more susceptible to impacts of climate change. Smit and Pilifosova (2007) argue that the heightened vulnerability of settlements in developing countries is as a result of non-climatic stressors such as poverty, lack of access to information, diseases and poor political and governance structures. Burton *et al* (2004) confirms that the adaptive capacity of a system is determined by the resources available for adaptation initiatives.

Du Plessis (2006) and Jongeling et al (2001) argues that housing construction in developing countries fails to conduct housing construction that is socially and ecological sustainable. Bond and Tait citied in Adebayo and Adebayo (2000) identify the insufficiency the housing subsidy amount as one of the challenges which hinders the South African government from providing decent accommodation. Amisi (2013); Block et al (2011) and Adebayo and Adebayo (2000) concur that the mass housing production of RDP settlements resulted in the quality of dwellings being poor. These factors increase the vulnerability of RDP settlements to climate change.

The RDP settlements were delivered through the once-off project-linked subsidy programme (Huchzermeyer, 2001). The programme provided housing subsidy to households based on an income sliding scale approach (Huchzermeyer, 2001). Only low-income households earning between R0.00 – R3500.00 qualified for the subsidy (Mackay, 1999). The subsidy programme delivered houses through a centralized housing delivery framework (Mackay, 1999). Local government acted as implementers of the programme and contracted private developers to construct the RDP settlements (Amisi, 2013). Adebayo and Adebayo (2000) argue that for low-income housing developments to be sustainable, the programme needs to be delivered through a supporter paradigm. The Environmentally Sound Task Team did acknowledge the need for additional subsidy 'green bonds' financing environmentally sound low-income housing improvements however, the lack of government funds does not allow for this (2004). Failure to consider the environmental performance of

dwellings increased the vulnerability of RDP dwellings to climatic changes (Donaldson-sebly et al (2007) and Winkler (2002).

Lack of finance hinders RDP households from consolidating their dwelling (Adebayo and Adebayo, 2000). This means households cannot use consolidative methods to adapt to climatic changes, making them more vulnerable to impacts of climate change. Amisi (2013) and Tissington (2010) argue that RDP settlements were located on the urban periphery afar from socio-economic opportunities such as employment. Lack of financial resources to consolidate the house decreases the adaptive capacity of the RDP dwelling.

Scholars within this field agree that the poor location of settlements in developing countries is a result of poor access to funding and the desire to access natural resources. These factors have contributed to the increased vulnerability of settlements to impacts of climate change. Magadza (2000) elaborates on how access to natural resources has driven communities in Asia, Japan and Africa to build on hazards prone zone such as river banks, low-laying areas, coasts, wetlands and floodplains. Amisi (2013) and Tissington (2010) posit that due to limited subsidy funding RDP settlements were located on poor land on the urban periphery. The United Nations Framework for Climate Change (1992:30) declared that there is a need to *"assist the developing country parties that are particularly vulnerable to adverse effects of climate change in meeting the cost of adaptation*".

The notion of sustainable housing has thus gained prominence. Whilst Premius cited in Winston (2009) defines sustainable housing based on present and future functional needs. Golubchikov and Badyina (2012) on the contrary identify the impact orientated relationship between housing and natural environment as the key determinant of how one affects the other. Prochorskaite and Maliene (2013) reiterate on the fact that sustainable housing is now used to refer to environmentally sustainable housing and further argue that greater consideration of health and well-being of households within the concept of 'sustainable housing' can help shift the focus from environmental protection to the other pillars of sustainable development. Du Plessis et al cited in Bowen (2009); and Goebel (2007) affirm that environmental aspects of RDP dwellings were not considered during construction and design process.

Winkler (2002); Kelvin and Meyer (n.d) and Irurah (2000) argue that RDP settlements have poor thermal performance thus, changes in temperatures easily affects the comfort of households. Whilst Conradie (2012) and Du Plessis emphasize the importance of understand the climate of the area proposed for housing development. According to Ching (2008: 226) “thermal comfort is achieved when the human body is able to dissipate the heat and moisture it produces by metabolic action in order to maintain a stable, normal body temperature”. The South African National Standards (SANS 204 -2, 2008) formulated a climatic zone map which is aimed at informing building constructor of the type of building materials and building designs suitable in different climatic zones (TIASA, 2010). This will therefore, ensure that buildings are ‘climate responsive’ and thus, will optimize all the affecting human comfort (Conradie, 2012). Durban is located in zone 5 and therefore receives sub-tropical climate.

Figure 14: Climatic Zone Map of South Africa

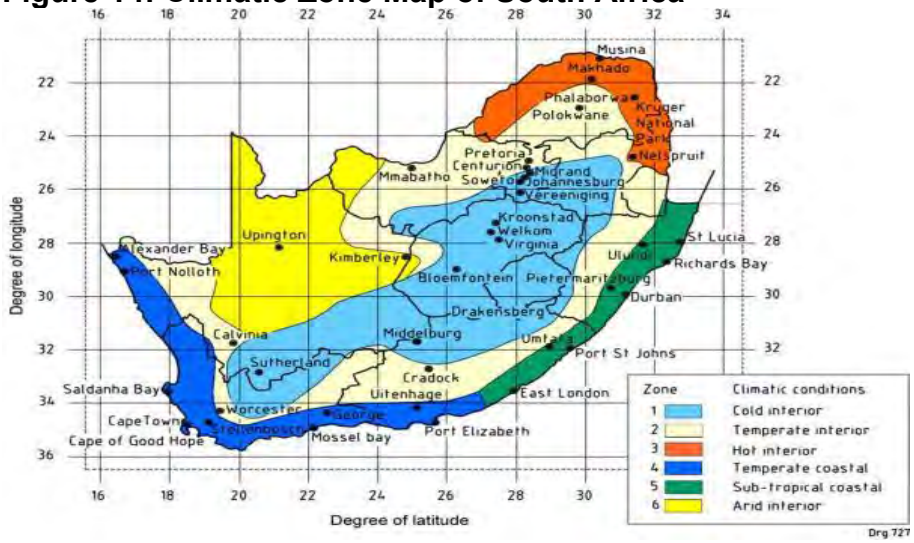


Figure 14 sourced from Thermal Insulation Association of South Africa (2010:37)

3.5 Housing policy responses

On a sectoral spectrum, The HABITAT: United Nations Conference on Human Settlements in 1976 conceived the Vancouver Declaration on Human Settlements and presented a plan of action which was to ensure that human settlements contribute positively towards the achievement of sustainable development. South Africa, being signatory to climate change and sustainable development international

agreements such as the United Nations Framework Convention on Climate Change UNFCCC, The Kyoto Protocol, Agenda 21, the Millennium Development Goals, The Istanbul Declaration on Human Settlements and many more; necessitated that the country's development policies are aligned to the international overarching development framework (Laros, 2012; Richards, 2008).

Section 24 of The South African Constitution (1996) states that "*all citizens have the right to a healthy environment and to have the environment protected"*. Chapter 2 of the South African Constitution, section 26(1) outlines: *"everyone has the right to have access to adequate housing"*. The Constitution being the highest law therefore, sets a national development framework within which all government departments are to adhere to when developing policy responses. In response to climate change, the Department of Environmental Affairs and Tourism (DEAT) undertook "South Africa's Initial Communication under the United Nations Framework Convention on Climate Change" study (Hounsome, Iyer and Naidu, 2006; Department of Environmental Affairs, 2011). The Department of Environment Affairs in 2004, formulated the National Climate Change Response Strategy and the National Climate Change Response White Paper in 2011 (Laros, 2012). The White Paper identifies human settlements as one of the key sector that is vulnerable to impacts of climate change. A response to the challenges identified by the White Paper as a follows "...in the *implementation of low cost housing, ensure to incorporate thermal efficiency into designs and use climate-resilient technology…"* (Department of Environmental Affairs, 2011).

The South African housing sector developed a vision aligned to the overarching sustainable development framework. Also, the mission of The Housing Act (107 of 1997) was to facilitate in the creation of sustainable housing development process. In attempts to achieve sustainable development the Department of Human Settlements introduced the following policy responses: Ministerial National Norms and Standards for Permanent Buildings, National Housing Codes (2000) and revised National Housing Codes (2009). Although the abovementioned measures would indirectly respond to challenges of climate change they were not necessarily pioneering issues of climate change (Department of Human Settlements, 2009) The Environmentally sound low-cost Housing Task team was one of the most direct responds to climate change initiated by the Department of Human Settlements.

For the successful implementation of climate change policies the municipality first developed municipal structures; the Environmental Management Department (EMD) which was later converted to the EThekwini Climate Change Protection Department (ECCPD). EThekwini Municipality in response to national policies on climate change has formulated the following local-level initiatives: The Durban Headline Climate Change Adaptation Strategy (2006), the Environmental Services Management Plan (ESMP), the EThekwini Municipal Climate Protection Programme (MCPP), and The Durban Adaptation Charter (Laros, 2012). The municipality addressed the vulnerability of climate change to impacts of climate change under the broader term 'infrastructure' (EThekwini Environmental Management Department, 2007; Hounsome and Iyer, 2006).

