GREENHOUSE GAS EMISSIONS AND ENERGY SCENARIOS FOR DURBAN:

THE IMPLICATIONS OF URBAN DEVELOPMENT ON FUTURE ENERGY DEMAND AND EMISSIONS

By

ZARINA MOOLLA

May 2010

Submitted in fulfilment of the academic requirements for the degree of Master of Science in the School of Environmental Sciences, University of KwaZulu-Natal, Durban

ABSTRACT

Cities are considered to be a major cause of climate change, as a result of city functions, which require energy and emit large quantities of Greenhouse Gases (GHGs). Therefore, cities are being targeted globally as key areas for climate change mitigation. In order to mitigate the impacts of climate change, it is important for policy makers to be able to understand the implications of possible future policy decisions and development plans on emissions. One possible way of developing forecasts is through emissions scenarios, which allow for the development of a series of forecasts based on changes in the drivers of emissions.

The city of Durban is a developing city, which aims to promote economic development; however, this development would increase the demand for energy and therefore impact on the GHG emissions in the city. The aim of this study is to develop a number of GHG emissions scenarios that illustrate the implications of various development paths for the city. The methodology applied involved first identifying the gaps in existing GHG inventories for Durban and the data required to close these gaps. The data was input into the Long-range Energy Alternatives Planning (LEAP) tool, which is a physical accounting and simulation tool that allows for the creation of scenarios. Five scenarios were created to illustrate different ways in which the city might develop which are the Growth without Constraints (GWC) Scenario, the Business as Usual (BAU) Scenario, the Natural Transition City, the Slow Go City and the Low Carbon City. Lastly, a sixth scenario, the Required by Science (RBS), was not modelled but created to illustrate what would be required if Durban followed the Intergovernmental Panel on Climate Change (IPCC) stabilisation guideline of a reduction of 60% - 80% of 1990 levels by 2100. Thereafter the IPCC scenarios were downscaled from a national level to a local level using a linear downscaling methodology, in order to illustrate the implications of global development paths on the city.

The different development paths had a range of impacts on emissions. Rapid economic growth, with no climate change mitigation in the GWC Scenario, results in a 6.3 times increase in emissions from the base year to 2050. If the city continues with its current policies and strategies as in the BAU Scenario, emissions will increase 3.5 times from the base year. If there is a transition to a post-industrial society, with no climate change mitigation, emissions will increase 3 fold from 2005 to 2050. The National Transition Scenario illustrated that if Durban moves towards a service sector economy, which are predominantly low carbon sector, with no climate change mitigation, emissions will still increase 3.15 times the 2005 levels. If the city is slow to respond to climate change as in the Slow Go City, emissions will increase 2.5 times from the base year. A shift in the structure of the economy and an increase in the use of renewable energy and energy efficiency (i.e. a Low Carbon City) results in reduction in emissions of 1% from 2005. These were compared to the IPCC downscaled scenarios, which followed a similar pattern. The scenarios are comparable to developing city scenarios, but illustrate that the city is lagging behind developed cities.

In order to make an impact in the reduction of emissions, it is essential for the city to target the commercial and industrial sector, which is the sector that emits the highest GHG emissions. However all

these scenarios are still insufficient for achieving the RBS emissions target of a 60-80% reduction from 1990 levels. Achieving this reduction would require more than a 50% improvement in energy efficiency, structural change in the economy to low energy intensive sectors and a 20% contribution of renewable energy to total energy supply.

PREFACE

The experimental work described in this dissertation was carried out in the School of Environmental Sciences, University of KwaZulu-Natal, Durban, from January 2008 to June 2010, under the supervision of Professor Roseanne Diab and the co-supervision of Mr Rob Hounsome.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged.

DECLARATION

I, Zarina Moolla declare that:

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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Signed: ....

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LIST OF ABBREVIATIONS

AIM	Asia-Pacific Integrated Model
ALM	Africa Latin American Middle East
AsgiSA	Accelerated and Shared Growth Initiative for South Africa
ASSA	Actuarial Society of South Africa
BAU	Business as Usual
CBD	Central Business District
CCP	Climate Protection Program
CFL	chloro-fluorescent lighting
DEAT	Department of Environmental Affairs and Tourism
DSM	Demand Side Management
EC	European Commission
EIA	Energy Information Administration
EM	eThekwini Municipality
EMA	eThekwini Municipal Area
EMES	eThekwini Municipality Energy Strategy
ERC	Energy Research Centre
EU	European Union
GDP	gross domestic product
GHG	Greenhouse Gases
GVA	gross value added
GWC	Growth without Constraints
HEAT	Harmonised Emissions Analysis Tool
HFO	heavy fuel oil
ICLEI	Local Governments for Sustainability
ICT	information and communication technologies
IDP	Integrated Development Plan
IEA	International Energy Agency
IEO	International Energy Outlook
IIED	Institute for Environment and Development
IMAGE	Integrated Model to Assess the Greenhouse Effect
IPAT	Impact = Population x Affluence x Technology
IPCC	Intergovernmental Panel on Climate Change

LEAP	Long-range Energy Alternatives Planning
LEDs	Light Emitting Diodes
LPG	liquefied petroleum gas
LTMS	Long Term Mitigation Scenarios
MARKAL	Market Allocation
MER	market exchange rates
MRG	methane rich gas
Mt	million tonnes
OECD	Organisation for Economic Co-operation and Development
ppm	parts per million
PPP	purchasing power parity
R&D	research and development
RBS	Required by Science
SAB	South African Brewery
SBT	Scenario Building Team
SACN	South African Cities Network
SEI	Stockholm Environmental Institute
SoER	State of Energy Report
SRES	Special Report on Emission Scenarios
Stats SA	Statistics South Africa
SUVs	sport utility vehicles
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
USA	United States of America
VMT	vehicle miles travelled
WEC	World Energy Council
WEO	World Energy Outlook

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ACKNOWLEDGEMENTS

First and foremost I would like to thank God Almighty for blessing me with the strength and the ability to complete this endeavour.

To my supervisor, Professor Roseanne Diab and my co-supervisor, Mr Rob Hounsome, I sincerely thank you for all your advice, guidance and utmost patience with me. Without your support this thesis would not have been possible.

To my husband, Arshad, I thank you for bearing with me during this time and for constantly encouraging me to accomplish my goals to the best of my ability.

To my parents, who have always supported me in my studies which followed 'the road less travelled' and have encouraged me to always work smart, I will always be indebted to you.

To all my friends, thank you for always being there to help, share a laugh and for keeping me de-stressed during the time, I will never forget those wonderful times.

I would like to acknowledge the National Research Foundation for the funding that was granted to me for my Masters. It was of great assistance. In addition to this I would like to also acknowledge Golder Associates, for generously granting me an internship during the time, which focused on aspects of my Masters.

Lastly, and most importantly, I would like to thank all those who kindly assisted me with information and data. Most importantly, Denny Thaver from the eThekwini Development Unit, Nyaniso Mlilo from eThekwini Electricity and Garth Loades from National Associates Collieries, thank you for gracefully enduring with my endless emails and calls.

1 INTRODUCTION

1.1 Background

There is a consensus among scientists that human activities over the past 200 years have been the main cause of climate change (IPCC, 2007; Joubert, 2008 and Stern, 2006). This is primarily due to an increase in activities that emit GHGs into the atmosphere; which include the combustion of fossil fuels, land-use change, agricultural activities and emissions from the decomposition of waste (IPCC, 2007; Joubert, 2008; National Academy of Science, 2001 and Stern, 2006). An excess of GHGs in the atmosphere traps the infrared radiation that is radiated by the earth that would otherwise escape into space, which results in average air temperature increases (IPCC, 2007; Pew Centre, 2008 and Stern, 2006). From 1906 - 2005 the average global air temperature has risen by 0.74°C, which is larger than the 1901-2000 increase of 0.6°C (IPCC, 2001 and Pew Centre, 2008). If development continues along current levels then by the middle of the 21st century average global air temperatures will increase by 1-3.5°C. According to Stern (2006), if there is no mitigation of GHGs, air temperature increases from 3-10°C could occur by 2100. Furthermore, Hadley Centre (2008) predicts a temperature increase from 2.1-7°C depending on the level of mitigation of GHGs.

The effects of climate change are already occurring, with observed increases in land and global ocean temperatures, the rapid melting of snow and observed increases in sea-level (IPCC, 2007). According to the Hadley Centre (2006) and Stern (2007), the ten warmest years on record have all occurred since 1990. Sea-level rise and melting of snow and ice are consistent with the global warming (IPCC, 2007). In addition to this, extreme weather and changes in rainfall patterns, such as droughts, floods and hurricanes, may be experienced (Harte, 2000, IPCC, 2007; Naidu *et al.*, 2006 and Stern, 2006).

As a result, water resources and availability could become unpredictable and scarce (Harte, 2000, IPCC, 2007; Naidu *et al.*, 2006 and Stern, 2006). Agricultural output could decrease due to drier soils in lower altitudes, which would place food security at a risk, however, it is expected to increase in middle to high altitude regions (Desanker and Magadza, 2001; IPCC, 2007 and Naidu *et al.*, 2006). Biodiversity may be altered and in some cases, species extinctions may occur. Changes could also impact on human health, resulting in malnutrition and higher incidences of deaths and injuries due to climatic events. Warmer and wetter climates in normally temperate areas could also result in the spread of tropical and water-borne diseases (IPCC, 2007 and Naidu *et al.*, 2006). Lastly, coastal towns and cities would be in danger of sea-level rise, which could result in infrastructural damage and loss (IPCC, 2007 and Naidu *et al.*, 2006). Therefore, there is a vital need to implement policies and regulations that would mitigate and adapt to climate change.

A global response to climate change mitigation and adaption was the introduction of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and its Kyoto Protocol in 1997 (Tladi, 2005 and UNFCCC, 1997). The Kyoto Protocol is an international agreement which sets binding targets for industrialised countries to reduce their emissions by 5% of 1990 levels by 2012. Developing countries did not have to accede to the targets due to their need to develop and their minimal contribution to GHG emissions in the past (UNFCCC, 1997 and Winkler, 2009). However, they have to maintain GHG inventories and promote initiatives that will mitigate and adapt to climate change. This may change post-

2012, when it will be likely that some developing countries, including South Africa, would have to commit to emission reduction targets (Blignaut *et al.*, 2005; Department of Environmental Affairs and Tourism (DEAT), 2004; Hallowes, 2008 and Winkler, 2005).

South Africa accepted the UNFCCC in 1997 and ratified the Kyoto Protocol in 2002 (Blignuat *et al.*, 2005 and DEAT, 2004). As a developing country, South Africa is undergoing rapid development and industrialisation, partly to address the country's apartheid history, which left many rural areas underdeveloped and black people disadvantaged. The South African government seeks to address this by stimulating economic growth to provide jobs and providing basic services to the poor. The challenge for policy makers is to find a balance between development goals and mitigating climate change through the reduction of energy consumption (Davidson and Winkler, 2003; Haw and Hughes, 2007; Winkler, 2009).

The South African economy is dominated by heavy industry, which is energy-intensive. Much of this energy is derived directly or indirectly from indigenous coal. As a result, South Africa is one of the largest GHG emitters per capita in the world (Davidson and Winkler, 2006; Department of Minerals and Energy (DME), 2005 and Winkler, 2009). Therefore, in addition to the Kyoto Protocol, South Africa has also implemented a number of national policies and strategies that address climate change issues. One of these is the National Climate Change Response Strategy of 2004, which aims to address key areas identified for mitigation and adaptation. The strategy identifies the need to ensure that local governments also actively participate in responding to climate change (DEAT, 2004).

It is important for local governments to implement climate change adaptation and mitigation measures because cities are vulnerable to climate change in that they contain large populations, infrastructure and activities in a small area. Cities in developing countries are particularly vulnerable to the impacts of climate change because they lack the resources and capacity to mitigate and adapt to the expected impacts (Satterwaithe, 2006).

It is also essential to mitigate the impacts of climate change in cities because a large proportion of anthropogenic GHGs are emitted as a result of urban activities (Satterwaithe, 2005). According to the International Energy Agency (IEA) (2008a), cities contributed 71% of energy-related CO_2 emissions in 2006, which is expected to increase to 76% by 2030 due to urbanisation. City functions depend on the usage of energy, which in most cases is fossil fuel based. The majority of emissions in cities are generated through the production and consumption of goods and services (Reid and Satterwaithe, 2007). The production and consumption of goods and services is driven by economic growth. Other contributors to GHG emissions in cities are dense transportation networks, large quantities of generated waste and land use changes through urbanisation (Hunt and Watkiss, 2007 and Reid and Satterwaithe, 2007). As such, some scientists view cities as 'breathing organisms' or ecosystems, which consume energy, raw materials, food and water and release waste (American Chemical Society, 2009 and Imura, 2009).

1.2 Motivation for study

In order for cities to effectively plan for climate change mitigation, there is a need to be able to forecast future GHG emissions. According to Anderson *et al.* (2008), 'the ability to forecast global GHG emission levels has become increasingly important in order to provide decision making support to policy makers'

(Anderson *et al.*, 2008: p1). Furthermore, forecasting emissions will allow decision makers to determine the implications of various policy decisions on future GHG emissions. For example, it would enable policy makers to understand the impacts of promoting growth in the manufacturing sector on GHG emissions. This would enable them to assess possible mitigation and adaption measures for the area (Fisher *et al.*, 2007).

However, simply forecasting GHG emissions is highly uncertain, because future emissions are dependent on a complex system, which cannot be completely understood (Nakicenovic *et al.*, 2000a). GHG emissions are driven by population growth, economic development, structural change, technological change and many other factors (Nakicenovic *et al.*, 2000a and Siddiqui and Marnay, 2006). These driving forces are vulnerable to external factors, such as economic recessions, disease outbreaks or significant technological progress that can result in unexpected changes in future GHG emissions (Schoemaker, 1995). Scenario analysis is a way of accounting for uncertainty through the creation of different storylines of how the future might unfold. The creation of scenarios provides policy makers with a range of possibilities for the future, by exploring the relationship between drivers of emissions and emissions (Coates, 2000 and Parson *et al.*, 2006).

The most influential emissions scenarios are the IPCC Special Report on Emissions Scenarios (SRES), which is based on a compilation of the outcome from a series of models and illustrates four main storylines. The storylines each depict a different development path for the world, based on population, economic, technological, environmental and political changes over the past century (Arnell *et al.*, 2004 and Nakicenovic *et al.*, 2000a). These scenarios were downscaled by many countries such as India, Finland and the United Kingdom (UK) (Carter, 2004; Lorenzoni *et al.*, 2000, Rajesh *et al.*, 2003, UK Department of Trade and Industry). Furthermore, van Vuuren *et al.* (2007) downscaled the IPCC scenarios to a national level for approximately 220 countries, including countries in Africa, Asia, Europe and America. Downscaling global scenarios recognises the interdependence between global and local factors. However, downscaling does not always account for aspects that are unique to specific localities (Hallegate *et al.*, 2008; Lorenzoni *et al.*, 2000 and Malone *et al.*, 2004).

Many countries have therefore developed emissions scenarios that are specific to the conditions and factors that would influence their emissions. Scenarios are also developed to illustrate different aspects of energy consumption. For example, some scenarios focus on changes in emissions in the transport sector or scenarios can illustrate the implications of renewable energy on emissions in the future (Capros *et al.* 2008 and Chen *et al.*, 2009). Examples of countries that have developed emissions scenarios include the United States of America (USA), Canada, China, Turkey, Switzerland, Japan and South Africa (Canada National Energy Board, 2003; Carter, 2004; Hallowes, 2008; Mintzer *et al.*, 2003; Rajesh *et al*., 2003; Say and Yucel, 2006; Schulz *et al.*, 2008).

In 2008, the report on Long Term Mitigation Scenarios (LTMS) for South Africa was endorsed by the government; the LTMS report illustrates different mitigation options for the country, in order to inform policy making and to aid in post-2012 UNFCCC negotiations (Hallowes, 2008 and Scenario Building Team (SBT), 2007). These scenarios, if implemented, will have implications for urban areas in South Africa.

The city of Durban has been actively involved in the mitigation of global warming through the reduction of energy consumption which is emphasised in its Integrated Development Plan (IDP) (eThekwini Municipality (EM), 2008), Long Term Plan (Imagine Durban, 2009) and through the implementation of the eThekwini Energy Strategy. The Energy Strategy aims to reduce the city's emissions by 27.6% by 2020 (Mercer, 2008). However, the city also aims to stimulate development in various economic sectors, promote economic growth and increase the supply of infrastructure, housing and other services to the city (Economic Development Unit, 2008 and EM, 2008). Accomplishing these goals would also stimulate an increase in energy demand and therefore GHG emissions and are as a result in conflict with the city's plans to reduce GHG emissions. Consequently, it is important to understand the implications of different urban development pathways on future energy consumption and related GHG emissions, in order to plan strategically and mitigate future emissions.

1.3 Aim

This research aims to develop GHG emissions scenarios, which portray the implications of different urban development paths on future energy demand and emissions, for the city of Durban.

1.4 Objectives

- To review the city of Durban's GHG emissions inventory and establish local key drivers of GHG emissions;
- To identify future development plans for the city of Durban to determine how this will impact on GHG emissions;
- To develop different possible scenarios for the future of city of Durban, based on current plans and alternative development paths, using a scenario accounting tool;
- To downscale the global IPCC scenarios to a local level, in order to determine the implications of global development pathways on GHG emissions in the city of Durban; and
- To compare global downscaled and local scenarios and make recommendations for an optimal development path.

1.5 Scope of the dissertation

Chapter One provided a brief background to the study, including the motivation, aims and objectives of the thesis.

Chapter Two reviews emissions scenarios on a global, regional and local level in order to understand how scenarios were created and the outcomes of these scenarios. The chapter also focuses on the main drivers of emissions scenarios, which are economic development, population growth and technological change.

Chapter Three follows on from Chapter Two by focusing specifically on the city of Durban, its baseline GHG emissions, factors that drive these emissions and relevant policies that can potentially influence emissions and drivers of emissions in the future.

Chapter Four describes the methodological approach taken for the study, including the process followed, the data that was collected, a description of the scenario accounting tool used and the limitations to the study. It also describes the storylines that were created and input into the tool.

Chapter Five presents the results and discussion of the study, by describing the scenarios that were created by downscaling global IPCC scenarios to a local level and the scenarios that were developed based on the different storylines. These scenarios are then compared to illustrate the variances in GHG emissions for different development paths and to identify scenarios that would reduce emissions.

Chapter Six outlines the conclusions of the study, followed by recommendations for future research.

2 EMISSION SCENARIOS

2.1 Introduction

Scenarios are defined by the IPCC (Nakicenovic *et al.*, 2000: Section 1.2) as 'images of the future or alternative futures'. Scenarios are not forecasts of the future, but represent pathways of how the future might transpire. Scenarios are created due to the complexities and uncertainties of the future, which makes predicting future outcomes, with a high level of accuracy extremely, unlikely (Hulme, 2001 and Malone *et al.*, 2004). Therefore, in order to account for uncertainties in energy planning and future emissions, many global and national organisations have opted to use scenarios instead of forecasting. Scenarios differ from other planning tools in that they attempt to illustrate a range of different possibilities, rather than a projection or forecast, which illustrates the most likely future development path (Coates, 2000 and Parson *et al.*, 2006).

Scenarios, which are also more flexible than other future analyses, can be narrative or quantitative, or a combination of both. Quantitative scenarios are often based on mathematical modelling, whilst the narrative scenarios are based on qualitative storylines (Fisher *et al.*, 2007). Scenarios can be based on past trends or they can be based on speculation. Scenarios do not aim to portray the future with much accuracy or detail, but rather to provide an understanding of the relationships between key drivers of change and the implications of these changes in the future. Scenarios can ensure that assumptions about future developments are transparent (Refsgaard *et al.*, 2007). Scenarios also differ from forecasting and projections because they do not provide a level of probability for the occurrence of each scenario (Parson *et al.*, 2006).

Scenarios may be distinguished into explorative and normative scenarios. Explorative scenarios describe 'what could happen', whereas normative scenarios describe 'what should happen in order to achieve set targets' (IEA), 2003: p111). Explorative scenarios are also called baseline scenarios because they portray development paths based on different assumptions of drivers of emissions and/or storylines that are consistent with past trends. Normative scenarios are also referred to as mitigation scenarios because they include policies and mitigation measures that are set to reduce GHG emissions (Anderson *et al.* 2008). Normative scenarios often consist of backcasting techniques, where a desired future outcome is set and scenarios are developed to illustrate different ways of achieving the outcome (Parson *et al.*, 2006).

Emission scenarios play an important role for policy makers, enabling them to understand the implications of short term policies on climate change over the long term (Anderson *et al.*, 2008; Fisher *et al.*, 2007; Hulme, 2001; Nakicenovic *et al.*, 2000a and Parson *et al.*, 2006) and enabling them to plan strategically for the future (Coates, 2000 and Schoemaker, 1995). Emission scenarios are also useful for scientific analyses, understanding dynamic systems and aid in the development of mitigation measures globally, nationally or locally (Fisher *et al.,* 2007 and Hulme, 2001). GHG emission scenarios are based on different assumptions of the driving forces of emissions, such as population and economic growth and technology.