Climate Change is a cross-cutting issue and therefore, requires policy responses which are all encompassing. Mokwena (2009; 20) identifies the following challenges as hampering successful implementation of climate change response at the EThekwini Municipality: A lack of coordination between the various departments within the municipality and a lack of coordination across the different spheres of government. To effectively respond to issues of climate change, The EThekwini Human Settlements Department has to pioneer climate change policy responses focused on the human settlements sector and work cohesively with the EThekwini Climate Change Protection Department. Furthermore, the department needs focus on developing climate change responses for the different public housing programmes that the government has implemented including the Reconstruction and Development Programme housing (RDP Settlements).

An ecosystem-based adaptation model to climate change has been developed which encourages communities to take stewardship of their ecosystems (eThekwini Muncipality , 2011). Golubchikov and Badyina (2012) accentuates that a key element of making housing resilient to climate change is by ensuring a good network of green spaces within a neighbourhood. The green network of an area supports the natural ecological processes important for the survival of humans and an essential component of local climate management strategies, important for both climate adaptation and mitigation Golubchikov and Badyina (2012); Donaldselby et al (2007)

3.6 Chapter Summary

The purpose of this chapter was to conduct a review on literature relevant to the research topic. Literature on climate change vulnerability, settlements and climate change adaptation was discussed. The chapter provided an insight into the various arguments that support or refute the research hypothesis.

Chapter Four: International Experience

4.1 Introduction

This chapter presents cases on international experience based on how settlements have been impacted by climate change and the response mechanisms adopted to cope, recover or adapt to the situation. The focus will be entirely on settlements. The researcher has selected the following case studies: Hong Kong, Brazil and Singapore. Firstly, the South African experience will be discussed followed by the abovementioned international experiences and lastly, a conclusion to the chapter will be provided.

4.2 Background

Failure by government to deliver environmentally sustainable low-income housing in urban areas is not a problem peculiar to South Africa. Both developed and developing countries have at some point struggled to prioritise the environmental pillar of sustainable development when delivering low-income housing. In most cases government funded housing, tends to focus on achieving the economic pillar in attempts to provide affordable low-income settlements in urban areas (Chan and Chan, 2002)

4.3 South Africa

4.3.1 Impacts of climate change on settlements in South Africa

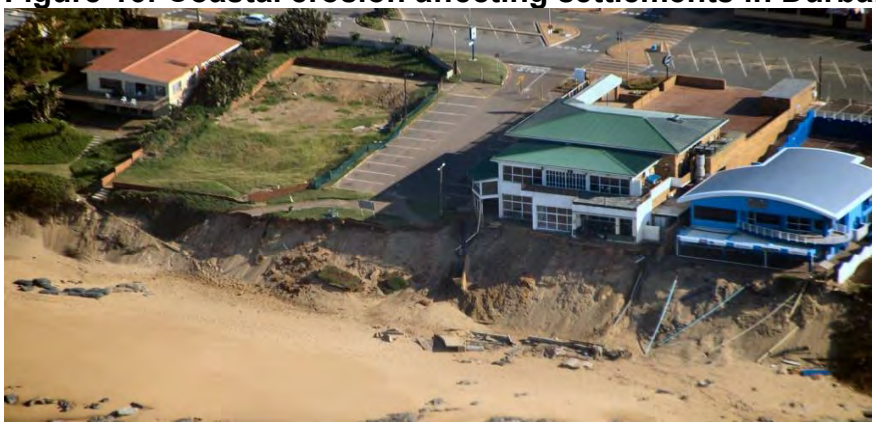
In South Africa settlements are observed to be impacted by the following climate change effects: flooding, seal level rise, droughts and extreme hot or cold temperatures (Hounsome et al, 2006). Below are pictures showing the effects of climate change on settlements in South African cities. The first picture shows the Isiqalo informal settlement located in Cape Town, South Africa. Cape Town is a low-laying region which makes settlements vulnerable to flooding. The level of vulnerability of settlements is also determined by the settlement type. Informal settlements are more vulnerable when compared to low-income subsidised housing. However, this is not to say that RDP

settlements are not vulnerable to impacts of climate change. The second picture shows high-income settlements of Ballito, Durban that had been affected by the 2007 coastal erosion.

Figure 15: settlements in South Africa impacted by climate change

Picture sourced from google

Figure 16: Coastal erosion affecting settlements in Durban



Picture sourced from google pictures

4.3.2 Response mechanisms to addresses climate change vulnerability

The National Climate Change Response Green Paper (2010: 25-31) identifies the following solutions to impacted settlements located in rural, urban and coastal regions: support the development of energy efficiency and renewable plans; encourage settlement planning and design that is resilient to climate change; develop adaptation strategies that encourage conservation agricultural practices;

design and implement livelihood diversification programmes in rural areas; and ensure that long-term planning for coastal areas incorporates relevant climate information.

In 2011, preceding to the COP 17 conference a study was conducted by the Green Building Council of South Africa entitle (GBCSA) “Improving lives by greening low-cost housing”. The study was undertaken at a township called Cator Manor in Durban. The task team identified elements of the RDP dwelling that could be improved so to achieve sustainable buildings (GBCSA, 2012). Amongst the buildings elements which they improved was the roof as they saw the need for roof gutters and ceiling boards for water harvesting purposes and improved indoor thermal comfort (GBCSA, 2012). RDP dwellings do not have roof ceilings which affects the thermal performance of buildings negatively (Greyling, 2009). Ceilings act is effective insulators (BESG, 2000). The picture below shows constructors adding the building materials to improve the sustainability of RDP dwellings at Cator Manor.

Figure 17: RDP dwellings upgrade

Sourced from: Green Building Council of South Africa entitled (GBCSA: 5 and 10)

Figure 18: RDP houses with solar water heater in Waterloo, Durban

Picture sourced from: EThekwini Municipality Report (2011/2012).

The picture above shows RDP settlements in Waterloo, Durban with solar water geysers. The EThekwini Municipality implemented this programme with the aim of mitigating climate change by reducing Greenhouse Gases contributed by households (EThekwini Municipality, 2011/2012).

4.4 Hong Kong

Hong Kong is a city located south east border of china (Hong Kong Government, 2008). It has a population of 7 million (Hong Kong Government, 2008). China is referred to a developing country in economic terms same as South Africa. Hong Kong became a Special Administration Region (SAR) governed by the People's Republic of China in 1997 (Hong Kong Government, 2008). Hong Kong experiences sub-tropic climate (Hong Kong Government, 2008). As most developing countries witness ever increasing urban densities population so has China, Although Hong Kong is considered to highly populate when compared to other cities in developing countries (Dwyer, 1971). Thus, increasing demand for affordable low-income housing in urban areas (Dwyer, 1971).

Since the outbreak of the Shek Kip Mea fire in 1953, the Hong Kong Housing Authority (HA) has been providing subsidized public rental housing in urban areas (Fung Yan, no date). To shelter the 50 000 people that were left homeless due to the fire the Housing Authority focused on providing mass low-income housing (Fung Yan, no date). The Housing Authority was established in 1973 with the aim to help low-income families' access affordable housing (Housing Authority Annual report 2013/2015). The housing delivery was quantity driven (Fung Yan, no date). One

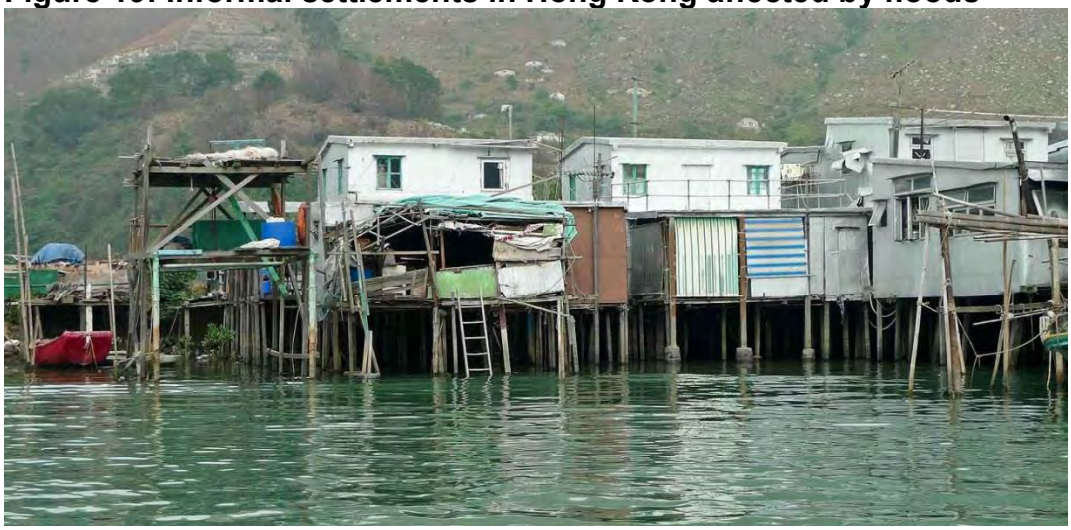
room houses with poor layout and no consideration at all of environmental factors. In 1961, the public Low-cost Housing programme was formally introduced to provide affordable flats to low-income households (http://www.housingauthority.gov.hk/).

Over one-third of the population lives in public housing and public housing stock accounts for 680 000 of the residential flats (John, no date). As the years passed, the focus of the Housing Authority shifted from a quantity driven delivery process to a one that seeks to achieve quality and sustainable low-income settlements (Environmental Protection Department, 2010). It is thus, the mission of the Hong Kong Housing Authority (HA) to provide subsidized public rental housing to low-income families (Fung Yan, no date). To achieve sustainable housing development, the HA has implemented initiatives such as: The Sustainable Public Housing Design, The Universal Design, Site Specific Design, Environmentally Responsive Design (Environmental Protection Department, 2010).

4.4.1 Impacts of climate change on settlements in Hong Kong

Based on the above projections the Hong Kong Observatory adopted the IPCC Framework for Vulnerability Assessment to identify vulnerable sectors. The framework is made up of four main stages: exposure and sensitivity analysis, identification of potential consequences, climate change impacts and vulnerability assessment and selecting 'key' vulnerabilities (Environment Protection Department, 2010). The built environment and infrastructure was identified as one of the sectors vulnerable to impacts of climate change (Oxfam Report, 2010). The HKO identified the following as projected impacts of climate change on the built environment and infrastructure: developments located on low-laying areas reclaimed land are highly sensitive to climate change; heavy rain, thunderstorms and extreme weather leading to the damage of buildings foundation, increase risk of rain penetration into building fabric and damage to utilities, cabling and pipes; and potential asset damage because of flooding, landslides, wing damage, storm surge and lightning strike (Oxfam Report, 2010).

Figure 19: Informal settlements in Hong Kong affected by floods

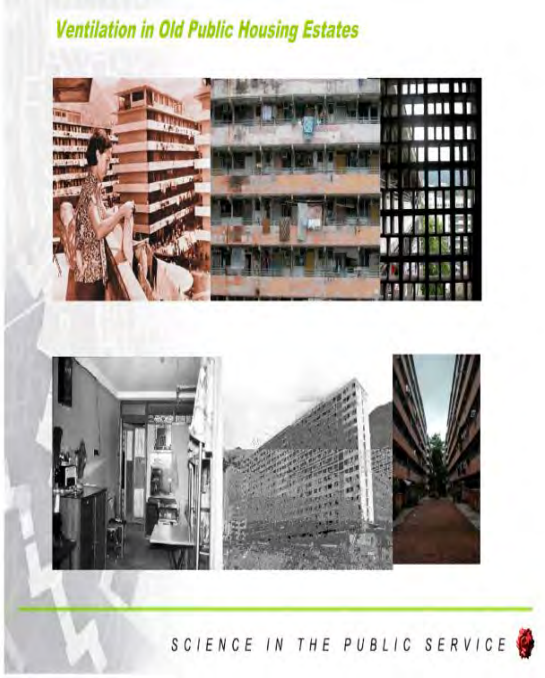


Sourced from http://flood-control-international.blogspot.co.za/

4.4.2 Response mechanisms to climate change vulnerability

In 2004, the HKHA introduced new policies which were to guide the Environmentally Responsible Development Policy which promotes healthy living, Green Environment and Sustainable Development http://www.housingauthority.gov.hk/). To realize this policy within the public housing sector the HKHA introduced 'the Micro-climate studies' which focused on achieving sustainable housing by maximizing the following building elements: wind environment, natural ventilation, natural daylight, solar heat gain, heat island effect and pollution dispersion http://www.housingauthority.gov.hk/). John (no date: 1) defines micro-climate as "*the local modification of the general climate that is imposed by the special configuration of a small area".* Before the implementation of sustainable housing development policy, public housing had poor environmental quality (Chan and Chan, 2002). The pictures below show public housing flats before implementation of the micro-climate studies and after the introduction of environmentally sustainable housing practice.

Figure 20: Depiction of public housing in Hong Kong



Sourced from: http://www.housingauthority.gov.hk/

Hong Kong is a city that experiences similar weather patterns as Durban as they are both located in the sub-tropics. Hong Kong has implemented high level technology innovation in addressing vulnerability of settlements to impacts of climate change. The city has adopted the 'micro-climate building designs' strategy to ensure the development of environmentally sustainable dwellings. Hong Kong has succeeded in delivering environmentally sustainable public housing and this has decreased the vulnerability of households to impacts of climate change. South Africa can also learn a lot from Hong Kong with regards to adapting RDP dwellings to climatic changes.

4.5 Brazil

Brazil is located in South America and experiences an equatorial climate (http://www.brazil.org.za). Climate observation in Brazil over the period 1960 – 2010 shows an increase in temperature both summer and in winter; and a small increase in annual precipitation (Department of Energy and Climate Change, 2011). Climate Change induced changes has resulted in Brazil experiencing an increase frequency of extreme weather events such as floods, prolonged droughts, heat waves, sea level rise, typhoons and tornados (Department of Energy and Climate Change,

2011). The Department of Energy and Climate Change (2011) believes this is induced by climate change. Settlements in Brazil are affected by direct effects such as floods and indirect effects such as droughts.

The pictures below show a typical one family unit public housing. Kowaltowski et al (2006:1101) argues that *"low-income housing developments are slow in adopting recommended practices and perpetuate a standard design model often not adapted to specific geographic and social situations".* The CHDU (Companhia de Desenvolvimento Habitacional e Urbano do Estado de Sao Paulo), housing company produced majority of the public houses in Brazil (Kowaltowski, 2006). However, houses produced by this company are said to inhabit poor settlement planning and layout design (Kowaltowski, 2006). The Urban, Water and Disaster Risk Management Report (2011) explains most homes in brazil as being built from pre-fabricated concrete blocks and/or ceramic bricks. Roofs are constructed of concrete slabs, wood, or steel frame with ceramic or PVC shingles (Urban, Water and Disaster Risk Management Unit, 2011). These settlements are usually located in poor land on the urban periphery. (Urban, Water and Disaster Risk Management Unit, 2011).

Figure 21: Depicts typical one family unit public housing in Brazil

Sourced from Kowaltowski et al (2006: 1104) and (Urban, Water and Disaster Risk Management Unit, 2011: 8).

4.5.1 Impacts of climate change on settlements in Brazil

In 2006, Brazil experienced heat waves which perpetuated the drought that was already affecting the state (Department of Energy and Climate Change, 2011). Some

regions experienced extreme temperature of over 40 degrees Celsius (Department of Energy and Climate Change, 2011). These are said to be amongst the highest temperatures during the last 40 years (Department of Energy and Climate Change, 2011). In 2010, Brazil lost lives to hypothermia and pneumonia due to extreme cold temperatures. These are some of the temperature extremes that have immensely affected Brazil.

Precipitation extremes include the drought of 2010 and the flooding of 2009 (Department of Energy and Climate Change, 2011). The droughts resulted in forest fires which affected the Amazon forest. Droughts have indirect impacts on settlements such as food shortages. The floods and mudslides affected over 186, 000 people (Department of Energy and Climate Change, 2011). Settlements and indoor contents were destroyed by the floods. The picture below shows one of the areas affected by the floods.

Figure 22: Settlements in Brazil affected by floods

Picture sourced from google

4.5.2 Response mechanisms to climate change vulnerability

The housing sector in Brazil view implementing sustainable housing practices as an opportunity to build hazard-resistant and climate adaptive housing developments (Urban, Water and Disaster Risk Management Unit, 2011). Housing constructions in Brazil are seen to have negative environmental impact on the environment. To rectify this, Product Certification Programs such as the PROCEL, ENCE and Acao Madeira Legal of IBAMA are promoted (Urban, Water and Disaster Risk Management Unit, 2011). Such certifications have been created to make the consumer aware of a

housing product is environmentally friendly or not (Urban, Water and Disaster Risk Management Unit, 2011). Brazil has Green building certification programmes these include: The leadership in Energy and Environmental Design (LEED), the AQUA and the Selo Casa Azul (Urban, Water and Disaster Risk Management Unit, 2011).