2.2 Global Scenarios

The first global scenarios developed in the 1970s, were narrative storylines that focused on the impacts of economic development and population growth on limited resources. According to Fisher *et al.* (2007), the scenarios developed in the early decades illustrated the usefulness and the disadvantages of using quantitative modelling techniques and narrative analyses. The approach identified the need to incorporate both techniques for developing scenarios, to ensure that the outcome is realistic, descriptive and quantifiable (Fisher *et al.*, 2007). Whilst there have been many emission scenarios published since the early nineties, the five main global scenarios used today are the scenarios produced by the IPCC, the International Energy Agency, the Energy Information Administration, the World Energy Council and Royal Dutch/Shell (Anderson *et al.* 2008). The IPCC scenarios main focus is CO_2e emissions, which are related to energy consumption and land-use change, while the other scenarios main focus is energy consumption, and CO_2e emissions are determined from the energy consumed.

2.2.1 *The IPCC Special Report on Emission Scenarios*

The IPCC SRES is noted to be the most widely acknowledged and used report on climate change emission scenarios (Arnell *et al.*, 2004; Mckibbin *et al.* 2004 and Wang and Watson, 2008). In 1990, the IPCC developed its first emission scenarios which reflected a "Business-as-Usual (BAU)" Scenario and three other scenarios. This was updated in 1992 with six IS92 Reference Emissions Scenarios, which illustrated the implications of various changes in population, economic growth and carbon intensity of energy supply (Hulme, 2001; Nakicenovic *et al.*, 1998 and 2000a). The IS92a Scenario was commonly used by researchers as a reference for the BAU Scenario (Hulme, 2001 and Nakicenovic *et al.*, 2000a). In 1994, the IPCC evaluated the IS92 Scenarios and based on a number of reasons, primarily new information concerning GHG emissions and their impacts on climate change, decided to develop an improved set of emission scenarios (Arnell *et al.*, 2004). Subsequently, the IPCC SRES was published in October 2000.

The process of developing the SRES began in 1997, with the appointment of the writing team, which consisted of 28 experts from 12 countries and six modelling teams. This was to ensure that the process included a wide involvement of the research community (Hulme, 2001). The first objective of the team was to compile a database of all existing literature on emission scenarios and to base the new scenarios on an analysis of the literature (Nakicenovic *et al.*, 1998). The database was published on the internet in 1997 and is continuously updated with new literature. In 1998, the database consisted of approximately 400 regional and global scenarios, which increased to more than 1000 literature sources in 2008 (NIES, 2008). To ensure the transparency of the process, advertisements were placed in relevant scientific journals, inviting researchers and modellers to participate (Nakicenovic *et al.*, 2000a).

The result was a set of four storylines, which are made up of forty emission scenarios. Each storyline represents a different development path for the world, based on population, economic, technological, environmental and political changes over the past century (Arnell *et al.*, 2004 and Nakicenovic *et al.*, 2000a). The IPCC scenarios are neither qualitative nor quantitative, but rather a tool that combines the two. Therefore they connect qualitative storylines with quantitative models (Nakicenovic *et al.*, 2000a). The scenarios are long-term projections, which span until 2100. The scenarios are baseline scenarios and do not include any climate change policies that might be implemented; however they do include environmental policies that might have an impact on GHG emissions (Nakicenovic *et al.*, 2000a and Winkler, 2005). The storylines are simply termed A1, A2, B1 and B2 (Figure 2.1) and are described below:

- The A1 family is economically characterised by high growth rates, market-based solutions and high rates of technological change. Global population growth is slow; it peaks mid-century and declines thereafter. There is a convergence among different regions due to open economies and extensive social and cultural interaction. The A1 family is divided into different groups based on their technological path:
    - A1F scenario is fossil fuel intensive, which can be a global economy predominantly based on alternative oil and gas resources (A1G) or an economy that is driven by coal consumption (A1C).
    - A1B scenario is a balanced technological change, wherein there are technological advancements in both fossil fuel and alternative energies.
    - A1T is a technology intensive scenario group that represents a world where there is rapid advancement in non-fossil fuel energy technologies, which leads to high levels of energy saving (Arnell *et al.*, 2004 and Nakicenovic *et al.*, 2000a).
- The A2 family represents a world that is very mixed due to closed economies, a drive to preserve local identities and uneven economic growth. Population growth is high, due to more emphasis on family life. Technological change is slow, because of less social and economic interaction, which results in high technological change in some places and slower change in others. Environmental preservation is only prioritised if it fulfils human needs (Arnell *et al.*, 2004 and Nakicenovic *et al.*, 2000a).
- The B1 family is characterised by a high level of environmental and social awareness. The scenario represents a convergent world, with a shift towards income equality and an increase in environmental policies and resource efficiency. Sustainable development is prioritised on a global level. Population growth is low, similar to the A1 scenario, due to a demographic transition towards low fertility and mortality rates. Economic growth is high, with a shift towards a service and information economy. Cleaner technologies are encouraged and incentivised, leading to a reduction in energy consumption. Alternative energy sources are more widely used, as a result of a decline in fossil fuels (Anderson *et al.*, 2008 and Nakicenovic *et al.*, 2000a).

- The B2 storyline represents a heterogeneous world like the A2 family, but it is more environmentally aware, with an emphasis on local solutions for sustainability. Population growth is moderate, due to a promotion of education and welfare programmes. Economic development is average compared to the other scenarios, and technological change is slow and uneven. Community and social advancements are highlighted, with a drive to promote equality and environmental protection, on a local and regional level. However, global environmental issues are not given enough attention (Anderson *et al.*, 2008 and Malone *et al.*, 2004).

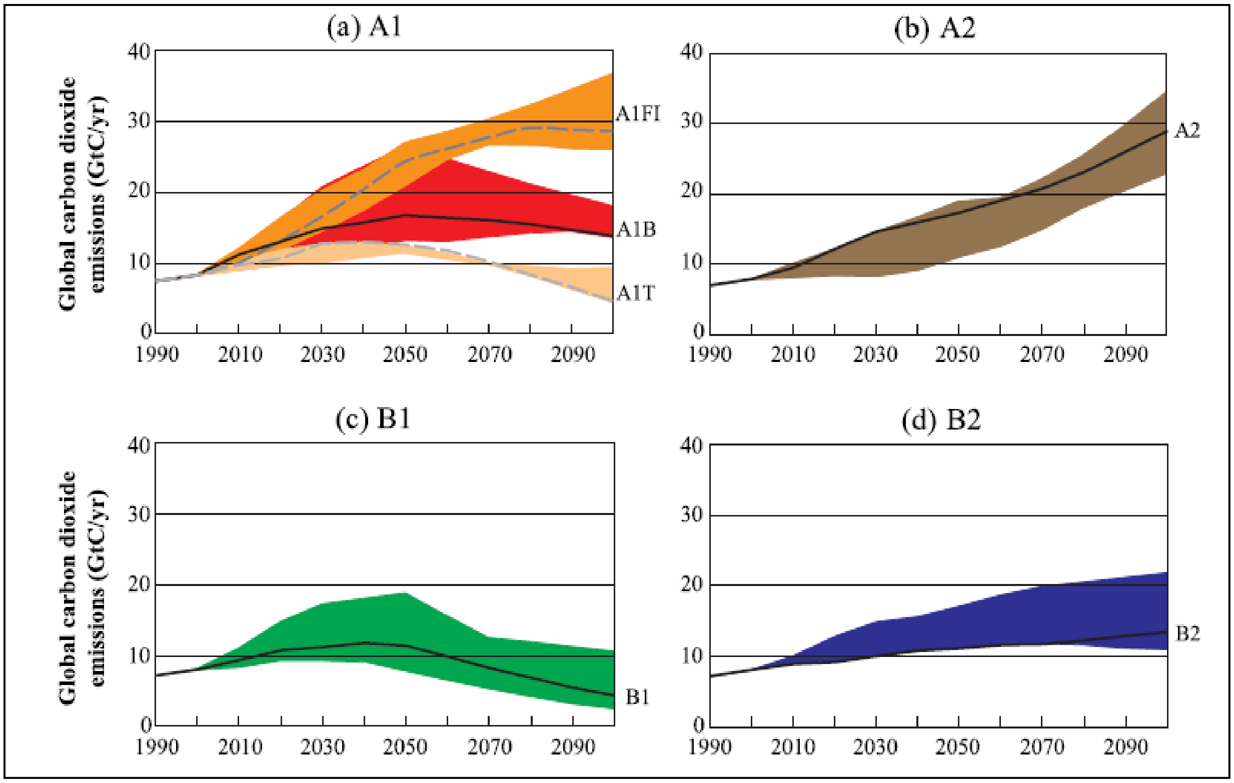


Figure 2.1: Total CO_2 emissions for all IPCC scenarios from 1990 - 2100, including energy, industry and land-use change

Source: Nakicenovic et al. (2001)

Figure 2.1 illustrates the global emissions for all scenarios. The graphs represent the 40 scenarios, which are divided into four families. The colour band for each family represents the range of results from the different models. By 2050, emissions range from 9 to 27 GtC, with an average value of 15 GtC and by 2100 emissions range from 3 to 37 GtC, which is between 50% decline or a 6 times increase from 1990 levels. High economic growth in the A1 scenario leads to an increase in energy demand and an increase in GHG emissions based on the different advancements in energy supply technologies. The A2 scenario is influenced by slow technological change, dominance in fossil fuels, which results in coal gaining prominence as oil and gas supplies decline. The result is a steady increase in GHG emissions until 2100. The B1 scenario reflects the least carbon emissions, which is due to global environmental concerns and shifts towards service orientated economies, which are less energy intensive. Lastly, the B2 scenario reflects a steady increase in carbon emissions, although at a lower rate in comparison to the A2 scenario. This is due to higher environmental concerns of society in this scenario (Nakicenovic *et al.*, 2000a).

The IPCC scenarios have been critiqued by Castles and Henderson (2003) for converting national gross domestic product (GDP) to a common measure using market exchange rates (MER) instead of purchasing power parity (PPP). This, they claim, has resulted in unlikely high GDP projections for developing countries. As a result the lowest emission scenario is not reflective of the actual plausible lowest emissions (Castles and Henderson, 2003). However the IPCC (Nakicenovic *et al.*, 2003) have responded to this critique by publishing a response, which states that MER was used because it is the favoured measure of GDP growth, whilst PPP is used to measure economic welfare. Further, it was argued that the IPCC did include PPP, which was ignored by Castles and Henderson (2003). Lastly, the IPCC stated that the scenarios are consistent with historical data and with projections of other forecasts and scenarios (Nakicenovic *et al.*, 2003).

2.2.2 *World Energy Outlook*

The IEA publishes an annual WEO, which projects global future energy consumption and carbon dioxide emissions. The most recent WEO was published in November 2009, however the 2008 issue is freely accessible to all (IEA, 2008a). The World Energy Outlook differs from the IPCC scenarios, in that they produce an annual report, which allows the IEA to update the projections on a regular basis, to account for unexpected changes in the global economy. For example, an excerpt (from the executive summary) from the 2009 Outlook states that it took into account the global recession and fluctuating energy prices in its forecasts (IEA, 2009). The WEO scenarios focus more on projecting energy demand, with energy-related CO_2 emissions being a secondary projection to the energy projections. The WEO projects energy consumption and GHG emissions until 2030, rather than 2100.

The IEA projections were made using a model that was designed to reflect world energy markets, called the World Energy Model. The World Energy Model, developed in 1993, is a mathematical tool which is updated on a regular basis. The model is capable of evaluating global energy use, the environmental impacts of energy supply and demand, the effects of policy implementation and technological changes and the investment required to supply future energy demand (IEA, 2008b).

The WEO comprises different scenarios to project changes in the future which are uncertain. Its 2008 scenarios comprised three main scenarios. The Reference Scenario describes a global future which takes into account government policies that were enacted or implemented by mid-2008. Therefore it assumes that governments would do nothing more during the projection period to impact on energy consumption (IEA, 2008a). This provides a baseline to compare alternative scenarios. In the Reference Scenario, the world GDP rises at an annual average of 3.3% and world population increases at an annual average of 1% per annum. There is an improvement in energy efficiency technologies, which occur at varying rates. The results of this scenario reflect an increase in energy demand and CO_2 emissions by 45% from 2008 – 2030. Global energy related CO_2 emissions increase from 28 Gt in 2006 to 41 Gt in 2030 (IEA, 2008a).

The other two scenarios are the 450 and 550 Policy Scenarios. These scenarios reflect a long-term stabilisation of CO_2 in the atmosphere at 450 and 550 parts per million, respectively. Emissions in these scenarios peak in 2020, and then begin to decline, with the 450 Scenario, declining at a faster rate. The energy and related CO_2 emissions in the 550 Policy Scenario are 19% lower by 2030, compared to the reference scenario. The energy fuel mix, displays an increase in the consumption of renewable energy and nuclear power. To achieve the 450 Policy Scenario, massive decrease in energy consumption and related CO_2 emissions will be necessary (IEA, 2008a). This will require global efforts to reduce emissions, such as stringent policy action and a rapid introduction of efficient, low-carbon technologies (IEA, 2008a and Anderson *et al.*, 2008). Therefore, achieving this scenario is unrealistic, as emissions projected in this scenario are less than the projected emissions for non-Organisation for Economic Co-operation and Development (OECD) countries in the Reference Scenario as illustrated in Figure 2.2.

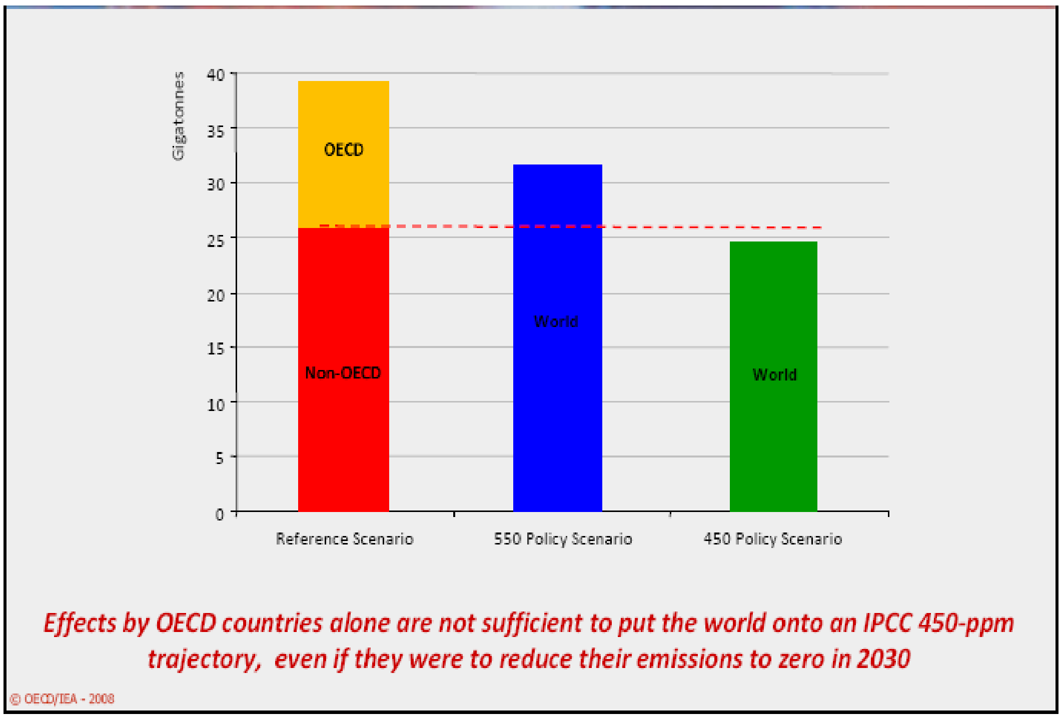


Figure 2.2: IEA Reference, 550 Policy and 450 Policy Scenarios for global energy-related CO_2 emissions in 2030

Source: IEA (2008)

2.2.3 *International Energy Outlook*

The International Energy Outlook (IEO) was developed by the United States Energy Information Administration (EIA). Its most recent publication was May 2009. The IEO is similar to the WEO in that both scenarios use 2006 as a baseline year to project emissions and both scenarios project emissions to 2030. The IEO2009 Reference Scenario is also similar to the WEO scenario in that both reference scenarios assume that policies remain the same during the forecasting period. The Reference Scenario projects global energy-related CO_2 emissions to increase at an annual average of 1.4% (EIA, 2009).

Alternative scenarios in these projections are predominantly based on macroeconomic growth and future oil prices. This is because according to the EIA (2009: 116), “Economic growth is the most significant factor underlying the projections for growth in energy-related carbon dioxide emissions in the mid-term.” The macroeconomic scenarios portray a Low Growth Scenario and a High Growth Scenario relative to the Reference Scenario. In the Low Growth Scenario, CO_2 emissions increase at 1% per annum and the High Growth Scenario reflects an increase in CO_2 emissions of 1.8% per annum (EIA, 2009). Emissions for 2030 for the three scenarios are illustrated in Figure 2.3.

Other alternative scenarios are Low and High Oil Price Scenarios, however they do not differ considerably from the Reference Scenario. The Low Oil Price Scenario reflects higher CO_2 emissions compared to the Reference Scenario (EIA, 2009).

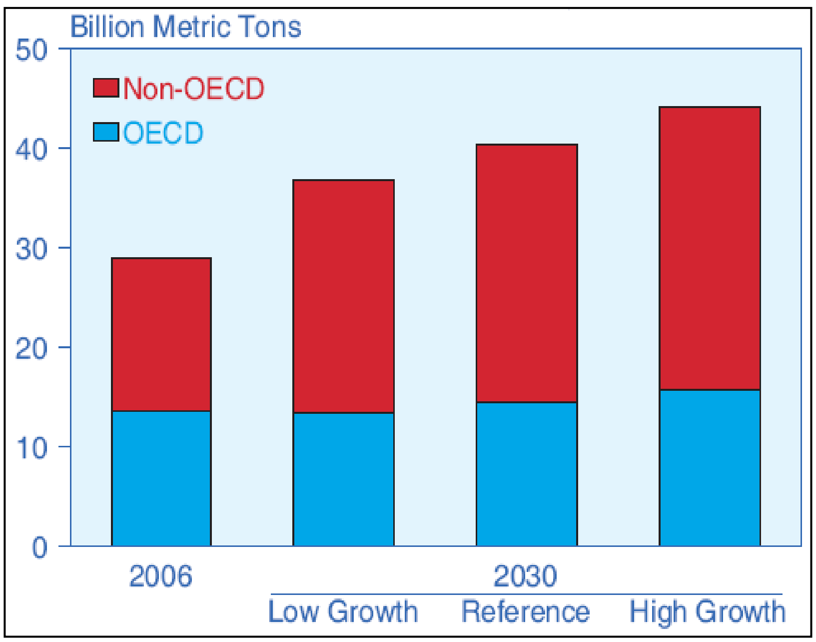


Figure 2.3: EIA Low Growth, Reference and High Growth carbon dioxide emission scenarios for 2030
Source: EIA (2009)

2.2.4 *Energy Policy Scenarios to 2050 (WEC, 2008)*

The main objectives of the World Energy Council’s (WEC, 2007) energy scenarios is to gain a better understanding of global energy patterns and the challenges they represent, and also to provide a framework for policy makers in order to attain a sustainable energy supply. The WEC took a qualitative approach, focusing predominantly on how policies can meet global challenges. However, a quantitative mathematical model was used for comparison with the outcomes of the qualitative model (WEC, 2007).

The scenarios developed are long-term projections to 2050 and contain policy recommendations to reach the different outcomes by 2050 (Schiffer, 2008).

Four scenarios were developed and are named after animals which have similar characteristics to the scenarios. The two main factors that differentiate the scenarios are the level of government intervention and the level of market integration and global cooperation (Schiffer, 2008 and WEC, 2007). Scenario 1, the Leopard, reflects an overall low level of state intervention and a low level of market integration and global cooperation, which is similar to the characteristics of a solitary leopard. Scenario 2 is named after the Elephant, which are very sociable within their herd but have no inclination to interact with other herds. It also finds it difficult to adapt to change. This scenario therefore has a high level of government intervention and a low level of global cooperation and integration. The Lion represents the Scenario 3, which has a high level of government intervention and global integration. Lastly, the Scenario 4 is the Giraffe, which due to its height can foresee danger and prospects and head towards positive outcomes, with no concern about social responsibility. Low state intervention and high levels of global integration and cooperation are the results of this scenario (Schiffer, 2008 and WEC, 2007).

The four scenarios are then evaluated based on whether they meet three criteria: "Accessibility" to energy resources and an affordable price; 'Availability' of energy over a long-term; and, "Acceptability" of the energy supply by the general public. The results show that the Lion is the most positive scenario, which has a high level of economic growth and the lowest CO_2 emissions. This is achieved primarily via an expansion in renewable and nuclear energy supply (WEC, 2007).

2.2.5 *Shell Energy Scenarios to 2050*

Royal Dutch Shell developed their first scenario in the early 1970s and is regarded as one of the founders of scenario analysis (Schoemaker, 1995). Shell scenarios are of an 'explorative' nature and are centred on a qualitative narrative approach, similar to the WEC scenarios. A quantitative analysis is conducted for certain drivers, however these are not emphasised. The methodology used involves using expert advice from people in all fields (IEA, 2003). Shell developed its first 50 year scenario in 1995, and its latest energy scenario was published in 2008.