The Brazilian housing sector identifies opportunities for achieving sustainable housing within the attempt to develop hazard-resistant and climate adaptive housing. The following sustainable housing practices are recommended: water conservation and water-efficient technologies, energy efficiency (passive buildings), improved indoor air quality (ventilation), and improved layout design (Urban, Water and Disaster Risk Management Unit, 2011). The Urban, Water and Disaster Risk Management Unit Report (2011) identifies the use of financial and regulatory incentives as way to promote green building housing developments. The incentives become available to housing developers that apply green building standards.

4.6 Chapter summary

The purpose of this chapter on international experience was to present different experiences which could be related South Africa's experience. The international inquiry was to identify if public housing in other countries are affected by climate change and explore their adaptation responses. The chapter discussed Hong Kong and Brazil. Both these countries have an economic growth pattern that is similar to South Africa making their experience easy to relate to. The inquiry indicated that public housing developments in the countries were also vulnerable to impacts of climate. The interventions were discussed in detail.

Chapter Five: Data Analysis and Discussion

5.1 Introduction

The objective of this chapter is to present and analyse research findings from data collection from an interview with a housing official and from the case study, Umlazi Y section. A multilevel mixed method analysis was applied were both quantitative and qualitative techniques were applied to analyse data. The quantitative findings were used to complement the qualitative research findings. For qualitative findings a thematic data analysis method was applied. The themes were developed using the research questions. The following themes were formulated: climate change impact, climate change vulnerability, and adaptation intervention measures.

5.2 Overview of data collection process

Within mixed methods research the data analysis process is structured in such a way that both sets of data methods (qualitative and quantitative) are represented and integrating to achieve the best results (Johnson and Onwuegbuzie, 2004). Mixed analysis is the terminology applied for analysing data in mixed research. Within the vulnerability assessment methodology adopted by the researcher, both qualitative and quantitative data collection methods were used. The methods were applied concurrently for complementary purposes.

Data was collected on the following dates 31 November 2015; 9 and 10 December 2015. An appointment was set with the key informant from the eThekwini Municipality Human Settlements and Infrastructure Unit. A semi-structured interview was conducted with the official and took approximately 30 minutes. The researcher took notes during the interview. Household data was on collected on the 9 and 10 December 2015. Temperatures in Durban were at a maximum of 25 and 27 degrees Celsius. Data was collected between 10am and 15:30pm. A mercury thermometer was used to collect indoor temperatures. The dwelling elongation assisted fieldworkers to determine the orientation of the building. Building with the long façade horizontally were facing west or east whilst those with the long façade vertically were facing south or north. Fieldworkers also took pictures to support their observations. A closed ended questionnaire was used to collect data from households.

5.3 Research Findings

5.3.1 Climate change impact

79% of the households said climate change does affect them whilst 21% said no, climate change does not affect them

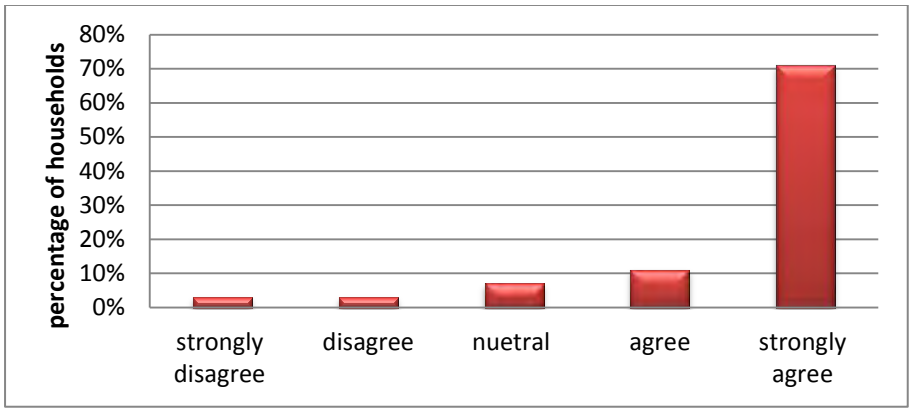
Table 3: Effects of climate change on households

Too hot
Water scarcity
Too much moist
Requires change in lifestyle
Causes dampness

Author (2016)

Majority of the households said they have noticed increase in indoor temperature. Households said they use cooling mechanisms to adapt to increased indoor temperatures. Ability of households to adapt decreases their vulnerability to climate change. 27 houses were measured for indoor temperatures using a mercury thermometer. Most RDP dwelling had their long façade facing east and west and not north and south as recommended. All houses were experiencing above normal maximum indoor temperature of 27 degrees Celsius. Some of the dwellings experienced a maximum indoor temperature of 35 degrees Celsius. Households have decreased their sensitivity by using cooling mechanism however; the poor orientation of the building undermines their efforts.

Figure 23: Households who have noticed increased indoor temperatures



Amongst effects of climate change as identified by the respondents water scarcity and inability to continuing performing agricultural activities were noted. Some households perform subsistence farming as a livelihood strategy. Households complained that the drought being experienced in Durban had destroyed their produce. Households planted spinach, cabbage and mealies but could not harvest as there was less produce that survived the drought. When asked if they used the water from eZimbokodweni river- households said no, the river was too far from the garden thus, it would be strenuous to carry water buckets from the river to the garden. Due to poor quality and scale of produce households have been forced to use their money to buy vegetables for cooking.

Figure 24: communal garden at Y section affected by drought

Source: Field survey

Table 4: households using cooling mechanisms

Answer	Percentage of households
Yes No	86% 14.%
Total	100%

Source: Field survey

Majority of the households said they have noticed increase in indoor temperature. Households said they use cooling mechanisms to adapt to increased indoor temperatures. Ability of households to adapt decreases their vulnerability to climate change. 27 houses were measured for indoor temperatures using a mercury thermometer. Most RDP dwelling had their long façade facing east and west and not north and south as recommended. All houses were experiencing above normal maximum indoor temperature of 27 degrees Celsius. Some of the dwellings experienced a maximum indoor temperature of 35 degrees Celsius. Households have decreased their sensitivity by using cooling mechanism however; the poor orientation of the building undermines their efforts.

Table 5: effects of increased indoor temperatures

1. Excessive sweating
2. Tiredness
3. Skin rash
4. Coughing
5. Increase prevalence of asthma
6. Increased mosquitoes
7. Increased bed bugs

Source: Field survey

Over 84% of the households are negatively affected by increased indoor temperatures. Most respondents identified health related stressor induced by such changes. Again, compromised health of household members results in increased sensitivity and decreased adaptive capacity. One female respondent mentioned that she uses her neighbour's house to lay her infant as her house is too hot during the day.

Figure 25: showing soil erosion and poor drainage system

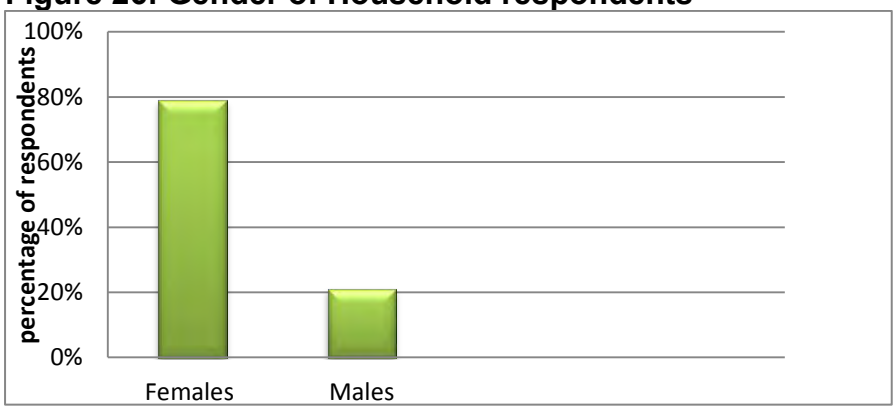
Author (2016)

90% of households experience flooding. Households said water enters the interior of the house through leaking building components. This results in interior dampness of walls and wet floor. Most households agreed that flooding negatively affects comfort of household members. The negative effects of this condition as expressed by households included the following: house ends up having a bad odour due to dampness; dampness damages furniture and clothes; it increases mosquitoes in the house; households tend to suffer from sinus and asthma; and an increase of household members with skin rash. Again, poor quality of the dwelling increases it sensitivity to impacts of climate change. Poor health status of household members could further undermine the adaptive capacity of households. Human resources is a tool households can use to improve/consolidate the dwelling. If household members are not healthy there are unlikely to apply their skills. This will result in increased sensitivity and a decrease in adaptive capacity resulting in increased vulnerability to climate change.