The 2008 scenarios are differentiated between two storylines, Scramble and Blueprints. Both scenarios examine possible paths for future energy demand and supply and technological changes. The Scramble Scenario represents a world, where national governments 'scramble' to achieve energy stability in their country (Shell, 2008). Therefore it is similar to the IPCC A2 and B2 scenarios, which have low levels of global integration. The Blueprint Scenario reflects a world where there is global, regional and local corporation to develop a new 'blueprint' for energy supply and demand. The two scenarios are driven mainly by differences in energy demand, resource availability and use, technological advancement and environmental policy and impacts (Shell, 2008).

In Scramble, national governments' main priority is to secure energy supply. Climate change mitigation and energy efficiency is postponed to the future, when it becomes vital, as a result of climate related disasters (Shell, 2008). Therefore atmospheric CO_2 equivalent is above the required 550 parts per million (ppm). The late response to climate change drives up energy prices towards the end of the period and results in the slow downturn of economic growth (Shell, 2008).

In Blueprints, alliances develop between different levels of government, who share common interests of ensuring energy security, whilst minimising environmental impacts and promoting economic growth (Shell, 2008). These aspects result in the formation of groups who seek to achieve similar goals. Consequently, market driven energy demand-side management initiatives and CO_2 reduction strategies become more prominent. Therefore CO_2 emissions are reduced, resulting in a cleaner, more sustainable future world (Shell, 2008).

2.2.6 *Comparison of global scenarios*

The global scenarios described above differ in the approach taken and key factors that impact on changes in emissions. The IPCC scenarios depict long term scenarios, which illustrate emissions until 2100. The WEC and Shell Scenarios are also considered to be long term scenarios; however the end-year of these scenarios is 2050. Lastly, the IEA and EIA scenarios are short term and the end-year is 2030. Short term scenarios are less susceptible to uncertainties that arise from assumptions made in long term scenarios (Ghanadan and Koomey, 2005; and Siddiqui and Marnay, 2006). However, according to Greenpeace (2008), a lack of long term projections in emissions forecasting makes it difficult to determine the long term impacts of climate change, globally.

The different scenario creators, focused on different drivers to develop their scenarios. For example, the IPCC scenarios were mainly driven by levels of environmental emphasis and global integration. The WEO scenarios were created based on 450 ppm and 550 ppm global policies. The IEA scenarios showed the implications of different levels on growth on emissions. Different levels of government intervention and global integration were the main drivers of the WEC scenarios. Lastly, the Shell scenarios were driven by levels of cooperation on a local, national, regional and international level. Therefore the different factors driving GHG emissions resulted in large differences between the scenarios.

A similarity amongst the scenarios is that growth rates in population, GDP and emissions are higher in developing countries as opposed to industrialised countries (EIA, 2009; IEA, 2008; Kram *et al.*, 2000 and Nakicenovic *et al.*, 2000). The Reference Scenario for the IEA and EIA project similar emissions for 2030, because both scenarios are based on similar assumptions. The Shell Blueprints Scenario has similar emissions to the IEA and the US EIA High Growth Scenarios but in 2050 emissions decline to 26,500Mt CO_2e, which are due to the policies and global cooperation to solving issues around climate change. The A1C projects the highest emissions due to a dominant use of coal in the future. The lowest emissions occur in the 450 Policy Scenario, but this scenario was designed to meet the 450 ppm target and requires a global paradigm shift in energy saving in order to occur (Anderson *et al.*, 2007).

Table 2.1 provides a brief summary of the energy-related CO_2 emissions for the different global scenarios. The emissions are in million tonnes (Mt) for the specified year. The projected emissions for 2030 vary between 70 705 Mt CO_2 to 23 000 Mt CO_2. This is due to a wide range of assumptions being made about key drivers of CO_2 emissions, such as population, GDP growth, fuel mixes and other factors. It is also because different models are used by the various agencies (Kram *et al.*, 2000 and Nakicenovic *et al.*, 1998). The variety of different possible outcomes accounts for uncertainty in forecasting the future. It displays possible emissions outcomes based on different development pathways the world might choose to follow.

Table 2.1: Comparison of selected global CO_2 emission scenarios in million tonnes CO_2

Author	Scenario	Range	Base Year Mt CO_2	2030 Mt CO_2	2050 Mt CO_2
IPCC SRES	A1C	High	25,300	70,705	98,220
	B2	Median	25,300	42,997	52,368
	B1	Low	25,300	35,811	31,089
IEA	Reference Scenario	Median	26,000	42,000	n/a
	Alternative Policy	Low	26,000	34,000	n/a
	High Growth	High	26,000	44,940	n/a
	450 stabilisation	Low	26,000	23,000	n/a
US EIA	Reference Scenario	Median	26,922	42,870	n/a
	Low Growth	Low	26,922	38,419	n/a
	High Growth	High	26,922	47,600	n/a
	High Oil Price	Low	26,922	41,800	n/a
	Low Oil Price	High	26,922	43,905	n/a
WEC	Leopard	Median	27,600	n/a	52,000
	Elephant	Median	27,600	n/a	38,600
	Lion	Low	27,600	n/a	37,200
	Giraffe	High	27,600	n/a	57,000
Shell	Blueprint	Low	25,000	45,000	26,500

Source: Anderson et al. (2007), Schiffer (2008) and Shell (2008)

2.3 Smaller scale scenarios

Smaller scale emission scenarios have been developed at a regional, national and local level. Some examples of countries that have developed future scenarios are the UK, China, USA, Finland, Switzerland, Turkey, India and Japan. Regional scenarios have been developed for the European Union and the Asia Pacific Region. Some regional and local scenarios were developed by using global scenarios and downscaling or altering them to represent a country level or regional scenario. Other scenarios were developed by focusing on policy and other data that are specific to the area. Some of these are reviewed in the following sections.

2.3.1 *Regional scenarios*

The Asia-Pacific Integrated Model

The Asia-Pacific Integrated Model (AIM) was developed to determine the impacts of high levels of industrialisation, population growth and urbanisation in many countries in this region on future CO_2 levels. The demand for energy in this region is growing rapidly, making this region a significant driver of climate change (Jiang *et al.*, 2000). Therefore to devise a response to climate change issues, it was necessary to produce emission scenarios for the Asia-Pacific region based on its development path. The scenarios focused on different emissions sources which are energy related emissions, agriculture, land use and forests. The model uses a top-down and bottom-up approach to develop its scenarios (Jiang *et al.*, 2000).

The bottom-up approach uses detailed information about energy services and technological change in the region to determine efficiency changes in the region. The top-down approach uses an energy supply and demand equilibrium estimate to determine energy prices and energy efficiency improvements (Jiang *et al.*, 2000). The two approaches are linked and are used to estimate future GHG emissions. Storylines were then developed for the region based on different possibilities of GDP, population, economic structure and energy efficiency. The storylines developed were similar to the IPCC A1, A2, B1 and B2 scenarios (Jiang *et al.*, 2000).

European Union scenarios

The European Union (EU) has developed scenarios for the region due to the promulgation of the Green Paper on the Security of Energy Supply published by the European Commission (EC) in 2000 (Capros and Mantzos, 2005). In addition, the need to address the climate change challenge and the establishment of a Single Energy Market, made it essential that all EU countries work together in developing emission scenarios and mitigation measures for the EU (Capros and Mantzos, 2005). The scenarios were created using the energy systems model called PRIMES to develop future energy demand and supply patterns. The EC have published scenarios called '*Trends to 2030'* in 2003, 2005 and the latest one was published in 2007.

The Baseline Scenario, which was established, includes all policies that were implemented to the end of the previous year. A comprehensive analysis was conducted on the baseline scenario, which looked at various factors that would impact on the EU's energy consumption and CO_2 emissions. Examples are the implications of world energy prices and demand, the EU's energy demand in industrial subsectors, transport, residential and services sectors, and the energy supply on CO_2 emissions. Other policy scenarios are also constructed to reflect the implications of further energy policies on consumption and emissions (Capros *et al.*, 2007).

2.3.2 *Local scenarios*

Emissions and energy scenarios, using different approaches and methodologies, have been developed for many countries. This section will briefly examine some of the scenarios that have been developed for countries, focusing on the methodologies used and the different scenario assumptions made. The country scenarios are differentiated between the prospective and backcasting scenarios. Prospective scenarios use the present as a baseline and develop different storylines for the future, based on different steps a country might take (Mander *et al.*, 2008). Backcasting scenarios tell us "how to get to where we want to be, taking into account the pathways to achieving a defined and desirable future" (Mander *et al.*, 2008: 3755).

The South African scenarios will then be discussed in more detail, as they are important in the context of this study.

<u>Prospective Scenarios</u>

Many of the country emission scenarios use the IPCC scenario assumptions to develop their baseline scenarios, for example India, Finland, UK, East Anglia in the UK (Carter, 2004; Lorenzoni *et al.*, 2000, UK Department of Trade and Industry, Rajesh *et al.*, 2003). India took a top-down and bottom-up approach to develop its scenarios (Rajesh *et al.*, 2003). Its scenarios were formulated using three models that were integrated to establish storylines for the country. Rajesh *et al*. (2003) focused on economic growth, technology and access to technology as key drivers for the scenarios.

The Baseline Scenario is based on current trends and a continuation of these trends into the future. This scenario serves as a reference scenario, which enables comparisons with other scenarios. The market reform scenarios are distinguished between Accelerated and Decelerated Market Reform Scenarios. The Accelerated Market Reform Scenario presumes faster improvements in the energy market, which results in more efficient technologies being introduced, whilst the Decelerated Market Reform Scenario presumes slower changes. The last scenario is the Accelerated Development of Renewable Technologies Scenario, wherein policies are introduced to promote the use of renewable technologies. The results of these scenarios show that the emissions related to the baseline and market scenarios are very similar, which is due to the continued dominance of coal into the future. Due to the dominance of coal, emissions forecasted are expected to increase eight times from 1995 to 2100. The Accelerated Development of Renewable Technologies Scenario also indicated a slight decline in emissions compared to the Baseline Scenario. This refuted the assumption that renewable technologies will have a large positive impact on the reduction of CO_2 emissions (Rajesh *et al*., 2003)

In Finland, various scenarios were produced to fulfil different objectives. However the most recent one, FINSKEN (Developing Consistent Global Change Scenarios for Finland), aims to depict the impacts of global change and other driving forces on Finland (Carter, 2004 and Kaivo-oja *et al.*, 2004). The Finland scenarios used the IPCC SRES to develop scenarios on a country-level. The Finnish scenarios were based on the IPCC A1, B1, A2 and B2 scenarios, to ensure the reliability of different socio-economic and environmental factors. However the scenarios have been modified to reflect polices and other issues that are specific to Finland. The scenarios were developed using expert opinion, stakeholder meetings, documents and research papers to provide an indication of future Finnish development pathways (Carter, 2004 and Kaivo-oja *et al.*, 2004). The scenarios developed were:

- "Global Markets Integrated Finland (related to A1);
- Neo-liberal Industrial Finland (related to A2);
- Sustainability Orientated Finland (related to B1);
- Local Stewardship Finland (related to B2)." (Kaivo-oja *et al.*, 2004: 115)

The advantage of these scenarios is that they are easily comparable to other scenarios. They also reflect a wide range of expert opinions and the scenarios developed consider a variety of factors that are specific to the country.

Another method of developing scenarios is based on changes in economic growth of a country, for example, Turkey. According to Say and Yucel (2006), previous studies in Turkey have shown that there is a strong correlation between GDP growth, energy consumption and CO_2 emissions. The model developed used a regression analysis to determine a relationship between the country's GDP growth, energy consumption and CO_2 emissions, using data from 1970 - 2001. The study showed a strong relationship between the variables, therefore CO_2 emissions and energy consumption were forecasted until 2015, based on this relationship. These were compared to the IPCC scenarios developed for Turkey. The result was that the IPCC method projected higher emissions, which is primarily due to differences in the baseline data (Say and Yucel, 2006). Whilst this methodology is a useful approach, it requires accurate historical data and a correlation between economic growth, energy consumption and CO_2 emissions, which is not apparent in all countries. It also is not suitable for long term scenarios, as technology changes are more apparent over the long term.

A scenario analysis was completed by Schulz *et al.* (2008) to determine the possibility of achieving 2000W primary energy consumption per person for Switzerland. Whilst Schulz *et al.* (2008) realise that achieving this goal by 2050 is not possible; they developed scenarios to act as intermediate steps to attain a 2000W society. The approach used the Swiss Market Allocation (MARKAL) model, which is a bottom-up, optimisation model that incorporates environmental, economic, energy and technology. A range of scenarios were generated and the results were analysed. The study showed that setting an energy target is not always the best strategy if it is not related to CO_2 emissions. Energy efficiency measures are not always effective if a large amount of energy is derived from non-fossil fuel sources. Therefore, it is preferable to make reducing CO_2 emissions the main goal rather than energy consumption (Schulz *et al.*, 2008).

Ghanadan and Koomey (2005) used the Long Range Energy Alternative Planning (LEAP) tool to develop four scenarios for California. The approach followed combined both qualitative and quantitative methods. The purpose of the scenarios is to determine possible energy paths the state might follow, based on different assumptions. The scenarios were used to integrate energy systems and strategic planning. Four scenarios were developed and compared; the BAU scenario and three other scenarios, which reflect different levels of change towards a cleaner fuel economy. Split Public is driven by individuals' initiatives towards a clean fuel society; Golden State has more active interventions by the state; and Patriotic Energy is impacted on by national energy efficiency policies. The scenarios were divided into different sectors: the industrial, commercial, residential, transportation and electricity generation. This portrayed the impacts of the different scenarios on emissions in these sectors (Ghanadan and Koomey, 2005). For example, residential emissions in the Split Public are low due to individuals making an effort to reduce their consumption. The study showed that national energy efficiency policies, in the Patriotic Energy Scenario has the greatest benefit for reducing GHG emissions, with emissions increasing only 10% from 2005 to 2035, whilst the Spilt Public and Golden State Scenarios illustrated an average increase of 60% during the same period. Ghanadan and Koomey (2005) found that in order to reduce emissions to an optimal level, a combination of national and local policies and initiatives are required, along with individual and community involvement.

Backcasting Scenarios

The most recent scenarios for the UK and China were developed by the Tyndall Centre for Climate Change Research. The methodology applied used a backcasting approach. A future target was set and scenarios were developed to look at different levels of energy demand, energy mixes, GDP, technology and other factors to achieve the target (Bows *et al.*, 2006). Prior to this, other scenarios were developed for both countries, using other methodologies. In 2004, the Chinese Energy Research Institute, with the aid of the Lawrence Berkeley National Laboratory, used the LEAP tool for an energy scenario analysis until 2020. The Energy Research Institute then used an Integrated Policy Assessment model to develop scenarios until 2050, which was more detailed than the previous scenario. These scenarios focused more on CO_2 emissions rather than energy consumption and looked at different policy implications for climate change.

In the UK, previous scenarios were developed by the Department of Trade and Industry called the Foresight Scenarios. The Foresight Scenarios were based on the IPCC scenarios, as mentioned earlier (UK Department of Trade and Industry, 1999). These scenarios were forecast scenarios, with the present energy consumption and carbon dioxide emissions being the baseline.

In 2005, the Tyndall Centre produced the first scenarios in the UK that included emissions from air and sea transport and incorporated the entire energy system. The purpose of including emissions from air and sea transport is because emissions from these sectors are growing rapidly, and they are not included in country inventories. The starting point of the scenarios is 2050, where a 60% CO_2 reduction target is set. In developing the scenarios, opinions of various experts were taken into account and five scenarios were created (Mander *et al.*, 2008). Whilst the scenarios had the same CO_2 emissions for 2050, they differed in their GDP growth rates, the dominant economic sectors, energy consumption, energy supply mix, household energy consumption, policies implemented and transport and transport fuels. The scenarios were given neutral names (of colours) to avoid any bias that might arise due to names. The Red Scenario reflected high economic growth and low energy demand, the Blue and Turquoise Scenarios have low and moderate economic growth and medium energy demand and the Purple and Pink Scenarios have high economic growth and energy demand, but they differ in their energy supply mix (Anderson *et al.*, 2008). A multi-criteria assessment was then conducted to determine which scenario is the most suitable (Mander *et al.*, 2008).

The main outcomes of this approach for the UK indicated that energy efficiency reduction has the potential to dramatically reduce CO_2 emissions. It is more feasible to reduce energy demand then to provide low carbon energy supply, due to the costs of constructing new infrastructure. Also, the study indicated that if the UK is to achieve its 60% reduction target, government involvement is vital (Anderson *et al.*, 2008).

China differed from this approach by using a cumulative emissions budget instead of a percentage reduction target, which is similar to the UK's next phase of scenarios, *Living within a carbon budget* (Bows *et al.*, 2006). The cumulative emissions budget was set based on the IPCC stabilisation target of a global GHG concentration of 550ppm CO_2 equivalent. However, allocating a budget for China was determined by using two approaches, which are CO_2 emissions per capita and CO_2 emissions based on GDP growth. This resulted in two different budgets, on which four carbon emissions pathways were based (Wang and Watson, 2008). The pathways varied due to different assumptions about drivers of emissions.

South African Scenarios

In South Africa, baseline scenarios were developed by the CSIR (Taviv *et al.*, 2008) and mitigation scenarios LTMS) were developed by the SBT for the Department of Environmental Affairs and Tourism (SBT, 2007). Scenarios were also developed by Haw and Hughes (2007) with the aim of updating the energy models and to develop future scenarios for South Africa's energy system.

The LTMS is a government mandated document, which aims to illustrate different mitigation options for the country, in order to inform policy making and to aid in post-2012 UNFCCC negotiations. The scenarios were developed by a scenario building team which consisted of experts in the government, industry, civil society, academics and other fields. The scenarios that were created are differentiated between the various approaches the country might take to mitigate GHG emissions and calculates the costs of these options (SBT, 2007).

The SBT (2007) began with developing a GWC Scenario, which assumed the Accelerated and Shared Growth Initiative for South Africa (AsgiSA) GDP growth rate between 3-6%. This scenario also assumes that no energy and climate change policies are implemented, there is no oil scarcity and the main priority for the country is to promote economic growth. The major result of this scenario is that GHG emissions quadruple by 2050 (SBT, 2007). This is compared to the Current Development Plan Scenario, which includes the implications of the Energy Efficiency Strategy and the renewable energy target. The comparison, shown in Figure 2.4, indicates that if the country were to remain on its current development path, emissions will not be significantly reduced. These scenarios are contrasted with the other extreme scenario, the RBS Scenario. This scenario reflects how much South Africa would need to reduce its emissions if the world takes a step towards meeting the IPCC stabilisation target of 550ppm. In order to achieve this, South Africa would have to reduce its emissions by 30% to 40% of its 2003 emissions, by 2050. The RBS Scenario could not be comprehensively modelled because it would require technologies that are currently unknown (SBT, 2007).

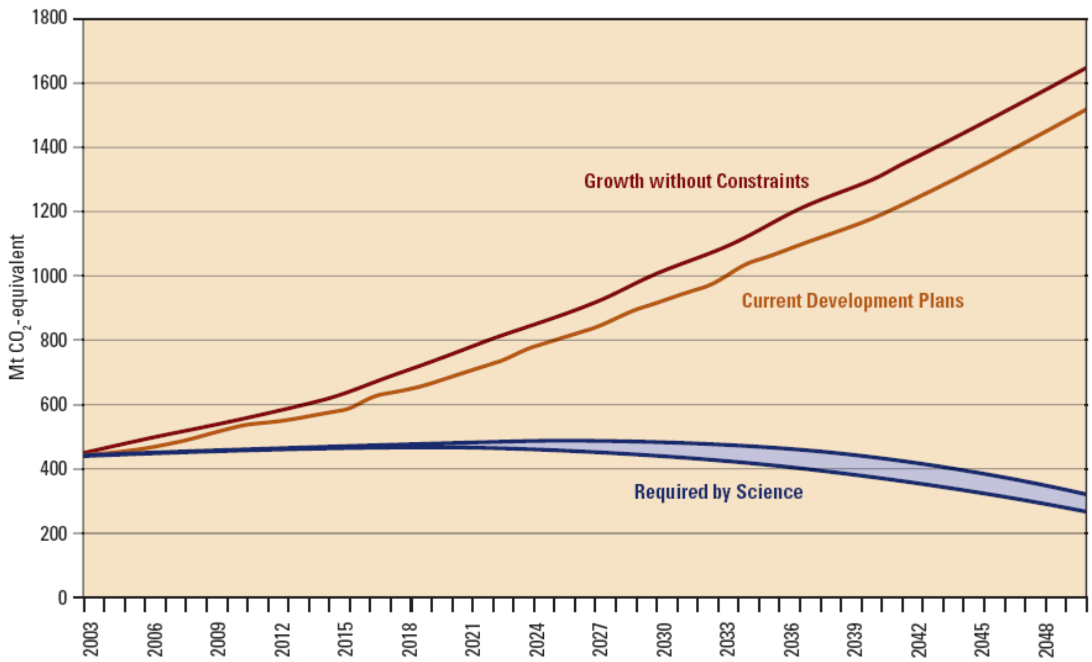


Figure 2.4: LTMS emission scenarios for South Africa to 2050

Source: SBT (2007)

Once this was established, the SBT (2007) then reviewed a series of mitigation options (wedges) to reduce emissions to attain the RBS scenario and the economic implications of these options. The wedges were then divided into four strategic options. The Start Now strategy includes options that save money over time. These include industrial and transport efficiency initiatives, as well as an increase in the usage of renewable and nuclear energy to generate electricity. The Start Now strategy reduces the gap between the GWC Scenario and the RBS Scenario by half (SBT, 2007). This is followed by the Scale Up strategy, which has similar wedges as the Start Now strategy, but also includes measures that would incur some expenses. The next strategy, the Use the Market strategy, uses carbon taxes and incentives to reduce emissions. The main negative impact of this strategy is its implications for economic growth, which declines due to taxes. However, the taxes also generate revenue for government, which could be used to provide incentives and subsidies. The last strategy is the Reaching for the Goal option, which would achieve the RBS goal; however this last step can only be achieved by the development of new technologies, a change in the behaviour of South African society and a transition of our economy from an energy intensive economy to a low carbon economy (SBT, 2007).

The scenarios produced by Taviv *et al.* (2008), built upon previous South African scenarios, especially the *Clean Energy and Development for South Africa* (Haw and Hughes, 2007). Taviv *et al.* (2008) also took into consideration the LTMS to ensure that there was no overlap between scenarios. The main objectives of these scenarios were to determine the main driving forces of emissions in South Africa for 2005-2030 and to determine the challenges South Africa might face in terms of energy supply and demand and to link this with environmental impacts. The scenarios were developed using the Long-range Alternatives Planning (LEAP) tool. Information was acquired by conducting a literature review in order to determine possible future development pathways for South Africa and also used the opinions of CSIR experts (Taviv *et al.*, 2008).

Three scenarios were created, which are the Reference Scenario, the Low Carbon Development Path and the Oil Peak Scenario. The Reference Scenario was adapted from the LTMS Current Development Path Scenario and the other two scenarios assume high mitigation, with high economic growth in the Low Carbon Development Path and Low Economic Growth in the Oil Peak Scenario. In the Low Carbon Development Path, South Africa drives toward reducing CO_2 emissions and achieving a low carbon economy. This is achieved mainly through large-scale energy efficiency initiatives and a high uptake of renewable energy. The Oil Peak Scenario assumes that the supply of oil will peak in the near future, resulting in high oil price increases and an economic decline (Taviv *et al.*, 2008).

2.4 Driving forces of emissions

There are many drivers of GHG emissions; however, the key driving forces of anthropogenic GHG emissions are population, economic growth and technology (Blodgett and Parker, 2008; Dietz and Rose, 1997; McKibbin and Stegman, 2005 and Nakicenovic *et al*., 2001). This is simply illustrated using the IPAT (Impact = Population x Affluence x Technology) equation first developed in the early 1970s by Ehrlich and Holdren (Dietz and Rose, 1997). The IPAT equation was first used to demonstrate that the severity of environmental degradation is a product of population (P), wealth per person (A) and the environmental impact of economic activity, which is represented by technology (T) (Dietz and Rose, 1997 and Yang and Schneider, 1998).

The IPAT equation has been modified to represent the impact of changes in population, affluence and technology on CO_2 emissions and is termed the Kaya Identity:

$$CO_2\ Emissions = Population \times GDP\ per\ capita \times energy\ intensity \times carbon\ intensity$$
$$n \quad \times \quad (GDP/n) \quad \times (Energy/GDP) \quad \times \ (CO_2/Energy)$$

The Kaya Identity implies that an increase in population, GDP per capita and CO_2 emissions per energy unit, will result in an overall increase in CO_2 emissions. The driving forces of emission scenarios are not independent of one another. For example, an increase in GDP, can result in an increase in the usage of new technologies, which would lower the energy and carbon intensity of an economy and can also result in a decrease in population growth (Nakicenovic *et al*., 2000a and Stern, 2007).

Other drivers of anthropogenic CO_2 emissions include exchange rates, discounting rates and future fuel demand and costs (Nakicenovic *et al.*, 2000a and Winkler *et al.*, 2009). These factors will be briefly discussed below, together with the main driving forces.

2.4.1 *Population*

Population growth is a major concern for governments and scientists globally, as it places pressure on the earth's resources (Yang and Schneider, 1998). Population is a key driver of GHG emissions because it influences the consumption of goods and services and the need for transportation. Goods and services and most means of transportation require energy to be produced, which consequently emits GHGs (van Vuuren *et al.*, 2006 and Winkler, 2009). Another reason for population growth impacting on GHG emissions is because high rates of population growth place pressure on the need for land, which results in deforestation and other land use changes (Karakaya and Ozcag, 2005 and Shi, 2003).

Studies by Engelman (1994) and Meyerson (1998) have shown that an increase in CO_2 emissions is closely correlated with an increase in population size, since the 1970s. This means that a 1% increase in population would result in a 1% increase in GHG emissions. However a more recent study by Shi (2003) has shown that a 1% increase in population would result in a higher increase in GHG emissions, of approximately 1.28%. According to Karakaya and Ozcag (2005), the impacts of population growth on emissions is greater in developing countries as opposed to developed countries.

The population size of a country is largely dependent on three main factors which are the rates of fertility, mortality and migration. The process of change from high birth and death rates to low birth and death rates is defined as demographic transition (van Vuuren *et al.*, 2006). Most high income countries have reached the final stages of demographic transition. Developing countries are still in the transition process, with many countries showing a decline in fertility (Harbison, 2005).

Therefore population projections are important in developing emission scenarios, as they enable researchers and policy makers to understand the implications of higher populations on emissions and to determine the vulnerability of a society to climate change based on socio-economic changes. This facilitates the implementation of constructive adaptation measures (Carter, 2007). For emission scenarios, preferable population projections are those that have a timeframe of a century or more and illustrate alternative projections due to unforeseen influences (Nakicenovic *et al.*, 2000a).

On a global level, population projections are estimated by four main institutions which are:

- United Nations (UN)
- World Bank;
- United States Census Bureau; and
- International Institute for Applied Systems Analysis .

The World Bank and United States Census Bureau have only one estimate and their data are for internal use only. Therefore the UN and International Institute for Applied Systems Analysis projections are more commonly used for emission scenarios (Nakicenovic *et al.*, 2000a and van Vuuren, 2006). More recent population projections illustrate a lower population growth rate than previous projections. This is primarily due to lower than expected birth rates in many developing countries and also a great impact of HIV/AIDS on the population levels in many African countries (Fisher *et al.*, 2007). This is a major contributor to a decline in population growth rates in South Africa (Dorrington *et al.*, 2006).

In South Africa, the most accepted population projections were conducted by Dorrington *et al.* (2006), to include the impacts of HIV/AIDS. Other factors influencing population changes in South Africa are future urbanisation and household size (Winkler, 2009). Energy consumption in rural households is different from urban households, due to higher levels of electrification in urban areas and high levels of biofuel consumption in rural areas. It is expected that population growth will be higher in urban areas compared to rural areas (Nakicenovic *et al.*, 2000a and Winkler, 2009). Household size is also important when determining energy consumption, because in general, energy consumption per capita is higher in households with fewer residents (Nakicenovic *et al.*, 2000a). In South Africa, the average number of residents per household has been decreasing over the past decade, which could result in higher rates of energy consumption per person in the future (Winkler, 2009).

2.4.2 *Economic growth and development*

Economic growth is another major driver of GHG emissions and is commonly measured as GDP per capita, which is defined as the value of all goods and services produced in a country over a specific period of time (Fisher *et al.*, 2007; Nakicenovic *et al*, 2000a). Whilst GDP is not viewed as the best measure of economic development, it is universally used to allow for international comparisons (Nakicenovic *et al.*, 2000a; Winkler, 2009). GDP growth is an important driver for GHG emissions because high GDP growth rates implies an increase in the production of goods and services, which results in an increase in energy consumption and waste (Haw and Hughes, 2007; Karakaya and Ozcag, 2005). Furthermore, an increase in economic growth results in industrial growth, which increases the demand for freight transport which increase emissions in the transport sector (EIA, 2009). Growth in GDP per capita also promotes household energy consumption, through a higher demand for private vehicles, electrification and domestic appliances (Haw and Hughes, 2007). Thus, changes in GDP are important for projecting emissions.

The existing literature suggests varied views on the relationship between GDP and energy usage. One may assume that an increase in GDP will automatically increase the energy usage in an area. According to Neumayer (2004), studies from 1960-1999 across approximately 160 countries have shown there is a strong relationship between CO_2 emissions per person and GDP per person(0.9). As a result, a 1% increase in GDP will result in a 0.9% increase in CO_2 emissions. However research has shown that this is not always the case (Grubb *et al.*, 2006). The first hypothesis that emerged to portray the relationship between the energy and income growth was portrayed in the Environmental Kuznets curve. The curve is an inverted U shaped curve, which illustrates that the level of pollution or environmental degradation increases with development up to a certain point and thereafter declines as GDP continues to growth. The Kuznets curve can be used to portray different pollutants and environmental variables (Stern, 1998, 2004).

The curve in this case therefore depicts the energy intensity (energy/GDP) or the carbon intensity (GHG emissions/GDP) of an economy (Martin and Cerda, 2003). This curve is an inverted U, depicting that as a country's income increases initially, so too do the GHG emissions at an equivalent rate. This continues until a certain level of income is reached. At this stage the economy has the ability to produce more output with a similar level of energy usage and therefore the GDP increases, with no effect on the energy consumption (Grubb *et al*., 2006 and Martin and Cerda, 2003). Thereafter, the economy continues to grow, whilst GHG emissions gradually begin to decline (Stern, 1998). The Kuznets curve therefore suggests that high levels of economic growth will in the long-run benefit the environment (Stern, 1998). This is explained by the fact that as an economy gets wealthier, there is a shift from energy-intensive heavy industries to growth in the service sector of the economy (Grubb *et al.*, 2006). Other explanations include improved energy efficiency and a change in consumption patterns and structural changes, which are changes in the types of industries within an economy (Ma and Stern, 2008 and Martin and Cerda, 2003).

However, more recent studies have shifted away from the Environmental Kuznets approach to determining the relationship between income growth and energy usage. An example of where the Kuznets curve theory does not apply is in the case of the UK and the USA. Both countries are developed countries and are two of the earliest countries to industrialise (Grubb *et al.*, 2006), therefore they should be in the downward slope of the inverted U shaped Kuznets curve. Figure 2.5 illustrates the GDP and the carbon emissions for both the countries from 1950 to 2000. The graph indicates that emissions closely follow GDP until around 1965 and then remained relatively constant, whilst GDP per capita continued to grow. This indicates a delinking of the relationship between GDP and emissions (Martin and Cerda, 2003). However, if the Environmental Kuznets curve theory were to apply, there should have been a decrease in emissions.

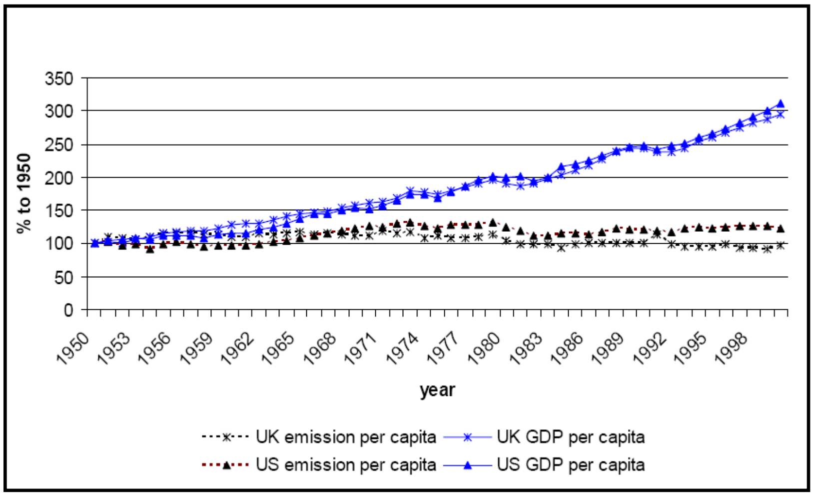


Figure 2.5: Relationship between emissions per capita and GDP in the UK and USA: 1950 – 2000

Source: Grubb et al., 2006

Another important observation from Fig. 2.5 is the peak in emissions in 1974 followed by a decline in emissions after the 1980s. This corresponds with the oil prices shocks, indicating that emissions are also impacted by external shocks and not always income (Grubb *et al.*, 2006).

Delinking is only possible when an economy has reached a certain level of income, which is very high for most of the world's economies and almost impossible to reach. Also many developed countries today are using new resources, where the extent of the pollution is unknown and not correctly reflected in the Kuznets curve. Developed countries, whose emissions have declined, sustain their consumerist, energy intensive lifestyle by importing goods from developing countries that are energy intensive (Martin and Cerda, 2003). Therefore this does not truly reflect a decrease in emissions in developed countries.

Similar studies conducted in other countries showed variable results that did not display a strong relationship between income and emissions. Examples are studies conducted in India, Malaysia and China (Grubb *et al.*, 2006), as well as studies by Martin and Cerda (2003) in Brazil, Spain and other countries. The studies, by Grubb *et al.* (2006) and Martin Cerda (2003), indicate that the relationship between GDP and emissions is unpredictable and variable according to the specific country. In India, China and Malaysia, the study revealed contrasting results. India reflected a similar relationship between GDP per capita and emissions per capita, whilst China revealed a decrease in emissions, corresponding with an increase in GDP. Malaysia indicated a small growth in GDP and a larger growth in emissions (Grubb *et al.*, 2006). These studies indicate that the relationship between income growth and emissions is a weak one and is affected by many unknown external factors. The relationship between these two factors appears to be country specific, where different countries respond differently to economic growth. This is due to other factors, besides GDP growth, that also have an impact on emissions (Martin and Cerda, 2003).

Structural change is also an economic development driving force behind GHG emissions (Fisher *et al.*, 2007). It is one of the main reasons for a decline in emissions, whilst GDP continues to increase. Shifts from energy intensive industries to low carbon service economies can significantly reduce GHG emissions. For example, in the UK, emissions peaked in 1973 and decreased by 20% by 1984 (Stern, 2007). Therefore according to McKibbin (2004), it is not only economic growth that impacts on emissions, but the composition of that growth. For example, GDP increases due to growth in the iron and steel industry will result in higher GHG emissions in comparison to an equal GDP growth in the Information Technology sector of the economy.

South Africa is an energy intensive country, where high energy consuming industries influence GDP growth. As a result, it is expected that an increase in GDP will in effect result in an increase in emissions (Haw and Hughes, 2007). According to Winkler (2007, 2009), if the other parameters affecting GHG emissions remain fixed, emissions closely follow GDP growth. Therefore a 2% growth in GDP will result in a 2% growth in GHG emissions. In the past, South Africa's GDP has generally increased, with slight dips in the 1980s and 1990s. Therefore, it can be assumed that South Africa's GDP is likely to continue increasing, with slumps in certain years (Winkler, 2009).

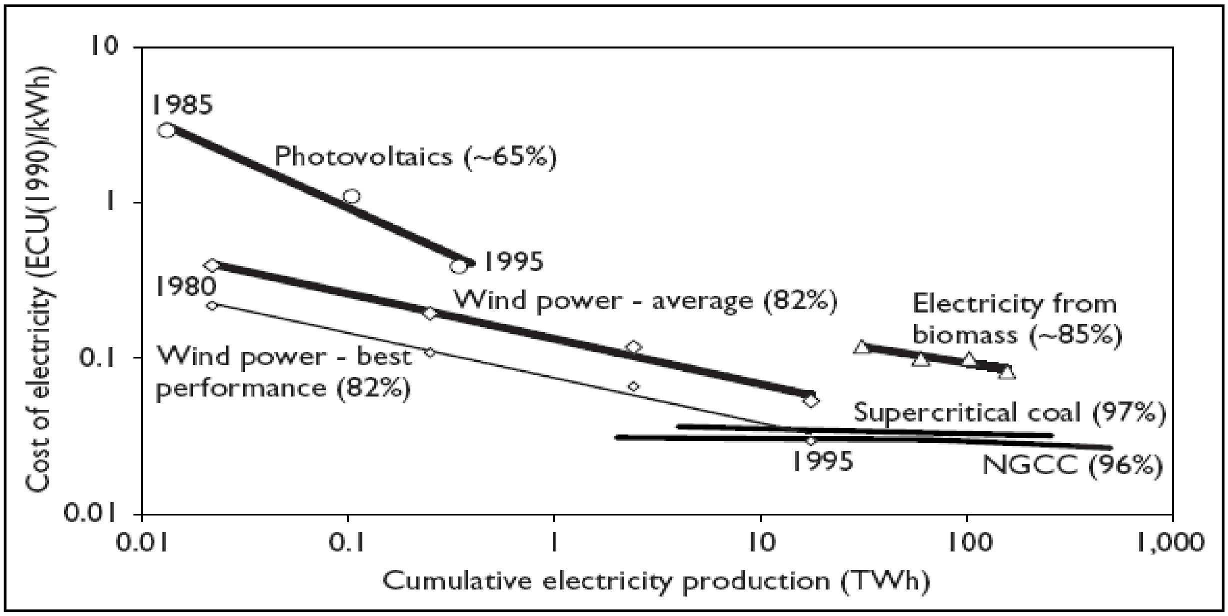
2.4.3 *Technological change*

Technology is another important driver of energy consumption and GHG emissions (Fisher *et al.*, 2007; Winkler, 2009). Technology plays an important role in reducing GHG emissions, because improved technology can result in the production of the same output, using less energy, and emitting less GHGs, which reduces the energy and carbon intensity of production. As such, in the IPAT equation technological change is reflected as a decrease in the energy consumed per unit GDP (WEC, 2007). Other technological change initiatives that reduce GHG emissions include carbon capture and storage technologies and technologies that enable users to switch to cleaner or renewable energy sources (Carrato *et al.*, 2006, Fisher *et al*., 2007; Karakaya and Ozcag, 2005). According to Grubb (2004), Nakicenovic *et al.* (2000a), Rao *et al.* (2006) and SBT (2007), in order to decrease GHG emissions to an acceptable level, rapid technological advancements are essential, much of which are yet to be discovered (SBT, 2007 and Schultz *et al.*, 2007).

According to Grubler *et al.* (1999) and Nakicenovic *et al.* (2000a) forecasting technological change is based on many assumptions as is it very dynamic, and therefore model representations of technological change are poorly developed. These assumptions of what drives technological change includes: the extent to which technologies get cheaper over time, 'learning-by-doing', research and development (R&D), innovation and 'economies of scale' (Stern, 2007 and Winkler, 2009:p109). Innovation is defined as 'the successful exploitation of new ideas' (Stern, 2007: p395). Accelerating technological innovation is vital for reducing costs of new technologies in order that they are implemented at a fast pace (Stern, 2007).

The IEA (2000) have illustrated the reduction in costs of energy technologies through learning and economies of scale, by publishing 'learning curves' (Figure 2.6). Figure 2.6 illustrates the change in the price of different energy technologies over a certain period of time. For example, from 1985 to 1995 the cost of producing electricity from photovoltaics has declined by 35%. The cost of generating electricity from wind has declined by 18%, whereas the cost of generating electricity from coal has only declined by 3%. This is because electricity generation from coal is an old technology; therefore cost savings occurred long before the illustrated timeframe (Winkler, 2009).

Figure 2.6: Learning rate curves for different energy technologies, illustrating the cost of the electricity in



relation to the cumulative electricity

Source: IEA (2000)

Technological change is also dependent on human capacity, constant R&D and investment to ensure that it is constantly evolving and improving in the future (Nakicenovic *et al.*, 2000b). Because technological progress is an outcome of human expertise and creativity, it is considered to be a renewable resource, as long as it is continuously improving (Nakicenovic *et al.*, 2000b).

Whilst long-term scenarios cannot accurately project future technologies, they can give an indication of where future prospects for technological advancement are (Nakicenovic, 2000b). According to Grubler *et al.* (1999), many of the driving forces of scenarios, such as economic growth, the energy required for production and the CO_2 emissions per unit of energy consumed are affected by technological change. Therefore the broad variation between different emission scenarios is mainly due to different assumptions of technological progress. Many long-term scenarios that use macroeconomic models are unable to illustrate how technologies change over time. Technological change is determined using past trends to depict future technological advancements. This is termed exogenous technological change, because it is not influenced by changes in other factors (Carraro *et al.*, 2006 and Grubler *et al.*, 1999). However, an exogenous approach to determining future technological change is not always suitable or possible, as most technological advancements in the past were the result of radical changes, for example, the invention of electricity in the nineteenth century (Grubler *et al.*, 1999).