5.3.2 Climate change vulnerability

Majority of the respondents were females and were unemployed. Respondents were still between the economically active age group which is 18 – 64. Compared to males, females find it more difficult to access job opportunities and this further undermines their adaptive capacity. Unemployment hampers households from having access to financial resources and other resources accessed through money. Unemployment acts as a social stressor undermining the adaptive capacity of a household thus, increasing its vulnerability to impacts of climate change. With access to resources households could be able to improve the dwelling structure hence, decreasing its sensitivity and exposure to hazards and perturbations.

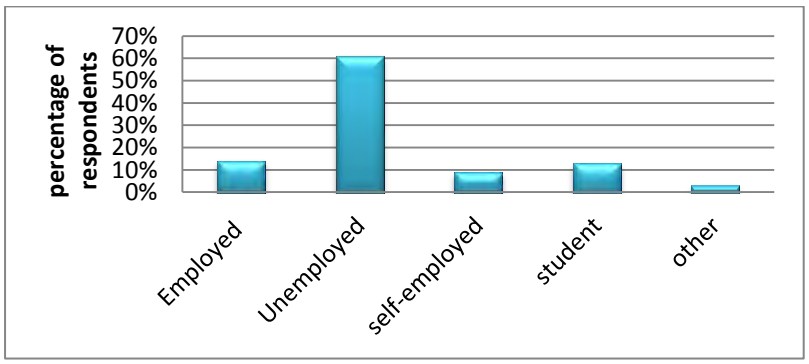
Figure 26: Gender of Household respondents



Source: Field survey

Household participants were between the ages of 18 and 67 years of age.

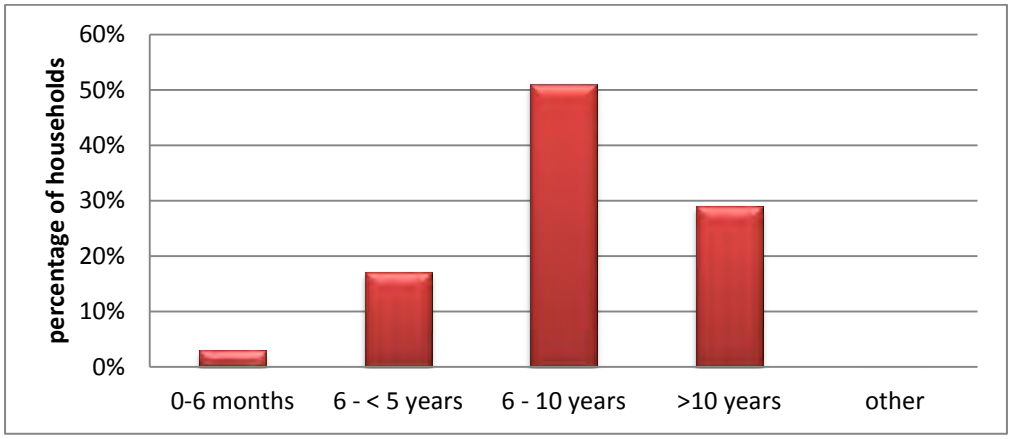
Figure 27: Employment status of respondents



Source: Field survey

Over 50% of households have lived in the dwelling for more than 6 years but less than 15. Most of the dwellings were between 8 and 15 years old and majority of the households were the first inhibitors. This enabled the researcher to assess post occupation evaluations of household's experience. Also, the building lifespan suggests that the dwelling and households have likely experienced climate change. Most dwellings except those that had gone renovations used the same building materials: asbestos roof, brick walls, steel window frame and glass windows, and dwelling had no ceiling boards. 70% of households identified the condition of the dwelling is being poor. Poor quality of dwellings increases the sensitivity of RDP dwellings thus, increasing climate change vulnerability.

Figure 28: Period households have occupied the dwelling

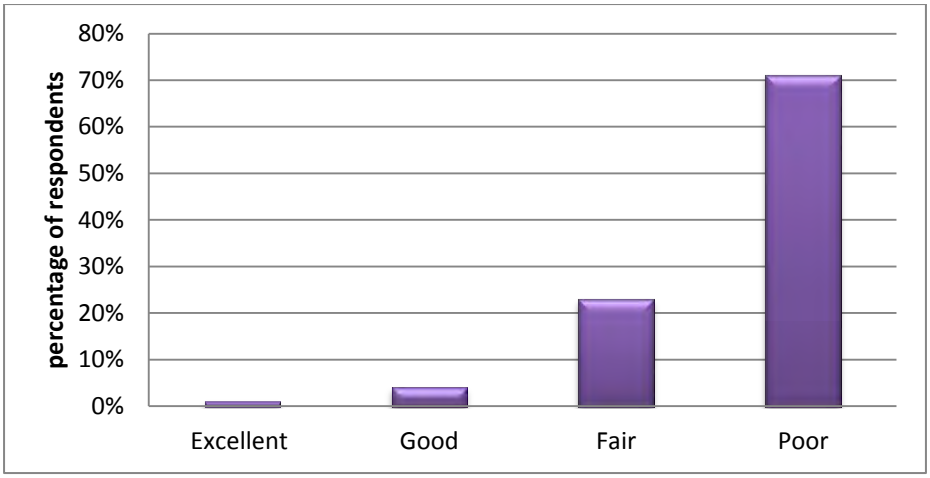


Source: Field survey

90% of households experience flooding. Households said water enters the interior of the house through leaking building components. This results in interior dampness of walls and wet floor. Most households agreed that flooding negatively affects comfort of household members. The negative effects of this condition as expressed by households included the following: house ends up having a bad odour due to dampness; dampness damages furniture and clothes; it increases mosquitoes in the house; households tend to suffer from sinus and asthma; and an increase of household members with skin rash. Again, poor quality of the dwelling increases it sensitivity to impacts of climate change. Poor health status of household members could further undermine the adaptive capacity of households. Human resources is a tool households can use to improve/consolidate the dwelling. If household members are not healthy there are unlikely to apply their skills. This will result in increased

sensitivity and a decrease in adaptive capacity resulting in increased vulnerability to climate change.

Figure 29: Condition of building structure



Source: Field survey

Table 6: Building material used

Building component	**87% households used the following material**
Roof	Asbestos
Walls	Bricks
Windows	Steel frame and glass
Ceiling boards	No ceiling board

Source: Field survey

90% of the households said they do experience flooding. 80% of the households said they experience interior wall dampness. Majority of households who experience dampness said it negatively affects their comfort.

Figure 30: RDP houses at Y section, Umlazi

Author (2016)

To decrease vulnerability of RDP dwellings at Umlazi Y section, households would need to consolidate/improve the dwelling. This would however, require financial resources which households do not have due to lack of job opportunities. Consolidating the dwelling would decrease the sensitivity of dwelling due to an increase in adaptive capacity thus, reduce vulnerability of dwellings to impacts of climate change.

5.3.3 Adaptation intervention measures

Although 79% of respondents said they do know about climate change a significant 21% said they do not know about climate change. Lack of knowledge about climate change is identified as one of the social stressors which compromise the adaptive capacity of a system. And, those households that knew about climate change and believes it affects them, could not explain what climate change is. This decreases the adaptive capacity of households as households will not know how to respond effectively to climatic changes thus, increasing their vulnerability to climate change.

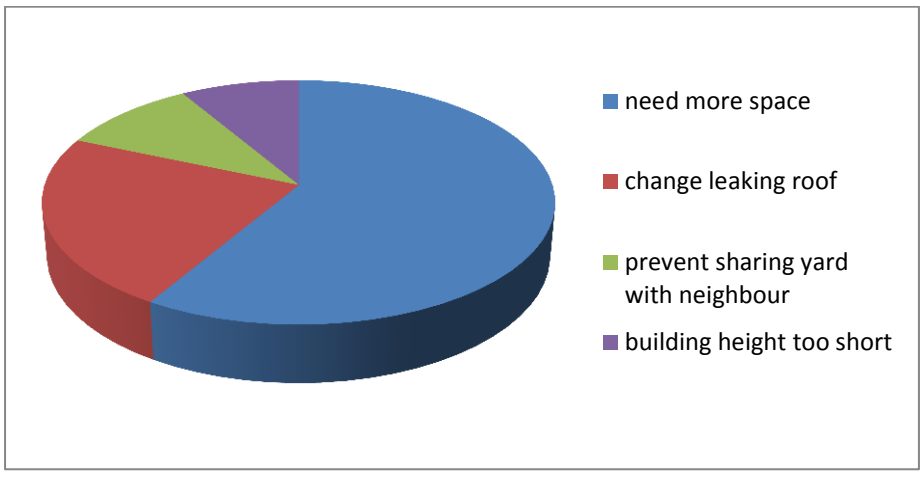
Table 7: Respondents description of climate change

change in weather patterns
causes drought
abnormal weather
less rainfall,
more rainfall
change in seasons
causes excessive heating
COP17
water scarcity
global warming

Source: Field survey

79% of the households said climate change does affect them whilst 21% said no, climate change does not affect them.