The rate of technological change is influenced by the diffusion of innovation in an economy (Rao *et al.*, 2006). The rate of technological diffusion in an economy is influenced by the costs of the technology and the level of investment in R&D. Initially the costs of a new technology are high, but over time as it begins to be produced on a larger scale, it becomes more cost effective (Winkler, 2009). As the cost of a technology decreases, it begins to be more widely adapted. This can occur at different paces depending on the policies that are implemented to promote technological change (Rao *et al.*, 2006). Technological diffusion may take from 10 years to 100 years to become adopted globally. Therefore technological decisions made in the next few years will have long-term impacts on GHG emissions. This means that it is important for governments and businesses to invest in R&D and learning-by-doing initiatives to ensure that sustainable energy technologies are available in the future at lower costs (Nakicenovic, 2000b).

Technological advancement can range from the improvement of fossil fuel technologies and the continued reliance on fossil fuel to technologies that require renewable energy (Nakicenovic, 2000b). This depends on the context wherein the technology is developed, which is usually specific to the needs of an area or company. Different innovations may then be improved and adapted so that they can be implemented in other areas. In general, some countries and companies are better at developing and enhancing technologies, due to their existing access to information, technologies, money and their willingness to take risks. This results in some countries and companies being more advanced than others over a period of time (Nakicenovic *et al.*, 2000a).

2.4.4 *Other drivers of emissions*

Other drivers of emissions include fuel prices, discounting and the exchange rate (Haw and Hughes, 2007; Winkler, 2006 and 2009). The volatility of the price of fossil fuels can have major impacts on the quantity of fuels consumed, as high liquid fuel prices can reduce emissions if people adopt cleaner alternatives, rather than coal (Karecha and Hansen, 2007).

Discount rates in cost-benefit analysis refer to peoples' time preference for money. This means that technologies that have high starting capital costs and good future returns in terms of energy saving, if favoured less than technologies that have low starting costs.

An exchange rate, which reflects the strength of the Rand, drives emissions in that it influences the amount of goods that are produced and exported. It also impacts on emissions in that it also affects the price of crude oil (Haw and Hughes, 2007, Winkler 2006 and 2009).

2.5 Discussion and conclusion

The purpose of this chapter was to provide a background to different scenarios developed on a global, regional and local level. Furthermore, the chapter provided an overview of some of the major drivers of emissions.

The scenarios described in this chapter use different approaches and techniques to create their scenarios and are predominantly based on the objectives of the specific scenarios. Therefore, before developing a scenario it is important that the goal and objectives are set. The advantage of using a downscaling approach to formulate scenarios (for example Finland and India), is that it enables easy comparisons between global and local scenarios. However, in some cases this approach may avoid including factors that are specific to the area.

The approach used in Turkey is useful in countries and cities where there is a strong correlation between economic growth and GHG emissions; however it could not be applied in developed countries where the relationship is not established. The Californian approach to developing scenarios emphasised different levels of government involvement in emission mitigation. This approach is useful when trying to determine an acceptable level of government involvement and to understand the implications of different mitigation measures.

The South African LTMS and the China and UK scenarios, used a target approach to develop scenarios, where a target was set in the future and different scenarios were formulated to meet those targets. All three scenarios used the IPCC global stabilisation target of 450ppm to develop their scenarios. The LTMS scenarios differ from the China and UK scenarios in that their scenarios illustrate different mitigation steps that should be taken to meet the RBS target, whereas the China and UK scenarios are based on different levels of GDP growth, technological change, population growth and global integration.

Scenario analysis has been criticised for illustrating extreme possibilities, without providing any indication of probability of the different scenarios. However, due to ‘extreme events’ such as recessions, technological advancements, flooding and droughts, it is difficult to forecast changes with an accurate level of certainty. Overall, scenarios are useful for shaping future emissions in that they illustrate the impacts that different drivers will have on GHG emissions over the long term. The review of emission scenarios shows that in order to achieve optimal emission reductions, it is important to include many different factors that influence emissions. For example, high levels of global integration, technological advancement towards cleaner fuels, government involvement and community awareness, will all aid in reducing emissions.

The main factors that drive emissions and are considered when creating scenarios are economic development, including structural change, population growth and technological change, which impacts on the fuel mix. Other drivers include fuel prices, discounting and exchange rates. Drivers are important when creating scenarios as they determine the extent of changes in future emissions.

3 REVIEW OF GHG EMISSIONS, ENERGY CONSUMPTION AND OTHER DRIVERS OF EMISSIONS IN DURBAN

3.1 Introduction

The previous chapter reviewed GHG emission and energy consumption scenarios that were developed on a global, national and local level. All scenarios began at a base year, which was selected mainly due to data availability. Another important factor that differentiated between the scenarios created, was changes in the drivers of emissions. Drivers of emissions influence the changes in GHG emissions over time; hence, to develop emission scenarios for the city of Durban, it is important to understand the existing GHG emissions and energy consumption. It is also essential to identify what drives emissions in the city of Durban, trends of these drivers in the past and what changes are expected in the future.

This chapter will first provide a brief context for the city of Durban and will then focus on its existing recorded GHG emissions and energy consumption. The GHG emissions and energy consumption of the residential, transport, local authority and industrial and commercial sectors will be discussed individually. Thereafter the chapter will focus on economic development, technological change and population and household development in the city of Durban. Each section will also briefly discuss related policy documents that would influence the specific sectors, in order to determine the implications this will have for GHG emissions and energy consumption.

3.2 Context

The eThekwini Municipal Area (EMA) is located on the eastern coastline of KwaZulu-Natal, South Africa (Fig. 3.1). It stretches from Tongaat in the north, Umkomaas in the south and Cato Ridge in the west (EM, online), as shown in Figure 3.1. It is a union of seven former council areas, which resulted in an increase of 68% to the initial Durban area, with only a 9% increase in the population. As a result, 36% of the land area in Durban is rural with numerous tribal areas, for example KwaXimba and Umbumbulu (Tulsiram, 2008). It covers an area of 2 297km^2 and has a population of 3.5 million (EM, 2007) and 833 859 households (Statistics South Africa (Stats SA), 2007). The population is racially and culturally diverse, with people coming from various historical backgrounds. The unemployment rate and poverty rate is high, with 34% of the working age population being unemployed and 40% of the population classified as ultra-poor (Mercer, 2006).

Whilst Durban is the third largest economic area in South Africa (EM, 2007), it is the second largest industrial area (after Gauteng), which is mainly due to the South Durban Industrial Basin (Scott, 2003). Seventy percent of Durban’s industry is located in this area, providing the city with 90 000 – 120 000 jobs. Even though South Durban is economically important, there has been no industrial expansion here within the last five years (SiVEST, 2005). Other major economic investment areas are Durban Central Business District (CBD), Umhlanga and Pinetown. Figure 3.1 illustrates the eThekwini Municipal area and shows the major and minor economic nodes in the area (EM, 2007).

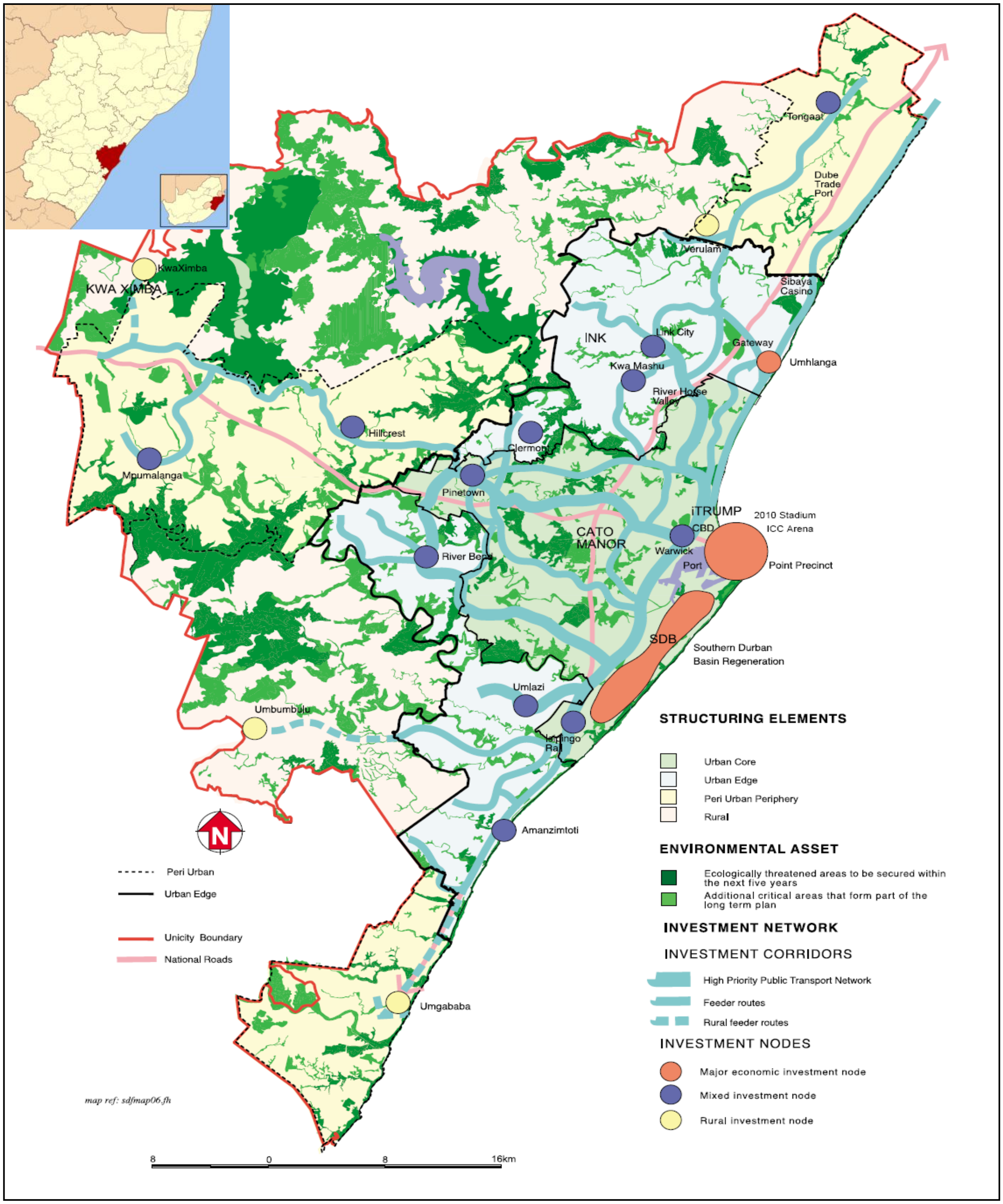


Figure 3.1: eThekwini municipal area

Source: EM 2007/8

3.3 GHG emissions and energy consumption

The eThekwini Municipality commissioned its first GHG emissions inventory in 2002 (Majoli and Hurt, 2003). The inventory was completed with the aid of ICLEI (Local Governments for Sustainability formerly known as the International Council for Local Environmental Initiatives), as part of their Climate Protection Program (CCP). The CCP was established in 1993, with the aim of providing local governments with tools to minimise their GHG emissions, thereby improving the air quality in a city (Mercer, 2004; Naidu *et al.*, 2006). Thereafter, the city commissioned two other GHG inventories, in 2003 and in 2005/6 (Antoni, 2007). The State of Energy Report (SoER) was also completed in 2005/6 but prior to the 2005/6 GHG Inventory. The SoER determined the energy consumption of various sectors in the city and its energy-related GHG emissions (Mercer, 2006), which was used to inform the eThekwini Municipality Energy Strategy (EMES) (Mercer, 2008).

The Energy Strategy is based on targets stipulated by the National Energy Efficiency Strategy of the Republic of South Africa (DME, 2005) and the White Paper on Renewable Energy (2003). The National Energy Efficiency Strategy sets a national target to reduce energy demand by 12% of projected growth by 2015 (DME, 2005). The renewable energy target for South Africa is to provide an additional 10 000 GWh of renewable energy to final energy consumed by 2013. Future energy consumption will also be influenced by the LTMS, which was discussed in Chapter 3. Energy efficiency and renewable energy is further prioritised in the National Energy Bill (DME, 2008), which states that a National Renewable and Energy Efficiency Division must be established in order to promote renewable energy technologies and energy efficiency initiatives (DME, 2008). The implications of this will filter down and influence the local level.

The CCP distinguishes between local authority emissions and community emissions. The community emissions are further divided into the residential, transport and industrial and commercial sectors. The 2002 and 2003 inventories focused specifically on emissions from the local authority, particularly due to a lack of data. These inventories estimated GHG emissions for community emissions, which remained constant for the 2002 and 2003 inventories, whilst the 2005/6 inventory included calculated emissions for the different sectors (Majoli and Hurt, 2003 and Antoni, 2007).

The inventories were compiled based on a methodology provided by ICLEI and a range of energy distributors and other key stakeholders were contacted to provide energy consumption statistics for the city. The data collected were input into the Harmonised Emissions Analysis Tool (HEAT), which calculates total emissions and reports emissions (Bell, 2004).

According to Antoni (2007), the total emissions for the city of Durban in the financial year 2005/2006 were 22 531 967 tCO_2e and the total amount of energy consumed was 133.7 million GJ. Of this, 5% (1118 061 tCO_2e) of emissions are attributed to municipal GHG emissions and 95% (21 413 906 tCO_2e) of emissions are from the community sector.

Figure 3.2 illustrates total GHG emissions and compares energy consumed by the different sectors. The industrial sector is the highest GHG emitter, emitting 45% of the total GHG emissions; however, it is the second largest energy consumer, using only 34% of the total energy. The transport sector is the second highest GHG emitter, but it consumes the largest quantity of total energy (47%). This is because the industrial sector consumes high quantities of electricity and coal, which have high CO_2 emission factors, in comparison to petrol and diesel. All the remaining sectors also emit a higher percentage of CO_2e emissions in comparison to the percentage of total energy consumed (Antoni, 2007). This is indicative of a dependence on electricity, which is mainly generated from coal (Winkler, 2009). It also illustrates how changes in the fuel mix of an economy can impact on emissions.

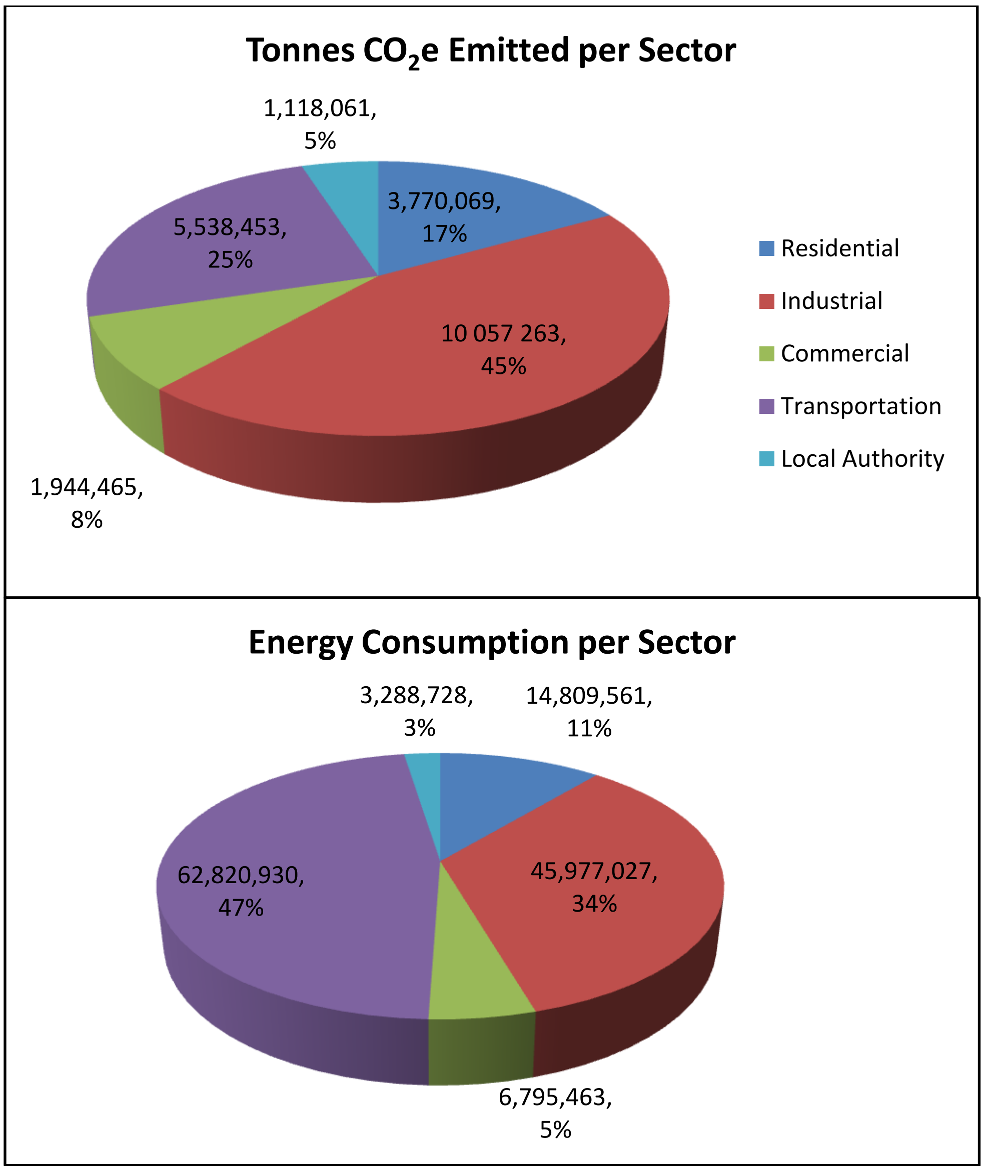


Figure 3.2: Total GHG emissions and energy consumption for the EMA per sector for the financial year 2005/6

Source: Antoni (2007)

3.3.1 *Industrial and commercial sectors*

The industrial and commercial sectors together comprise 53% of the city's total GHG emissions and consumes approximately 40% of total energy. The percentage of industrial and commercial emissions in Durban is comparable to industrial emissions in other South African cities such as Cape Town and Johannesburg (Sustainable Energy Africa, 2006). However, it is much higher in comparison to developed country cities, such as New York City, London, Washington DC and Tokyo (Dickinson, 2007; Dodman, 2009 and Green Homes, 2009). One reason for this is because of the relatively cheap electricity being provided to bulk users, which are primarily industrial sectors. Another reason is that developed country cities are more service-based economies, in comparison to developing country cities that are still reliant on the manufacturing sector for economic growth (Dodman, 2009).

As a result, GHG emissions from electricity consumption consist of 52% of total industrial emissions (Fig. 3.3). Another contributor to the large quantities of GHG emissions is the consumption of coal in the industrial sector (17%). Coal is a preferred energy source for boilers because it is mined in the country and is therefore easily available. The third largest contributor to GHG emissions is refinery gas, which is consumed by the Engen and Sapref Refineries (Fig. 3.3). Durban also has a large quantity of manufacturing industries in the South Durban Industrial Basin, which rely on energy-intensive processes.

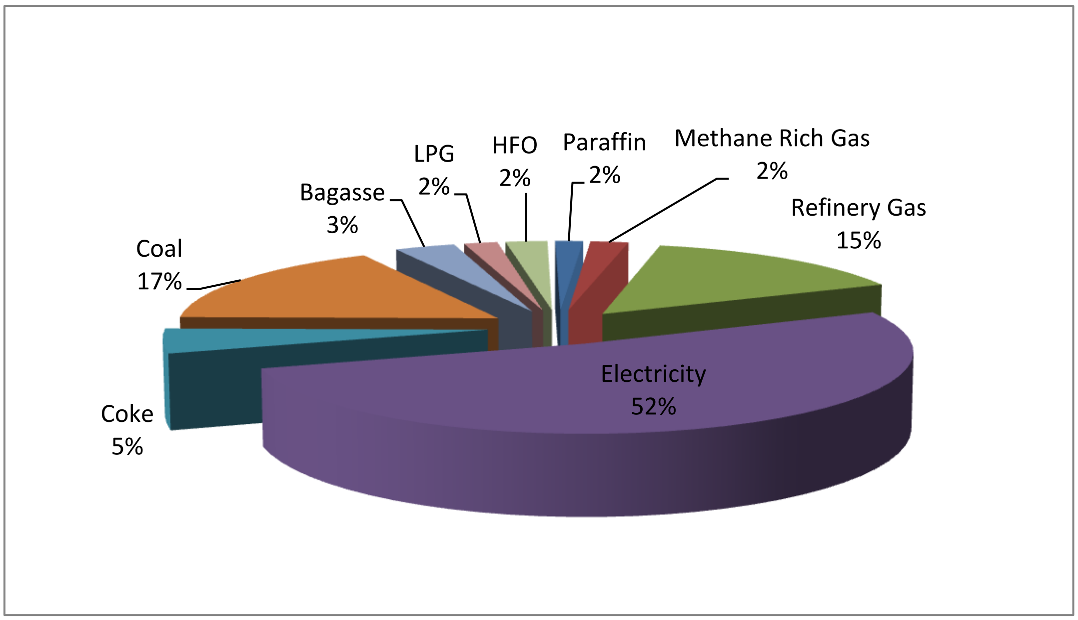


Figure 3.3: Percentage of industrial emissions in Durban by fuel/energy type
Source: Antoni (2007)

The major data gap in this sector is the lack of accurate coal consumption data. Therefore previous coal statistics were based on estimates and assumptions. According to Antoni (2007) there is a need for a database of coal consumption and distribution in the Durban area. The other data gap for this sector is that the emissions are not differentiated by manufacturing sector; thus there is no indication of which sectors are most energy intensive. The total consumption for the commercial sector is based on the assumption that only electricity is consumed in this sector, and the data were taken from the eThekwini Electricity's Annual Report (2005/2006). It does not account for liquefied petroleum gas (LPG) consumed in hotels and restaurants or any other fuels that are consumed in this sector. In addition, the division of LPG and paraffin consumption between the industrial and residential sector was based on an estimate, with no clearly defined reason (Antoni, 2007). These assumptions could impact on the energy intensities of the different sectors in the city, which could result in inaccurate CO_2e emissions per sector.