Figure 31: reasons households provided for wanting to consolidate their dwelling



Source: Field survey

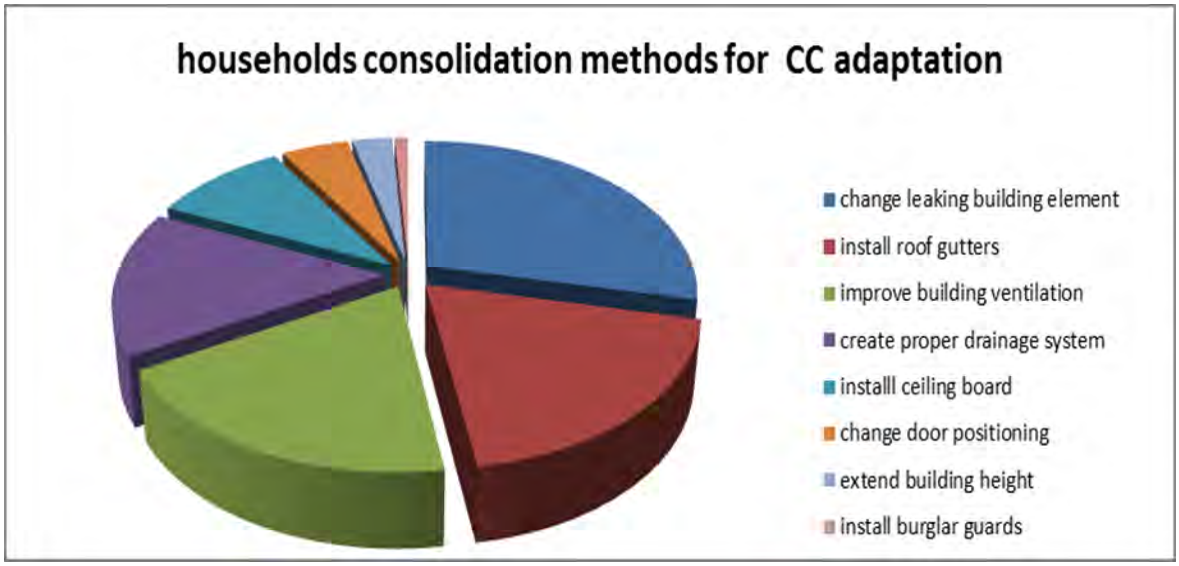
Over 90% of households would improve their RDP dwelling. However, consolidation methods identified by households were more aimed at improving the dwelling than adapting to climatic changes. This outcome is directly linked to the lack/limited information households have on climate change. Even if households improve the dwelling, if these improvements do not directly respond to climatic changes than the sensitivity of dwellings remains the same resulting in continued climate change vulnerability. The adaptive capacity might improve as climate change is a crosscutting issue thus, consolidating the house indirectly affects adaptive capacity.

Table 8: Respondents willing to consolidate the dwelling so to adapt to climate change

Answer	
Yes No Not sure	87% 10% 3%
Total	100

Source: Field Survey

Figure 32: Households consolidation methods for climate change adaptation



Source: Field survey

Figure 33 and 34 show some of the reactive adaptation methods used by RDP households to decrease their vulnerability to climatic factors. It is a common phenomenon to see household using old tyres to prevent soil erosion. Due to poor drainage system households create their own drainage system by paving a water channel. Although not done professionally, the drainage system helps to prevent water from flooding the house. Figure 34 shows the roof of a RDP dwelling with tyres and stones placed on the roof top. The heavy materials help to keep the roof from being blown away by heavy winds.

Figure 33 and 34: Reactive adaptation methods

At a policy level data information on existing adaptation intervention was gathered from an official from the eThekwini Municipality Human Settlements and Infrastructure unit. The official indicated that more is needed in order to mainstream issues of climate change into housing policy and thus, increase the adaptive capacity of households. Although, the official did believe that climate change is affecting RDP housing developments and that it is a matter of urgency, the department had not created a relationship between climate change and housing which highlights a lack of intergovernmental cohesion.

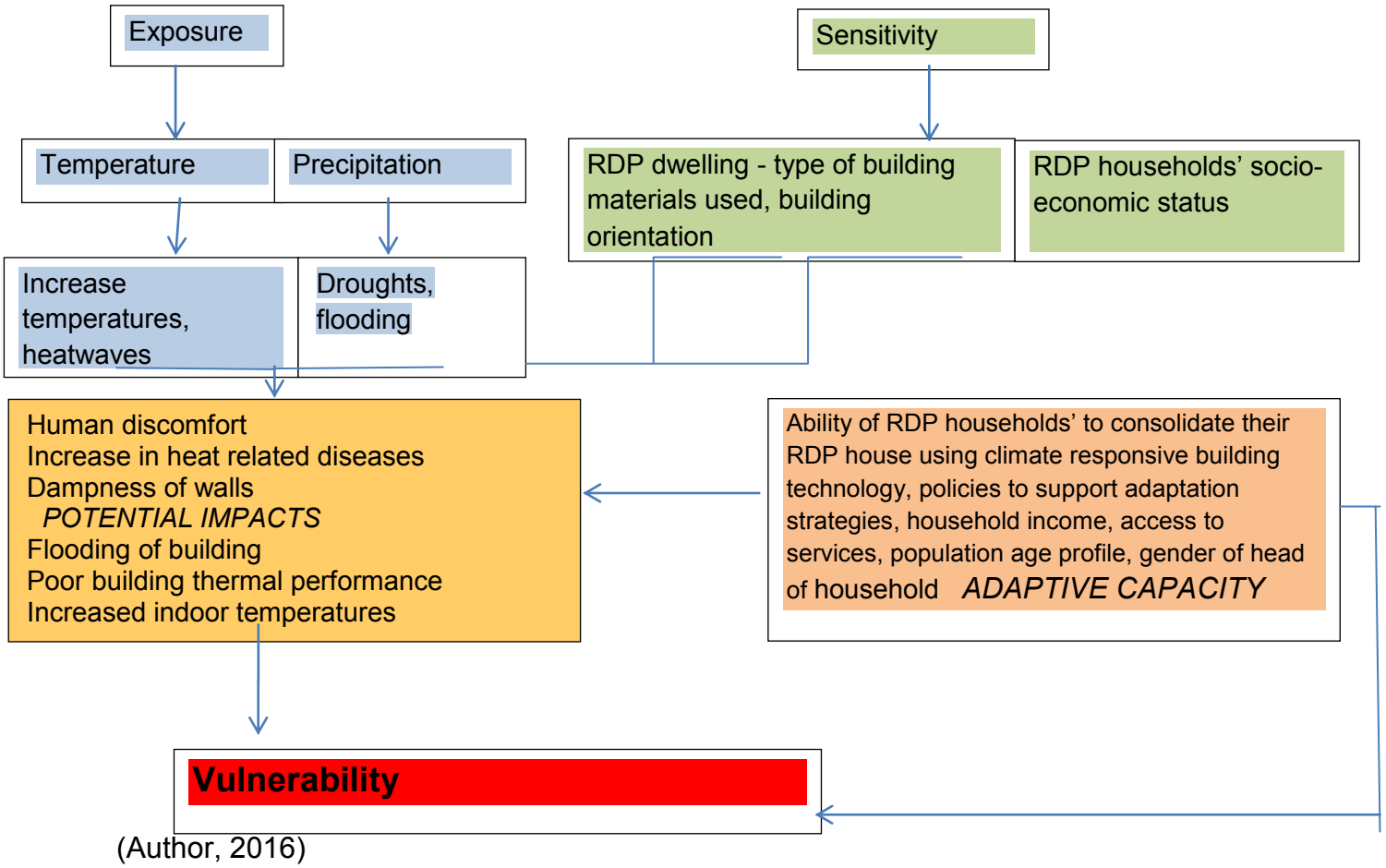
The official views climate change as a policy issue that needs and is addressed by another department. The official did acknowledge the need to mainstream climate change into housing policy. It is evident that Environmental Impact Assessments (EIAs) play a crucial role in informing housing officials about environmental issues pertaining public housing developments. However, EIAs do not address issues of

climate change. The official did identify possible adaptation methods and government interventions for RDP settlements.

5.4 Data Analysis

Figure below shows the modified analytic tool as implemented in this research study to analysis climate vulnerability of RDP dwellings. The figure shows RDP dwellings in Umlazi Y section as being exposed to changes in temperature and precipitation. The dwellings a sensitivity level is measured by assessing its natural/physical form in this case the building and its societal environment which is associated with socio-economic opportunities and policy responses. Potential impact is amalgamation of exposure and sensitivity factors of a system. Adaptive capacity of RDP dwellings is dependent on the ability of households and policy developers to formulate and implement climate change adaptation responses. Determining climate vulnerability of RDP dwellings was achieved by investigating all the abovementioned factors.