The main mitigation strategy in terms of energy consumption and GHG emissions in this sector is the EMES. The strategy provides a framework to achieve a 30% reduction in CO_2 emissions in this sector by 2020, of which 24.4% will be achieved through energy efficiency and 5.6% will be achieved through renewable energy initiatives. The 30% reduction is measured against a projected expected growth and therefore assumes a reduction in the growth of emissions, rather than an overall reduction in emissions. This target would be achieved through a range of support mechanisms, policy, finance instruments and stakeholder involvement (Mercer, 2008).

3.3.2 *Transportation sector*

The next largest contributor to GHG emissions is the transportation sector, which contributes 26% of total emissions and 47% of total energy consumed. This figure was calculated using the total fuel sales data in the EMA and did not account for fuel purchased in the EMA but used outside its boundaries (Antoni, 2007). The transport sector includes GHG emissions from aviation transport and road transport; however, it does not account for emissions from marine transport and rail. The approach applied was a top-down approach that uses the energy supply data to estimate emissions (IPCC, 2006). Other inventories such as the New York City (Dickinson, 2007) and the Springfield, Oregon Climate Leadership Initiative , 2007) GHG emissions inventories use a bottom-up approach to obtain their transportation figure. This is done by using total vehicle miles travelled (VMT) within the municipal area, by different vehicle types and size classes. Thereafter, the average fuel efficiency for different vehicle types is determined, which is multiplied by the CO_2e coefficient for fuel type Climate Leadership Initiative, 2007 and Dickinson, 2007). This, however, is difficult to achieve in Durban, due to a lack of detailed data on vehicle miles travelled within the boundary of the city.

According to Winkler (2009), the transport sector is the fastest growing contributor to GHG emissions in the country. The main driver of emissions in the transport sector is GDP per capita. As people get wealthier, they switch from low carbon transport modes, such as buses, trains and bicycles to private vehicles, whilst people with private vehicles switch to bigger vehicles such as sport utility vehicles (SUVs) as their wealth increases. Economic growth is also a driver of emissions in the transport sector, because it increases the demand for freight transport (EIA, 2009 and Winkler, 2009). Another driver of emissions in this sector is fuel prices. There are many debates about the actual year that oil production will reach its peak and thereafter decline. However, this decline in oil production will result in major changes in fuel prices, which will have a major impact on the transport sector (Wakeford, 2007 and Winkler, 2009).

One of the objectives of the city's IDP is to establish a 'Good Public Transport System'. This can potentially minimise emissions from transport, as more people would use the public transport system instead of private vehicles (EM, 2008). The Integrated Transport Plan (eThekwini Transport Authority, 2005), identifies the need to improve the public transport system so that it appeals to all income levels. The IDP also prioritises the need to reduce urban sprawl, which will reduce the need for people to travel long distances to work. Additionally, the Plan aims to reduce energy consumption in the transport sector through the promotion of cleaner fuels and improving traffic management (eThekwini Transport Authority, 2005).

The EMES (Mercer, 2008) sets a target to reduce emissions in this sector by 24% by 2020. This is based on a continuation of the national energy efficiency target to reduce transport sector emissions by 9% by 2015 and the draft biofuels strategy target for South Africa, which aims to achieve a 4.5% market penetration of biofuels by 2015 (Mercer, 2008). However, since then the finalised Biofuels Industrial Strategy (2007) has reduced this target to 2% by 2015 (DME, 2007). The EMES aims to meet its target by effective transport planning, promoting the use of biofuels, creating awareness to reduce petrol consumption and encouraging the use of rail and public transport

3.3.3 *Residential sector*

The residential sector contributed 3 770 069 tCO_2e (17%) to GHG emissions and 11% to energy consumption in Durban. This figure includes emissions as a result of electricity, kerosene and LPG consumption. It does not include emissions from the consumption of coal, which according to Statistics South Africa (Stats SA, 2007) is consumed by 1 660 households. According to the Community Survey 2007 compiled by Stats SA, there has been a decline in the number of households that use other sources of energy and an increase in households that use electricity, such that 80% of households were electrified in 2001, which increased to 87% in 2007. This is due to the National Electrification Programme, which aims to electrify all formal households by 2012 (DME, 2008).

Figure 3.4 illustrates the percentage of households that use various energy sources for cooking, heating and lighting. Most of the energy used in households in Durban is electricity and this will most likely continue due to the National Electrification Programme and the National Free Basic Electricity Programme, which seeks to provide poor households with 50 kWh free electricity per month (DME, 2008). The second largest source of energy is paraffin, which is used mainly for cooking and lighting. Candles are still an important source of energy, lighting 9% of households. Other energy sources, such as gas, wood and coal, are used by a very small percentage of households, which is likely to decline even further in the future due to electrification plans and solar water heating incentives from Eskom's Demand Side Management (DSM) initiative (DME, 2008 and Eskom, 2008). Eskom's DSM plans to reduce peak load electricity consumption through the efficient use of electricity (Eskom, 2008).

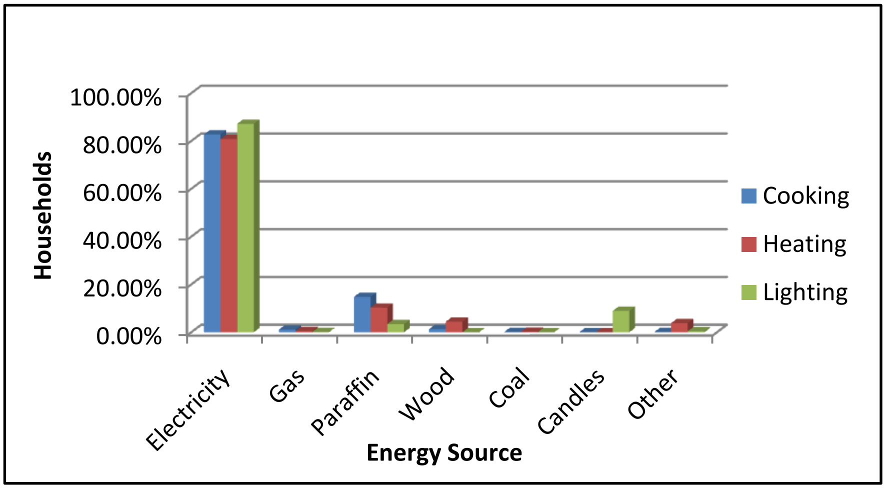


Figure 3.4: The percentage of households consuming various energy sources for different end-uses in Durban

Source: Adapted from Stats SA (2007)

The EMES sets a target to reduce energy consumption and emissions in this sector by 24.5% based on national renewable energy and energy efficiency targets, by 2020. This would include a reduction in emissions of 16.3% due to energy efficiency improvements and an 8.3% reduction from increased renewable energy usage. A range of strategies has been proposed, including the introduction of energy efficiency standards for new households, awareness creation, appliance labelling of household goods and the promotion of green power and solar water heaters.

3.3.4 *Local authority*

City governments have a major role to play in mitigating climate change directly and indirectly. Through the provision of services such as water, sanitation, public transport etc, municipalities influence emissions directly, through land-use planning and implementing energy efficiency regulations for buildings (Jollands, 2008). According to Alber and Kern (2008), a local municipality has four different roles of governing. The first one is 'self-governing', which means the ability of municipalities to govern their own activities, for example improving the energy efficiency of municipal buildings. The next mode is 'governing through enabling', which involves interacting with the community and private institutions to encourage energy efficient practices. Thirdly, local authorities 'govern by provision' which involves providing the community with services, infrastructure and resources. Lastly, 'governing by authority' involves using regulation and legislature to mitigate climate change. All four modes of governing are important for the mitigation and adaptation of climate (Alber and Kern, 2008).

However, local governments are also influenced by national and regional legislature and policies, which often do not provide the guidance and support required for cities to act effectively on climate change issues (Betsill, 2001 and Jollands, 2008).

The local authority sector is the smallest energy consumer and GHG emitter in Durban, utilising 3% of total energy and contributing 5% to emissions, respectively (Antoni, 2007). Local governments are responsible for street lighting, waste, water and sewage, municipal vehicles and buildings, which emit GHGs. Figure 3.5 illustrates that GHG emissions were the highest during 2003/4 and thereafter decreased in 2005/6. The highest GHG emitter is the 'Other' sector, which includes electricity distribution losses due to technical errors and theft. The second largest GHG emitter is waste, which is mostly comprises methane emissions from landfill sites. Emissions in this sector have decreased in 2005/6, which is most likely due to the eThekwini landfill gas to electricity project (Antoni, 2007). Changes in emissions of the other sectors however, have been attributed to a lack of data or changes in the way emissions were calculated (Antoni, 2007). Therefore, it is difficult to draw any significant conclusions on the changes in emissions in the local authority sector from the existing inventories.

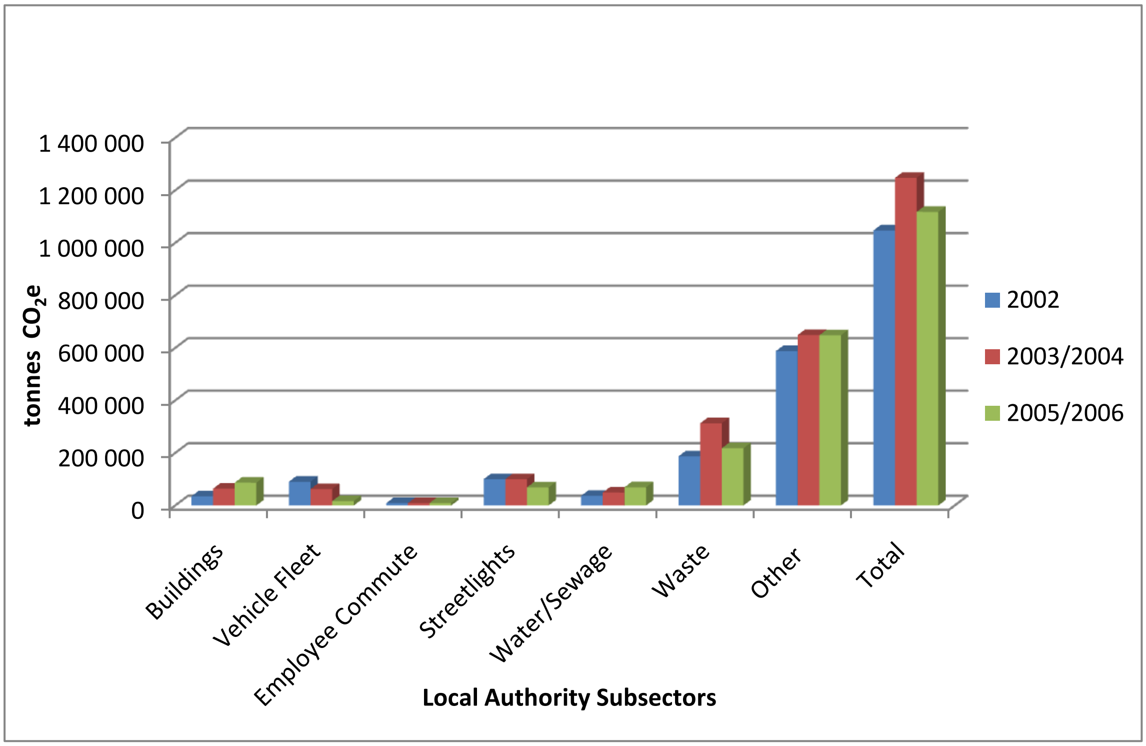


Figure 3.5: Comparison of local authority subsector emissions for 2002, 2003/2004 and 2005/2006

Source: Adapted from Antoni (2007)

The local authority sector has the most potential to reduce emissions because they determine land-use policies, authorising if and where development can occur. They also influence infrastructural developments such as roads and types of transportation used and can also easily regulate emissions within their own sector by implementing efficiency strategies (Yienger *et al.*, 2002).

The eThekwini Municipality has embarked on a building energy efficiency programme which targets eleven municipal buildings to become more energy efficient. The programme consists of a series of low, medium and high cost efficiency initiatives, which can potentially reduce emissions by 4 683 tCO_2e per annum. In addition to this, the city is in the process of replacing incandescent traffic signal bulbs with Light Emitting Diodes (LEDs), which consume a fraction of the energy consumed by normal traffic lights. With the aim of replacing 200 traffic lights with LEDs per annum, the completion of this project can potentially reduce emissions by 12 000 tCO_2e per annum (Mercer, 2006).

If the local authority sector meets the national energy efficiency and renewable energy targets, and continues them into the future, the sector can potentially reduce its emissions by 33% of projected emissions. This can be achieved by a combination of planning, implementation, capacity building, carbon financing and the introduction of energy audits and standards for municipal buildings (Mercer, 2008).

3.4 Economic growth

Economic growth is an important driver of emissions, particularly because the industrial and commercial sector is the largest GHG emitter in the city. As such, an increase in economic growth will increase the demand for energy sources and thus GHG emissions. The city of Durban is the third major economic area in South Africa, after Johannesburg and Cape Town, and contributes 10% to the National GDP. The GDP growth rate of Durban over the period between 1995 and 2005 was approximately 3.65%. This compares favourably with the rest of KwaZulu-Natal, which averages around 2.3% for the period. The GDP of Durban in 2005 amounted to R118 billion, which is equivalent to 75% of KwaZulu-Natal's GDP (Economic Development Unit, 2007). Figure 3.6 illustrates the trends in Durban's GDP from 1996-2008, furthermore it shows the forecasted GDP of the city from 2009-2013. The graph shows that the economy was consistently growing from 1996-2008, with a dip in economic growth in 2009, which is due to the impacts of the economic recession. Thereafter the economy is expected to recover in 2010 and economic growth begins to increase, such that by 2013, the annual growth rate is 5.11% per annum.

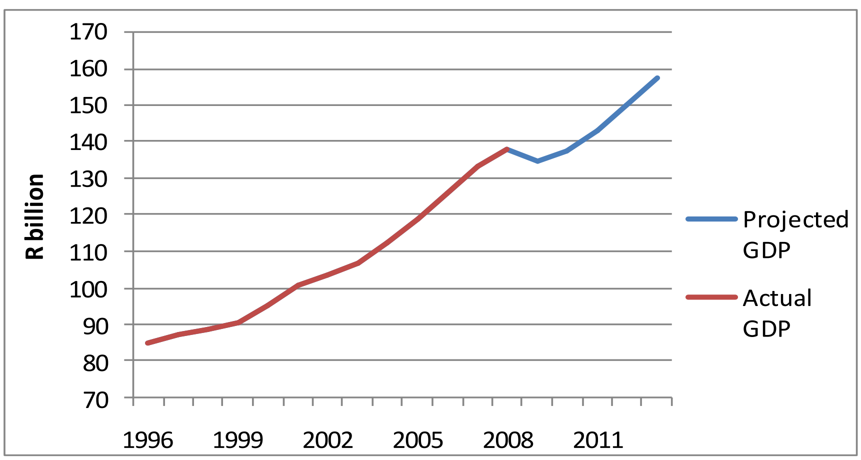


Figure 3.6: Actual and projected GDP of Durban from 1996 – 2013

Source: Adapted from the Economic Development Unit (2009)

Nationally, Durban is viewed as a port and logistic economy and in total contributes 15.6% to the national transport and communication sector. This is the largest contribution to this sector, making Durban important in terms of its harbour activities. Durban is considered to be the biggest and busiest port in southern Africa (EM, 2005). The Durban harbour therefore makes the city a viable manufacturing area, due to its easy access to importing and exporting of goods. The manufacturing sector is thus the largest sector in terms of its contribution to eThekwini's GDP, being responsible for 25%. This is followed by the financial sector (21%) at and thereafter the wholesale and retail trade sector (17%), as shown in Figure 3.7.

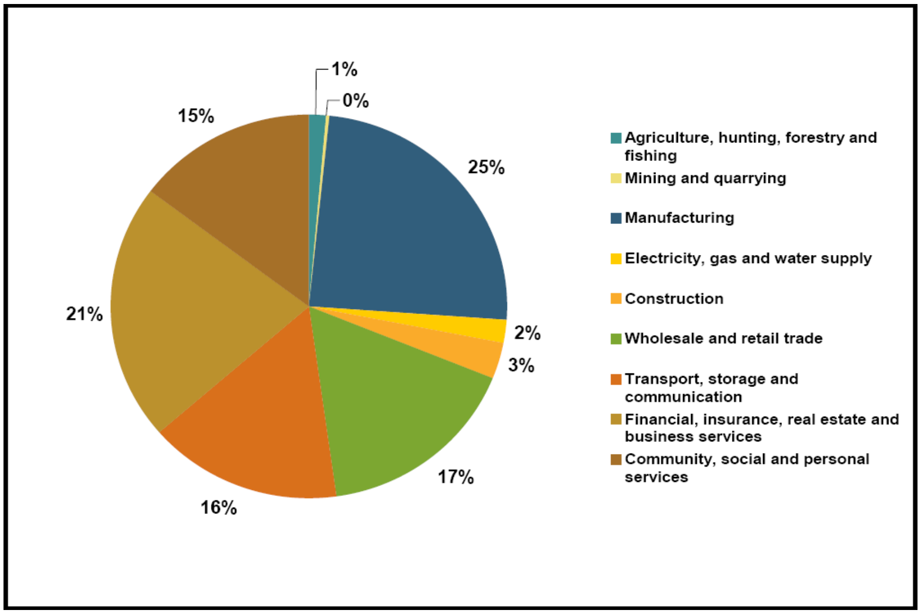


Figure 3.7: GDP for eThekwini by sector

Source: Economic Development Unit (2006)

Whilst the manufacturing sector is the largest sector in terms of GDP contribution, it is not the fastest growing sector. The transport and communication sector is the fastest growing sector, which grew at an annual average of 6.25% per annum from 2001-2005. This is followed by the finance and real estate sector and the wholesale and retail trade sector, both of which grew at 4.5% per annum. In comparison to this, growth in the manufacturing sector was only at 2.75% per annum (Economic Development Unit, 2006).

The manufacturing sector is the largest economic contributor and also emits the largest quantity of GHG emissions (Economic Development Unit, 2007). As such, it is important that this sector is broken down into subsectors, so that each economic contribution within this sector is understood. The four main manufacturing activities that account for over 60% of the total manufacturing sector are:

- Petroleum and chemical products,
- Food beverages and tobacco,
- Transport equipment (including automotives), and
- Metals and related products.

Other activities within this sector include:

- Wood and paper products,
- Radio, TV, instruments, watches and clocks industry,
- Other non-metal mineral products industry,
- Electrical machinery and apparatus,

- Textiles, clothing and leather goods,
- Furniture and other manufacturing, and
- Metals, metal products, machinery and equipment.

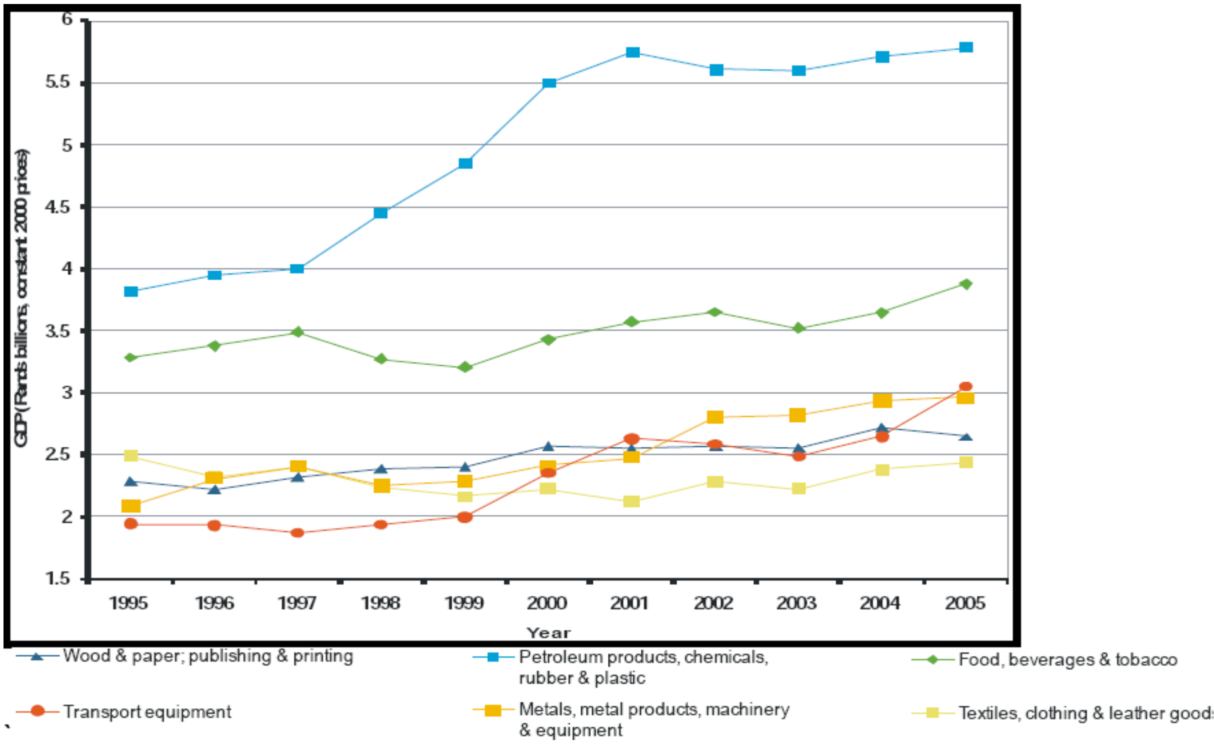


Figure 3.8 Trends in the GDP of manufacturing subsectors

Source: Economic Development Unit (2007)

The petroleum and chemical products industry is the largest in the manufacturing sector (Fig. 3.8). It contributes R5.8 billion to the economy and comprises 23% of the manufacturing sector. Whilst it is an economically important subsector, it is not a growing part of the economy, with a growth rate of 0.2% (Economic Development Unit, 2007). The two main contributors to this sector are the oil refineries, Engen and Sapref (Economic Development Unit, 2007), which consume large quantities of energy in their refining process (Antoni, 2007 and Mercer, 2006).