Figure 35: Analytic tool used to assess climate change vulnerability



(Author, 2016)

The households have found reactive methods of adapting to environmental issues such as using used tyres and stones to prevent the roof from being blown away and using tyres to prevent soil erosion. This indicates that although households lack the capacity to professionally consolidate their houses they have used accessible methods to adapt. The department of Human Settlements runs workshops prior and post the handing over of public housing. The eThekwini municipality Human Settlements unit could include issues of climate change in such educational workshops. This would make public housing recipients aware of climate change and have knowledge on how to adapt dwellings without investing huge amounts of money. Currently RDP households lack financial resources necessary to improve their building performances and thus decrease their vulnerability

It is a common phenomenon to see household using old tyres to prevent soil erosion. Due to poor drainage system households create their own drainage system by paving a water channel. Although not done by professionally the drainage system helps to prevent water from flooding the house. Most houses place an iron sheet on the bottom part of the door to prevent water from entering the house in case of heavy rains. This is also a method of adapting to effects of climate change. Participating in subsistence farming is also a livelihood strategy of adapting to impact of climate change. As impacts of climate change increase food prices will increase. Engaging in subsistence farming decrease the need for household to invest in food and thus, can use that money to improve their dwelling.

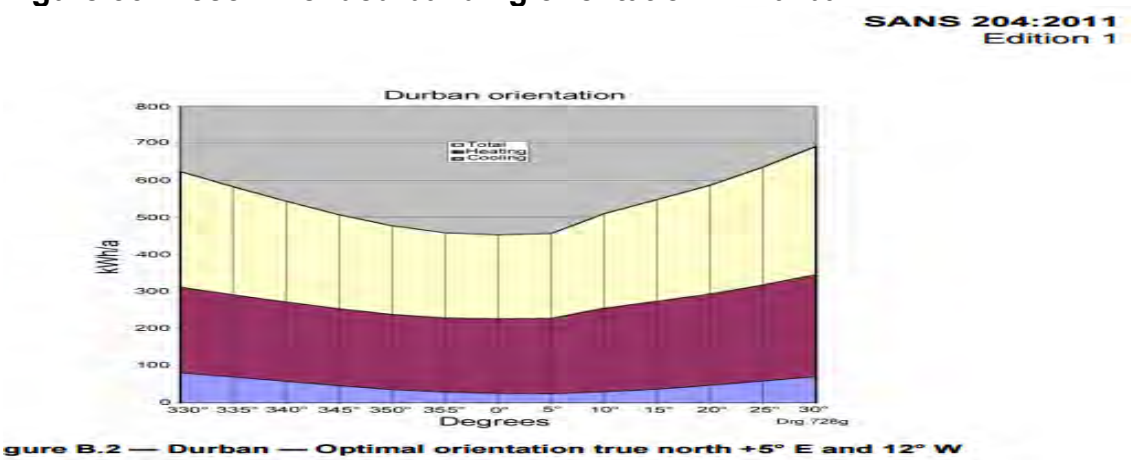
Most households place heavy materials on the roof to prevent the roof from being blown away by winds. Therefore, the placement of tyres on the roof of this RDP dwelling might indicate that this area is affected by excessive winds. Building orientation also prevents such prevailing climatic effects from negatively affecting the dwelling. With prevalence of Climate change, Durban has been experiencing increased heavy winds. In November 2015, EThekwini municipality issued a number of warnings of heavy gale force winds that would rise from 40km/h in the afternoon to 70km/h overnight. Poor orientation compromises the building performance of RDP dwelling and thus, the quality of household life.

Adaptation at a household level is more aligned in this case with consolidation methods. The researcher believes that if households are aware of potential impacts

of climate change this would re-channel their consolidation efforts towards adapting to climatic changes. Most of RDP household's consolidation efforts had ignored impacts of climate change. Community Adaptation Programmes would help to make communities aware of climate change and channel consolidation methods towards adapting to climatic changes.

According to TIASA climate responsive buildings should be designed and constructed to suite that specific climate region (2010). Conradie adds that *"to design energy efficient buildings using an optimal combination of passive design strategies it is necessary to understand the particular climate designed for"* (2012:1). According to the South African National (204-2) [1] climatic zone map, Durban is situated in zone 5 and thus, falls under the sub-tropical zone. According to SANS 204 (2011) the following would be required in order to build a climate responsive building in this zone: walls with a surface density of less than 180kg/m-squared, shall have a minimum total R-value of 1.9.; except for zone 5 buildings with a floor area of less than 500 m2, with a concrete slab-on-ground, shall have insulation installed around the vertical edge of its perimeter which shall. The diagram below shows the prefect building orientation for buildings in Durban according to the SANS criteria. However, RDP dwellings did not have the building components meeting the required building standards. The orientation of the dwellings was incorrect and dwellings were of poor quality.

Figure 36: Recommended building orientation in Durban



gure B.2 — Durban — Optimal orientation true north +5° E and 12° W

Sustainable housing should however, aim at achieving social, economic and not just only the environmental pillar of sustainable so to ensure sustainable development. From the technical perspective sustainable buildings have become synonymous with the term 'green buildings'. Earlier the paper discussed different elements of sustainable buildings which include: energy efficiency, building orientation, passive buildings and building materials. It became clear that RDP dwellings still fall short on the principles required to achieve sustainable buildings. However, with the formulation of the SANS 204 Energy Efficiency standards there is hope that future public housing developments will be sustainable

South African municipal departments include the EThekwini Human Settlements unit translates their challenges and vision for this department through a 5 year plan called the Integrated Development Plan (IDP) The EThekwini Housing Chapter in the Integrated Development Plan (IDP), 2012 identifies the need to respond to high demand for affordable low-income housing in a sustainable manner however, it does not identify climate change as a major key challenge within the housing sector. This highlights a major gap within policy responses to climate change at the national and local spheres of government and between the various government departments in this case between the EThekwini Climate Change Protection unit and the EThekwini Human Settlements unit.

Table 9: showing vulnerability of RDP dwellings based on calculations using the climate change vulnerability toolkit provided earlier

Exposure to climate hazards and perturbations	**Sensitivity**	**Adaptive capacity**	**Vulnerability**
Heatwaves = **3.5**	Poor environmental performs of dwellings, poor orientation increases sensitivity of households; no	Lack of resources and poor mainstreaming of climate change policy decreases adaptive capacity of households = **5+1**	***3.5 * 10 – (5+1+4) = 25*** **Extremely vulnerable**

	household income **=6 + 4**		
Flooding **= 2.5**	Poor drainage system; lack of gutters, walls not plastered; soil erosion; poor building foundation; poor building orientation; no household income **= 6+4**	Lack of resources and poor mainstreaming of climate change policy decreases adaptive capacity of households; unemployment; lack of knowledge= **4+1+5**	***2.5*10- (4+1+5) = 15*** **Highly vulnerable**
Drought=**3**	Lack of water tanks and gutters; lack of use of water from the river; poor quality and magnitude of produce to harvest No household income **= 6+ 4**	Lack of resources and poor mainstreaming of climate change policy decreases adaptive capacity of households; unemployment; lack of knowledge=**4+1+5**	***3*10 –(4+1+5)= 20*** **Highly Vulnerable**
Soil erosion **=1**	No retaining walls; flooding; no green cover to prevent surface runoff ; no household income **=6+4**	Lack of resources decreases adaptive capacity of households; unemployment; lack of knowledge= **4+5**	***1 *10 –(4+5) = 1*** **Vulnerable**

5.5 Chapter summary

This chapter presented the data analysis method used to analyse data collected from both quantitative and qualitative data sources. The research findings provided answers to the research questions and sought to fulfil the objective of the study. Research findings identified RDP dwellings to be vulnerable to impact of climate change

Chapter Six: Conclusion and Recommendations

6.1 Introduction

The purpose of this chapter is to provide a conclusion and recommendations. The chapter seeks to establish if the research questions were successfully answered or not. Therefore, reference will be made to the research questions. Themes have been formulated from the research questions which will accommodate research conclusions that helped to answer a specific question.

6.2 Impact of Climate change

Climate Change is relatively a new concept however, it gained dominance as it is a cross-cutting issue. Climate change undermines efforts to achieving sustainable development. Climate change response measures have included mitigation and adaptation response mechanisms. It is evident that efforts to deal with climate change become a step towards achieving sustainable development. South Africa has been identified to be affected by the following climatic changes: increased temperatures, increased frequency of hazards, seal level rise and intense rainfall over a short period of time. Because South Africa is a developing impacts of climate change are having immense effects of the various systems. Communities in developing countries, due to lack of access to resources are seen as being more vulnerability to impacts of climate change.

Systems affected by climate change include: human settlements, infrastructure, water resources and agriculture. Human settlements are affected by direct and indirect effects. Settlements in South Africa, RDP settlements included, are affected by the following direct impacts: flooding, heat waves, coastal erosion and soil erosion Indirect impacts include: droughts and food insecurity. Evidence shows that RDP settlements in Durban have been exposed to server hazards such floods and heat waves. The households at Umlazi Y section, had noticed an extreme increase in temperatures, intense rainfall over a shorter period and droughts.

6.3 Vulnerability of RDP settlements

Vulnerability of a system is said to be influenced by factors by both environmental and non-climatic factors. Thus, to assess the vulnerability of RDP settlements one firstly, looked into the physical aspect of the dwelling and its immediate environment and then proceeded to exploring the social aspect of the households. Communities who lack financial and other resources are more vulnerable as they do not have the resources to cope, recover or adapt to the changes. Households who receive RDP dwellings are assisted by government to effect their housing demand as they lack the necessary resources to attain decent housing. This indicates that households are vulnerable as their inability to consolidate the house decreases their adaptive capacity.

The RDP dwelling was found to have a number of structural defects which increased the vulnerability of households to impacts of climate change. The settlement planning and layout design had failed to acknowledge environmental aspects of the building such as window and door orientation, natural ventilation and importance of eco-systems services. Household thus, suffered from: increased indoor temperatures and soil erosion.

Households were also affected by climate change effects such as: wall and floor dampness. This was caused by leaks and poor building material. Another factor increasing the vulnerability of settlements was location. RDP settlements were developed on the urban periphery afar from socio-economic opportunities. Without financial resources households cannot consolidate the dwelling. Continuous impact of climatic elements on the RDP dwelling will result in the dwelling deteriorating at a faster pace.

Lack of knowledge on climate change was also a factor decreasing the adaptive capacity low-income households. Without the necessary information on climate change, households are not able to plan and respond effectively. Household's climate change response have been reactive, meaning that once households had experience a shock than only do they consolidate their dwelling. However, there is

still a lack of information on consolidating the dwelling in a climate responsive manner.

6.4 Interventions

Climate change adaptation intervention measures are required both at a policy and household level. At the policy level, a greater need was identified for both the eThekwini Human Settlements and Infrastructure Unit to work with other departments when developing climate change policies so to create a coherent policy framework. Governments departments appeared to be working in silos. High reliance of policy makers on EIAs for assessing the environmental performance on dwellings is distorted. EIAs do not assess potential impacts of climate change. The government therefore, needs to conduct Impact and Vulnerability Assessments to evaluate the vulnerability of housing developments to impacts of climate change. Housing contractors would be mandated to comply with the new procedure.

The first and second clause of the Durban Adaptation Chapter for Local Governments which was adopted on the 4th December 2011 advocates the following: (1) mainstreaming adaptation as a key informant of all local government development planning and; (2) understand climate risks through conducting impact and vulnerability assessments. It is extremely important that every department including Human Settlements Department incorporates these adaptation efforts into policy. Although climate change mostly possesses negative impacts there are also positive effects that climate change offers. However, for these to opportune, government needs to educate communities and formulate policy that promotes for such.

Adaptation at a household level is more aligned in this case with consolidation methods. The researcher believes that if households are aware of potential impacts of climate change the knowledge would influence their consolidation process. Households would consolidate the dwelling with the aim to adapt to climate change.

6.5 Verification of hypothesis and assumptions

The research study hypothesis was verified. The first assumption was that RDP dwellings are vulnerable to impacts of change. The second assumption was, climate responsive housing consolidation methods would improve the adaptability of RDP dwellings. Both the assumptions were correct. Due to factors identified in earlier chapters, RDP dwellings were found to be impacted by climate change induced effects thus, vulnerable to climate change. Although households lack resources to consolidate the dwelling professionally, the informal adaptation measures applied by households successfully improved their adaptability climatic changes, thus decreasing their vulnerability.

6.6 Recommendations

The availability of 'green finance' would assist communities to convert these reactive methods of adapting into viable and affordable business ideas. This would promote green entrepreneurs and address the issue of high unemployment. Communities are not aware that the 'informal' methods of adapting are as of value as formal or prominent adaptation methods. It is important that government begins to development integrative housing policy. This is possible through the promotion of green jobs/businesses thus addressing unemployment and climate change adaptation issues (green issues). Communities can form cooperatives and begin to engage in green entrepreneurship. The South African government invests significantly on cooperatives.

Table 10: Recommended Consolidation methods as climate change adaptation measures

Housing consolidation method	Intervention	Benefits
External quality improvements	Installation of roof gutters	Channel water Enable water collection Prevent soil erosion
Site improvement	Installation of water tanks	Collect rain water Prevent soils erosion
Site improvement	Planting of tress and sub-sustenance farming	Livelihood strategy and use ecosystems services
Extension and conversion	Ensure extended rooms are of suitable orientation	Good building orientation will increase building performance. Protect households from rain, wind and heat
Internal quality improvements	Install ceiling boards	Will keep the house warm in winter and cool in summer
External quality improvements	Build concrete walkway around the dwelling	Protect households from experiencing flooding
Service improvements	Install solar geysers	Save electricity
External quality improvement	Change window placement to suit site orientation	Bigger windows and properly placed windows improve the air circulation within the building
External quality improvement	Installation of roof over hangs	Will keep houses cooler by protecting the house from direct sunlight

(Author, 2016)

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Appendix 1: key Informant's Questionnaire

Data Collection tools

Date	Comments

1. What do you understand by vulnerability to climate change
2. Are RDP dwellings vulnerable to impacts of climate change? If yes, how?
3. What are some of factors contributing to the vulnerability of RDP dwellings?
4. Do you think RDP households are aware of climate change?
5. What can be done to improve the adaptability of RDP dwellings to impacts of climate change
6. What are some of the policy initiatives adopted by department to improve the adaptability of RDP dwellings?
7. Do you think the use of EIAs is effective in identifying impacts of climate change on settlements? Explain
8. Can RDP dwellings adapt to changes of climate change? If yes, How?
9. Do you think climate change is a matter of urgency? Explain
10. Do you think the department has done much to mainstream climate change into policy? Explain
11. Is there anything you would to add to our discussion?

Appendix 2: Household Survey Questionnaire

Date	Comments

Section A: Respondents information

A Area Name		
A2 Respondents' name		
A3 Age		
A4 Gender	**M**	**F**

Section B

B1	**How long have you lived in this area**	
	0-6 months	**1**
	6 months -< 5 years	**2**
	6 years -10 years	**3**
	>10 years	**4**
	Other	**5**

B2	Total number of people living with you?

B 3	Employment status	
	Employed	1
	Unemployed	2
	Self-employed	3
	Student	4
	Other	5

Section C: Questions about the RDP dwelling

C1 Is the building structure in a ……..condition?	
Excellent	1
Good	2
Fair	3
Poor	4

C2 What is the age of the dwelling?	

C3 What type of material was used for the following building elements?	

Roof	
Walls	
Windows	
Ceilings	

C4 Do you have flooding?	
Yes	**1**
NO	**2**

C5 Do you have dampness interior walls?	
YES	**1**
NO	**2**

C6 If you replied YES in question C5, does this affect comfort of members	
Yes	**1**
NO	**2**

C7 If you replied yes for question C6, How does the dampness affect the comfort of households?	

C8Have you noticed increase in indoor temperatures?	
Strongly disagree	**1**
disagree	**2**
Neutral	**3**
Agree	**4**
Strongly Agree	**5**

C9 Do you use cooling mechanisms?	
Yes	**1**
No	**2**

C10 If you answered Yes to question C9, what Cooling mechanism do you use to maintain conducive indoor temperatures?	

C11 Do you think the high indoor temperatures affect the comfort of your household members?	
Yes	**1**
No	**2**

C12 If you answered Yes for question C11, How do you think high indoor temperatures affect household members? HOW	

Section D: Climate Change

D1 Do you know about Climate Change, If no proceed to D3	
Yes	**1**
No	**2**

D2 If yes, What is climate change?	

D3 Do you think climate change affects your household?	
Yes	**1**
No	**2**

D4 If answered yes for question D3, How do you think climate change affects your household?	

Section E: Consolidation methods

E 1 Would you improve your RDP house? If no proceed to E3	
Yes	**1**
No	**2**

E2	**Why would you improve your house?**

E3 Would you improve your house in order to better deal with impacts of climate change? If yes proceed to D14	
Yes	1
No	2

E4 How would you improve your house?	

Appendix 3: Observations

Foundation	
Floors	
Walls exterior	
Walls interior	

Roof	
Ecosystems services	
Windows	

Appendix 4: Recordings of indoor temperature and building orientation

Indicator	Measurement
Indoor temperature Time date	
Orientation of Building Time Date	