The food, beverages and tobacco industry is the second largest subsector in the manufacturing sector (Fig. 3.8). It makes up 15.8% of the sector, contributes R3.8 billion to city's GDP and grew at an average of 2% from 2001-2005 (Economic Development Unit, 2007). The process that requires the most energy inputs in this sector is the sugar cane industry during the conversion of sugar cane to sugar (Antoni, 2007).

Transport equipment is also a growing subsector in the Durban area, as shown in Figure 3.8, which shows that the industry has been growing since 1995. It consists mainly of the Toyota Automobile Association and is responsible for approximately R3 billion of the city's GDP, with a growth rate of 3.7% from 2001-2005 (Economic Development Unit, 2007). The largest source of emissions in this sector is at the Toyota Manufacturing Plant in Prospecton. This plant is believed to be the most technologically advanced Toyota

Plant in the world apart from Japan and has the potential output of 220 000 cars per annum (South Africa Information (SA info), 2008).

The paper and pulp industry includes paper production, printing and publishing. It is contributes R2.6 billion of the manufacturing sector but is stagnating in growth with a growth rate of 0.9% from 2001-2005. This industry contributes 10% to the national paper and pulp sector. The main industry in this sector is the Mondi Paper Mill in Merebank, which is a subsidiary of Anglo-American (Economic Development Unit, 2007).

3.4.1 *Future economic development in Durban*

The Durban economy is a vibrant economy and is the hub of many large and small scale developments. The Economic Development Strategy (Economic Development Unit, 2008) set a goal to achieve a GDP growth rate of 1% above the AsgiSA national growth target, which set a target of a 4.5% average growth rate from 2005-2009 and a 6% growth rate from 2010-2014 (Mlambo-Ngcuka, 2006). According to the IDP 2008/2009 (EM, 2008), sectors that will be targeted to stimulate growth, are those that create employment and promote economic growth. Sectors that focus on export related manufacturing industries will also be targeted. These sectors are the:

- Automotive sector,
- Information and communication technologies (ICT), tourism,
- Agriculture and agri-processing, chemicals,
- Creative industries (crafts, film, TV and music),
- Clothing and textiles,
- Wood, pulp and paper, and
- Maritime sector.

The economic development and GDP growth in the city will inevitably result in an increased demand for energy sources, resulting in a higher GHG emission output. However, according to the Economic Development Strategy (Economic Development Unit, 2008), it is projected that 60% of growth in the future will be in service sectors. This will result in a structural shift in the economy, which in turn will impact on future GHG emissions. The key development nodes are the Port of Durban Harbour Expansion Project, the Dube Tradeport and King Shaka International Airport, River Horse Valley Estate, the Point Waterfront Development and the Moses Mabhida Stadium (Economic Development Unit, 2007).

3.5 Population and households

The population of Durban drives emissions by increasing the demand for transport, housing and other goods and services. Changes in the population of the city will increase the demand for housing and therefore increase emissions in the residential sector. According to the EM (2007), the population of Durban in 2007 was just over 3.3 million people with approximately 833 860 households (Stats SA, 2007).

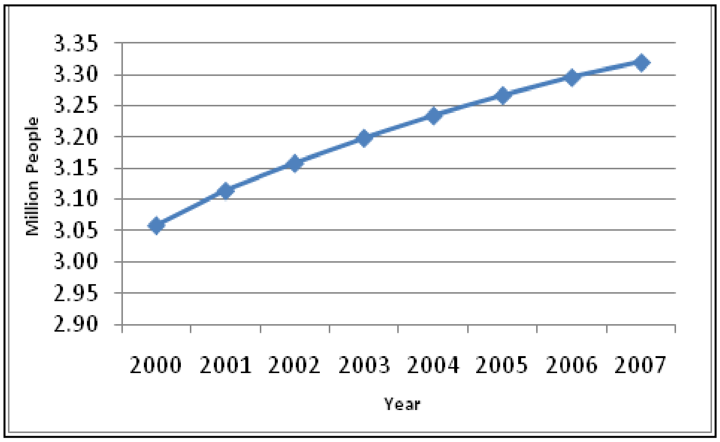


Figure 3.9: Population growth in Durban from 2000-2007
Source: Economic Development Unit (2009)

As shown in Figure 3.9, the overall population of Durban has been increasing from 2000-2007 at an average of 1.18% per annum. Within this seven-year period, the rate of population growth has been declining, with an annual growth rate of 1.81% in 2000 decreasing to 0.73% in 2007. This is comparable to national trends (South African Cities Network (SACN), 2006). One of the reasons for a decreasing population growth rate is because of the impact of HIV/AIDS (Haw and Hughes, 2007).

The EM (2007) forecasted population to increase to approximately 4.07 million by 2020. However, in the 2005 IDP, it was projected that by 2020, the population would level off at 3 million people (EM, 2005). This illustrates the various possibilities for population growth.

According to Winkler (2009:106), 'energy use in many respects relates more directly to households than to individuals'. For example an increase in the number of households would increase the demand for electricity connections. There has been a general trend in South Africa of a reduction in the number of people residing per household (SACN, 2004). Possible reasons for this include an increase in per capita income and the migration of individuals from rural to urban areas (Winkler, 2009). In Durban, the number of households with formal shelter has increased from 1996-2004, but so has the number of households without formal shelter, as shown in Figure 3.10. Therefore, there has been an increase in the demand for formal housing in Durban from 1996-2004. From 2001-2004 there was a more accelerated increase in households without formal shelter, in comparison to households with formal shelter. Consequently, the EM identified the provision of housing to the poor as a priority.

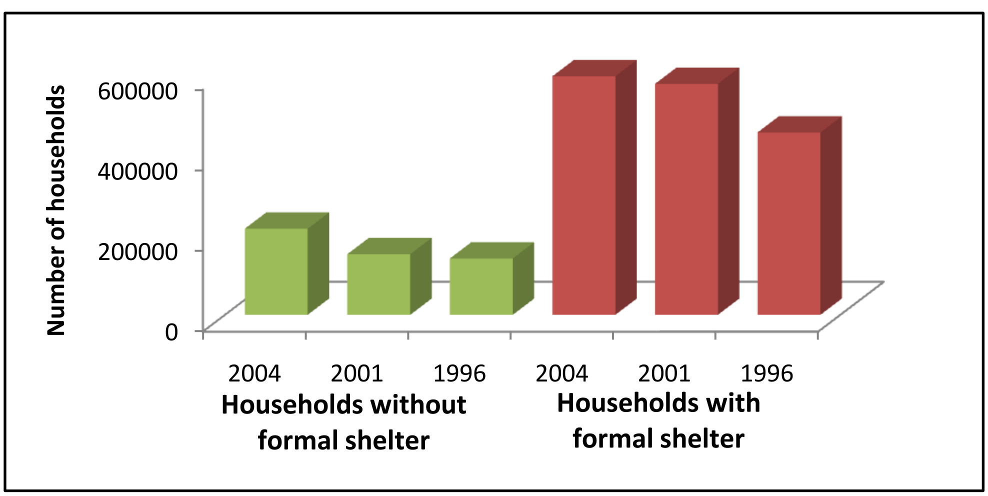


Figure 3.10: A comparison of households with and without shelter over time

Source: SACN (2004)

The goal of the Integrated Housing Development Plan (EM, 2005) is to provide all residents of Durban access to formal housing, with basic services. In 2005, the housing backlog was approximately 200,000 households. The backlog is expected to grow at a rate of 3.5% per annum.. The Municipality, taking this growth into consideration, aims to provide formal housing to all by 2017. This would be achieved by constructing approximately 16,000 houses per annum. The increase in housing would have implications for energy demand in the housing sector over time.

3.6 Technological change

The rate of technological change in the city of Durban will be influenced by changes in South Africa's technological progress and individual company's initiatives for technological advancement. As mentioned in Section 3.4.2, technological change may result in the same quantity of output, while consuming less energy or consuming a cleaner energy source.

In Durban, technological change has been identified as an important approach to reduce GHG emissions in the city. In response to this, an initiative in the IDP (2008) is to develop the city as a 'Learning and Smart City' which includes an emphasis on technological advancement in all fields. One of the strategies in the Economic Development Strategy, is to make Durban a 'Cyber City', which aims 'to provide an enabling environment for innovation and technological advancement in the city' (Economic Development Unit, 2008: 21). The EMES has listed the introduction of energy efficiency standards, capacity building in energy efficiency and renewable energy and promoting voluntary energy efficiency commitments (Mercer, 2008). These strategies would encourage industries to implement more efficient technologies.

Furthermore a partnership was established in 2009, between the United Nations Industrial Development Organisation (UNIDO), the Durban Investment Promotion Agency , the EM and the Durban Chamber of Industry to establish mitigation and adaptation measures in the city's industrial sector. The partnership will focus on opportunities for technological advancement and will also encourage industries to share and exchange technological knowledge with similar industries in China (UNIDO, 2009). Some industries are already taking the initiative to improve technologies in order to reduce energy consumed and CO_2 emitted.

An example of a major industry that has reduced emissions through technological change is Toyota, which in 2006, installed over 200 solar panels at its Prospecton Plant. The panels are used to heat water, which was previously heated by electricity and gas. The project is expected to save 1 350 tCO_2 per annum (Imagine Durban, 2009 and (SAinfo), 2008). Another major industry in Durban that used technological change to improve energy efficiency and reduce CO_2 emissions is Tongaat Hulett. They have switched technologies from coal fired to natural gas boilers and have improved the efficiency of the plant and boilers. The company has also been generating electricity using bagasse, which is the fibrous residue of sugar cane and therefore a renewable energy source (Tongaat Hulett, 2007).

Both refineries, Sapref and Engen, have also aimed to become more energy efficient and have switched fuels from heavy fuel oil (HFO) to fuel gas and methane-rich gas to fire their boilers. This technological change not only reduces CO_2 emissions but also has air quality benefits such as a reduction in SO_2 and particulates (Engen, 2006 and Sapref, 2007). The South African Brewery (SAB) Plant is also committed to reducing its GHG emissions and aims to reduce emissions by 15% by 2015. The SAB aims to achieve this through energy efficiency initiatives and switching to cleaner and renewable fuels, by improving its operation technologies (SAB, 2006).

3.7 Summary and Conclusions

This chapter reviewed the current situation of Durban in order to inform the creation of the baseline year for the study and to determine what the future plans are for the city. In general, it appears that Durban has been effectively planning to reduce energy-related GHG emissions, through the publication of the GHG Inventories and the eThekwini Energy Strategy. The overall target is to reduce the city's emissions by 27.6% by 2020. To date, the community sector of the GHG inventories has not been updated and therefore trends in GHG emissions have not been established. Policies and national and local plans and strategies that will impact on future emissions and drivers of future emissions, were identified.

This chapter discussed the main drivers of emissions for Durban, which are economic development, population and households and technological change. The city set high targets of GDP growth, which will have implications on future energy demand and GHG emissions. The population of Durban is growing at a declining rate and is expected to level off in the near future. This will influence the energy demand in the household sector. The city has made progress in the implementation of technological change in the city in the IDP and the EMES, however plans and strategies are what the Government hopes to achieve, rather then what exactly will be implemented.

Thus, it is important to forecast what the city hopes to achieve, in relation to other possible scenarios. For example, the global economic recession has implications for the city's GDP growth target, which will also impact on energy consumption and GHG emissions that could not be accounted for in government plans. Therefore it is important to create different scenarios to illustrate the impacts of different changes in the city on energy demand and related GHG emissions. Chapter 4 will discuss the methodology applied to create these scenarios, followed by Chapter 5 illustrating and comparing the different scenarios.

4 METHODOLOGICAL FRAMEWORK

4.1 Introduction

The aim of this dissertation is to determine the implications of economic development on CO_2e emissions in the city of Durban. In order to achieve this, a scenario-based approach, which accounts for uncertainties in future emissions due to changes in key drivers of emissions, was chosen.

The methodology first involved conducting research to identify and fill data gaps in the existing GHG Inventory and State of Energy Report. Once this was completed, scenarios were formulated and input into the LEAP System. The results of these scenarios were evaluated and compared to determine the implications of changes in drivers of emissions on future emissions. Thereafter, SRES scenarios were downscaled to a local level to determine the implications of the A1, A2, B1 and B2 development pathways on emissions in Durban. The downscaling approach was applied to provide a general indication of future emissions for the city of Durban. It was also applied to allow for comparisons between the IPCC Scenarios and the scenarios created with LEAP.

4.2 Scenario-based approach

The methodological approach for creating scenarios followed a combination of processes that were identified in Chapter 2: Emission Scenarios. The methodology also followed a combination of the energy demand analysis processes and the scenario-based analysis processes (Merven, 2009 and van Notten *et al.*, 2003). Figure 4.1 illustrates the theoretical phases of the scenario-based process. The steps followed in this project were:

- Define the project scope and level of detail required
- Identify data required and compile a database
- Input the data into the model
- Creation of scenarios
- Evaluate scenarios

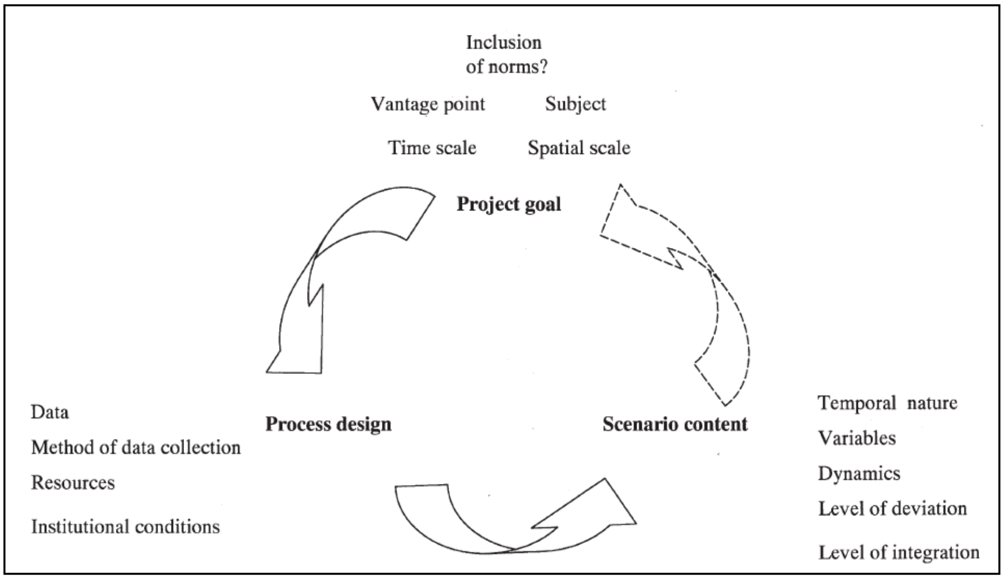


Figure 4.1: The phases of a scenario-based process
Source: van Notten et al. (2003)

4.2.1 *Definition of the project scope and level of detail required*

The purpose of this research is to determine the implications of urban development on GHG emissions and energy consumption in the city of Durban. In order to achieve this goal, it was necessary to divide energy demand into sectors and determine the main drivers of emissions in the various sectors. The main sectors chosen were based on the GHG Inventory (Antoni, 2007) and included the residential sector, the industrial and commercial sector, the local authority and the transport sector. According to Merven (2009), it is preferable to keep the system simple and only divide sectors where necessary.

Therefore the residential sector was divided into its end-uses of energy demand, which included cooking, heating, lighting and other uses. The drivers of demand that were considered in this sector were population growth, the number of people per household and the rate of electrification of households.

The industrial and commercial sector was divided into the manufacturing subsector and the commercial and service subsector due to the different levels of energy demand and GHG emissions in these subsectors (Jung *et al.*, 2000 and Winkler and Marquard, 2007). The manufacturing subsector is energy intensive, whilst the energy demand of the commercial and service subsector is relatively lower. The main driver in this sector is GDP, which determines the level of growth in the economy and therefore the change in energy demand. Furthermore, the structure of the sector is also a driver of change as it can influence energy demand and GHG emissions. For example, a shift in the structure of the economy from energy-intensive industries to low energy consuming industries can have an impact on the energy demand of the sector. This sector was not further divided into end-uses, such as lighting, cooling and other processes, since this study is a primary assessment, however it is recognised that it will be necessary for future studies.

The transport sector was disaggregated into road, air and marine transport. Rail transport was not included in this sector as the electricity consumed for rail could not be disaggregated from the total electricity consumption for the commercial and service sector and therefore rail transport was included in the commercial and service sector. The main drivers used for this sector were urban sprawl, fuel prices and changes in the structure of public transport. Other drivers for the sector include population and GDP.

A baseline year of 2005/2006 was chosen as this correlated with the SoER and the GHG Inventory of 2005/2006, where data were already available. The timescale for the project was chosen to be 2050, as this correlated with the South African LTMS and other international scenarios.

4.2.2 *Identification of data required and compilation of a database*

The data that were necessary to determine the energy consumption by fuel/energy type for the different sectors, subsectors and end-uses were obtained from the SoER and the GHG Inventory 2005/2006. However, where missing gaps could be filled, data were acquired from other sources.

Households

For the household sector the total energy consumed by fuel type was taken from the SoER, except for electricity consumption, which was taken from eThekwini Electricity, as this was found to be more accurate. This is because the eThekwini Electricity is the direct source of electricity consumption and the SoER and GHG Inventory based their information on different start and end dates for the year. The energy types consumed were broken down into lighting, heating and cooking using the Stats SA Community Survey (2007), which provides the percentage of households that use a particular fuel type for different end-uses, as shown in Table 4.1. The study by Simmonds and Mammon (1996) was used to break down electricity, biomass and LPG consumption into end-uses and the study by Robert and Wentzel (2006) was used to determine average paraffin consumption by end-use.

Table 4.1: Percentage of households by type of energy/fuel for cooking, heating and lighting consumed

Energy Source	Cooking (%)	Heating (%)	Lighting (%)
Electricity	82.7	80.8	87.2
Paraffin	14.8	10.3	3.4
Wood	1.3	4.4	0.0
Gas	1.1	0.5	0.1
Coal	0.1	0.2	0.0
Candles	0.0	0.0	8.9
Other	0.0	3.8	0.4

Source: Stats SA (2007)

Industrial and commercial sector

For this sector it was necessary to determine the energy consumption by fuel/energy type for the manufacturing and commercial sectors separately. The GHG Inventory and the SOE were used to determine the total energy consumed for this sector. Gaps in this sector were however identified. The GHG Inventory assumed that all bulk electricity falls under the manufacturing sector and the SOE did not differentiate between the manufacturing and the commercial and service sector. Therefore a list of approximately 750 of the largest electricity consumers was obtained from eThekwini Electricity (Table

4.2) and was broken down into the manufacturing industries and commercial and service sectors (Appendix 1). This illustrated that the commercial and service sector used more electricity than previously assumed.

The other missing gap was that the GHG Inventory and the SOE based coal consumption on an estimate. According to Antoni (2007) there is a need for a database of coal consumption and distribution in the Durban area. A list of coal consumption for Durban was obtained from the Natal Associated Collieries (Table 4.2), which was also divided into manufacturing consumption and commercial and services consumption (Appendix 2).

Furthermore, the GHG Inventory assumed all other fuels such as LPG, HFO, paraffin and Sasol methane rich gas (MRG) were consumed in the manufacturing sector. Springlights, which is a supplier of Sasol gas in the eThekwini area, was contacted to determine the breakdown of MRG consumption for Durban. It was confirmed that MRG is only consumed in the manufacturing sector. LPG consumption was broken down based on informal telephonic interviews with the LPG Association, an LPG distributor and the Energy Research Centre (ERC) in Cape Town (Table 4.2). It was assumed that approximately 75% of LPG was consumed in the industrial, commercial and service sector, primarily by hotels and restaurants and 25% was consumed in the residential sector. Additionally, as in the GHG Inventory, it was assumed that all HFO and paraffin was consumed in the manufacturing sector (Appendix 2).

Other fuel types, which include bagasse, biomass and refinery gas, are all consumed within the manufacturing sector.

In order to determine the energy intensity (GJ/R ’000), GDP data were needed, which were provided by the Economic Development Unit (Table 4.2). These data included recorded GDP per sector for Durban from 1996 to 2008, and forecasted GDP for 2009-2013 (Appendix 3). Once the fuels consumed were distributed into the manufacturing and commercial subsectors, the energy intensity of these subsectors was calculated using the following equation:

Energy Intensity (GJ/ R 1000) = Total Energy Utilised (GJ) by subsector/ GDP of subsector (R '000)

Table 4.2: List of distributors or organisations contacted and the data received

Distributor / Organisation	Contact person/Author	Date Contacted	Information obtained
ELECTRICITY			
eThekwini Electricity	Nyaniso Mlilo	2009/03/09	Electricity consumption of the top 750 electricity consumers (which represents 70% of the electricity consumed in the industrial and commercial sector). Total electricity consumption for main sectors.
LPG			
Afrox (Handigas)	Steven Ferreira	2009/04/01	Stated that the main sectors that consume LPG are the hospitality, manufacturing and low-income households.
LPG Association	Bob De Lange	2009/03/31	Stated that the LPG Association kept no records of the distribution of LPG, but observed that large quantities of LPG are consumed by hotels and restaurants.
Energy Research Centre (ERC)	Andrew Marquard	2009/05/19	Estimated that approximately 50% of total LPG is consumed in the industrial and commercial sector and the other 50% is consumed in the residential sector.
COAL			
Natal Associated Collieries	Garth Loades	2009/04/16	Provided a detailed breakdown of the coal distribution in Durban.
METHANE RICH GAS			
Springlights	Pradashnee Govindsamy	2009/03/26	According to Ms Govindsamy all MRG in Durban is consumed in the manufacturing sector, primarily in the South Durban area.
BAGASSE			
Tongaat-Hulett	Allan Ferguson	2009/08/18	Provided data of bagasse used to generate electricity and the calorific value of the bagasse.
ECONOMIC DATA			
eThekwini Economic Development Unit	Denny Thaver	2009/01/21	Provided detailed GDP data for eThekwini (1997-2008) and South Africa (2000-2008) Provided population data for eThekwini Provided data on growth trends in the economic sector.

Local Authority

The data used for the local authority sector were taken from the GHG Inventory 2005/2006. This sector was divided into municipal buildings, street and traffic lights, water and sewage, vehicle fleet and distribution losses. Waste is not included as the scope of the project involved focusing on emissions as a result of energy consumption.

Transport

The fuel consumption for road transport was taken from the GHG Inventory, and is based on the total fuel sold within the municipal area. This was not divided further into end-uses due to a lack of data on vehicle kilometres travelled by vehicle type within the municipal area. The methodology applied is consistent with the Tier 1 approach as stipulated in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

Fuel consumed for marine transport was obtained from the National Ports Authority , which includes jet fuel, diesel and petrol. The main activities that fall within this sector are dredging, the tug boats and the container sector. The jet fuel consumed by the harbour helicopters was also included in the marine fuel consumption (Appendix 2.2).

Lastly, estimates for air transport fuel consumption were taken from the GHG Inventory 2005/2006.

Limitations and assumptions

Assumptions, based on information gained from informal interviews with key informants, were made in order to distribute these fuels into subsectors. The assumptions were:

- Heavy fuel oil is utilised only within the manufacturing sector to operate boilers,
- 75% of total LPG is consumed in the industrial and commercial sector and 25% in the residential sector. This was based on conversations with Andrew Marquard, Bob de Lange and Steven Ferreira (Table 4.2).
- 20% of total paraffin consumption in Durban is consumed in the industrial and commercial sector, whilst the remaining 80% is consumed in the residential sector.
- The transport services subsector consists solely of air, rail and water transport, due to difficulties in allocating liquid fuel consumption for freight and passenger transport by road. Freight and passenger transport was incorporated in the transport sector.

4.2.3 *Input of data into the model*

The scope of this dissertation is to determine the implications of urban development on energy consumption and GHG emissions in the city, based on different future scenarios. Therefore the tool selected to develop these scenarios needed to allow for energy demand analysis and energy related GHG emissions. It also needed to allow for a series of projections to be developed, which are easy to compare. As such the LEAP tool was chosen.

The LEAP system is a tool created by the Stockholm Environmental Institute (SEI) that allows for energy planning and GHG emissions mitigation. LEAP is an integrated physical accounting and simulation tool, which was chosen because it is very flexible and easy to use, due to its similarity to other Windows programmes (Heaps, 2008). LEAP allows users to input the data in various formats and does not require any specific disaggregation of data in order to generate results. The tool consists of three main divisions, which are energy demand, energy transformation and resources (Taviv *et al*., 2008); however, the tool allows the user to work with only one division if necessary. It is also flexible in that it can be used for global to local level planning and analysis and to simulate short to long term energy projections (EnergyScape, 2007; Heaps, 2008; Phdungsilp, 2006). The other advantage of LEAP is that it has a large database, which consists of emission factors for different fuel types and technologies, that are specific to South Africa. This is due to the involvement of the ERC, at the University of Cape Town, in the development of the tool (Phdungsilp, 2006).

Scenario analysis is a key feature of LEAP, which allows users to create a range of storylines to illustrate how energy demand and GHG emissions may change over time. The scenarios are based on a variety of different assumptions of population growth, economic growth, technological change, fuel mix and other drivers. "Scenarios are developed by asking 'what if' questions", for example what would happen if the population of the city stabilises (Phdungsilp, 2006: 12). The scenario analysis function allows policy makers to create different scenarios and evaluate what the best options are based on energy consumed, environmental impacts and costs (Heaps, 2008). The LEAP interface consists of a series of different views, each depicting different aspects of the energy analysis, as shown in Figure 4.2. The analysis view consists of a data tree structure, which can be divided into a number of main branches and sub-branches depending on the level of detail required. The Key Assumptions Branch consists of basic information that is related to the energy consumption of an area. The next branch is the Demand Branch, which consists of all sectors related to energy consumption. The energy demand for the various sectors identified in Section 4.2.3 was input into the Demand Branch of the tool. The other main branches are Transformation, Resources and Non Energy Sector Effects; however, these were not used for the study, as Durban does not generate its own electricity and resources and non energy sector effects are was not part of the study.

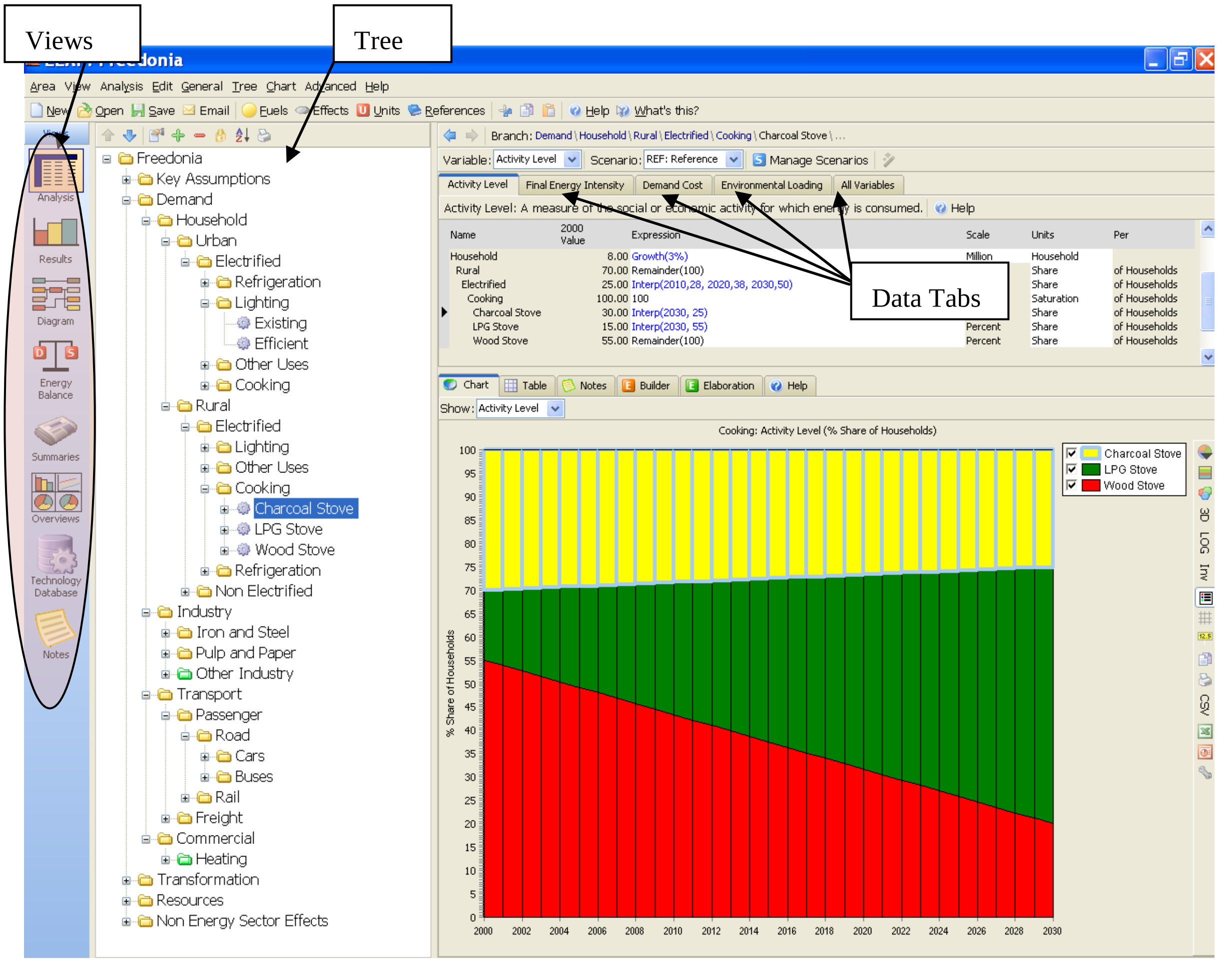


Figure 4.2: The LEAP interface – the Analysis View

Source: Heaps (2008)

The tool calculates energy consumption and environmental loadings based on baseline data such as Activity Level, Final Energy Intensity and Environmental Loading that are input into the tool. The total energy consumed and CO_2e emissions are calculated based on the equations below:

Total Energy Consumption = Final Energy Intensity x Activity Level (4)

Total CO_2*e Emissions = Total Energy Consumption x Emissions/Unit Energy Consumed* (5)

- Activity Level: Measures the activity associated with a particular demand, for example the activity level for the manufacturing sector can be GDP output.
- Final Energy Intensity: The energy required by the particular activity level, for example the energy required to generate a unit of GDP in the pulp and paper sector.
- Environmental Loading: measures the environmental impact of the energy consumed (EnergyScape, 2007). The CO_2e emission factors are recorded as the amount of CO_2e emitted per unit of energy consumed.

Once the baseline data are entered into the tool, scenarios can then be created using the ‘Manage Scenarios’ button. LEAP has a series of functions to assist in the development of scenarios, such as the interpolate function, the end-year value, or the growth rate function, to illustrate how energy consumption will change in the future.

In order to calculate energy demand and GHG emissions many different methodologies can be applied using the tool. The activity level for energy demand and GHG emissions were calculated as a function of economic growth for the industrial and commercial sector, number of households for the residential sector and total consumption for the transport sector. The emission factors for the different fuel types and activities were taken from the LEAP Technology and Environmental Database for some fuel types, which included coal, Sasol MRG, AvGas, diesel, petrol and heavy fuel oil. The emission factors for the other fuel types were manually input into the tool, for example the emissions for electricity, which is updated by Eskom on a regular basis.

Once the scenarios have been created the user may then generate results by clicking on the ‘Results’ button on the ‘Views’ toolbar. The results (shown in Figure 4.3) can be displayed as charts or tables and in any acceptable unit of measurement. The results can also be viewed by fuel type, scenarios or branches, which are by sectors or subsectors. By providing users with a flexible interface, it makes it easier to visually see the implications for the different scenario options on future energy demand and GHG emissions.

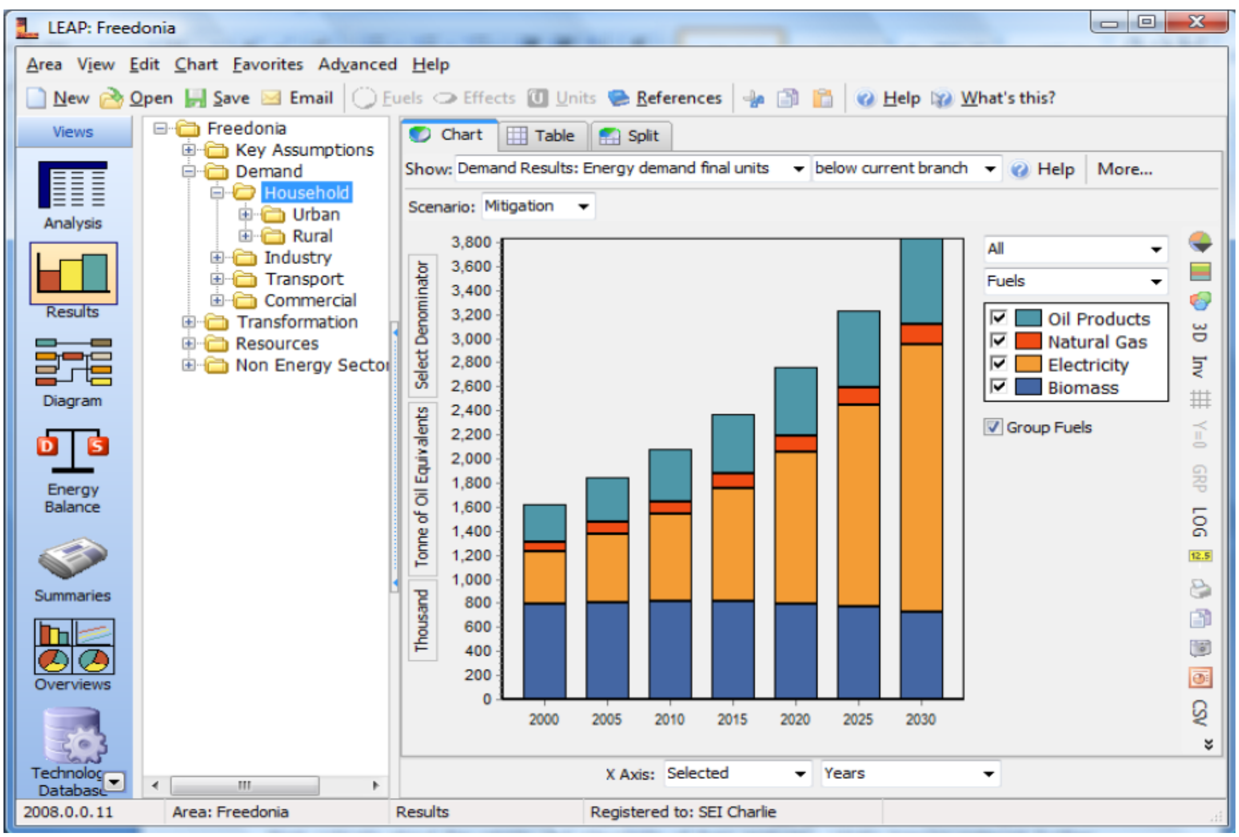


Figure 4.3: The LEAP interface – Results View
Source: Heaps (2008)

4.2.4 *Creation of scenarios*

Key uncertainties were first identified in order to create plausible scenarios. This study focused on urban development, therefore uncertainties in forecasting future emissions would include:

- Economic development and structural change in the city;
- The level of technological change and energy efficiency in different sectors in the city;
- Changes in the energy/fuel mix used over time; and
- Population growth and an increase in the number of formal households.

The scenarios created would need to reflect how changes to the above uncertainties would impact on the future emissions of the city. According to Schoemaker (1995), one approach to constructing initial scenarios is by identifying two extreme scenarios, one which includes all the positive aspects and the other which includes all the negative aspects. Whilst the chances of extreme scenarios occurring are minimal, it still allows for decision-makers to plan and to adapt more easily to the outcome, if it occurs (Hallegate *et al.*, 2008).

<u>Growth without Constraints</u>

The main aim of the GWC Scenario is to illustrate the future if no climate change interventions are made in the city, which is similar to the GWC Scenario in the LTMS, as described in Chapter 3. In the GWC Scenario it is assumed that climate change interventions are no longer a concern and there are no disasters as a result of climate change.

The structure of the economy remains the same as the base year and there are no changes in the fuel mix as there is no need to switch to cleaner or renewable technologies. This scenario assumes that the city's economic growth target of 1% above national AsgiSA growth targets are met and the economy grows at 7% per annum from 2010-2014 and thereafter a growth rate of 1% above the growth rate of the LTMS which is 3% per annum is assumed. However, the actual growth rates from 2005-2009 were input into the scenario.

In terms of population and housing, the population grows at 1.5% per annum as more people enter the city in search of jobs. The number of people per household decreases, such that households grow at double the rate of population and the number of people per household decreases from four people per household to two by 2050. The scenario also assumes that by 2020 all households in Durban will be electrified and no alternative energy sources are used.

As the number of households increase and people become wealthier, the city sprawls and the number of private vehicles increase at the same rate as GDP. Similarly, marine and air transport grows at a similar rate as GDP, with the new King Shaka International Airport and the harbour expansion.

<u>Business as Usual</u>

For this study a Business as Usual (BAU) Scenario was developed, which was based on the city's current development goals as stated in the IDP 2008/2009 Review, the Economic Development Strategy 2008 and the targets set by the EMES. The scenario assumes that all the existing strategies and plans for Durban are achieved, but that no other goals are put in place in the future. This is similar to the Reference Scenario of the WEO and the IEO scenarios (EIA, 2009 and IEA, 2009), which is based on a global future which only takes existing policies into account. It is also similar to the Baseline Scenario of the EU that includes all policies implemented by the end of the year prior to the creation of the scenarios (Capros *et al.*, 2007). In addition, it is also comparable to India's baseline scenario and California's BAU scenario (Ghanadan and Koomey, 2005 and Rajesh *et al.*, 2003).

The Economic Development Strategy (Economic Development Unit, 2008), set a goal for GDP growth to be 1% above the national level. The AsgiSA programme sets the growth target average for South Africa at 4.5% from 2005-2009 and an average growth rate of 6% from 2010-2014. However, due to the economic recession, South Africa and Durban did not meet the 2005-2009 growth target (Stats SA, 2009). Therefore, until 2013 the GDP projections made by the Economic Development Unit were assumed, thereafter a GDP growth of 1% greater than the growth rate set for the LTMS were assumed for Durban until 2050. The LTMS assumes a growth rate of 3% from 2014- 2050 (SBT, 2007), therefore the growth rate assumed for this scenario was 4% until 2050.

In addition to this, the city also aims to drive development in the following sectors (Economic Development Unit, 2008 and EM, 2008):

- Automotive sector,
- ICT, tourism,
- Agriculture and agri-processing, chemicals,
- Creative industries (crafts, film, TV and music),
- Clothing and textiles, and
- Wood, pulp and paper.

Other economic implications taken into account in this scenario are the growth in the transport sector as a result of the Dube Tradeport adjacent to the new international airport and the harbour expansion. These changes will also have impacts on the export sectors of the economy (Global Insight, 2004).

In terms of population and housing, the population growth levels follow current trends and increases to 4.07 million by 2020 as stated in the EM (2007), thereafter a growth rate of 0.67% per annum was assumed, based on the South African population projections by the Actuarial Society of South Africa (ASSA) (ASSA, 2002). The city achieves its target of providing 16 000 houses per annum until 2017. In addition to this middle and upper income households increase at 1.5% per annum, as per capita income increases. The scenario also assumes that by 2020 all households in Durban will be electrified, with some households using gas, paraffin and solar energy as alternative energy sources for cooking and heating.

The transport sector in this scenario grows, as economic growth increases GDP per capita and more people begin to drive private vehicles. However, concurrently the city also achieves its goal of improving public transport and reducing urban sprawl, as stated in Section 3.3.2. The new King Shaka Airport and the harbour expansion increase the amount of air and marine traffic, at higher levels than the city's economic growth rate.

In terms of carbon dioxide emission reduction, the scenario assumes that the targets set out by the EMES are achieved by 2020, for all sectors. Therefore, overall the projected CO_2e emissions are reduced approximately 27.6% from the total GWC projected emissions by 2020. An improvement in energy efficiency, particularly in electricity consumption is also attributed to high national electricity price increases by Eskom (Njobeni, 2009).

<u>The Low Carbon City</u>

The Low Carbon City Scenario assumes that climate change mitigation becomes a priority globally, nationally and locally. Therefore the city makes it mandatory for all sectors in the economy to reduce their emissions using taxes, incentives and targets. This results in all sectors becoming more energy efficient and thereafter resorting to cleaner technologies and renewable energy. In addition to this the increase in oil and electricity prices also makes it more viable for consumers to use alternative energy sources. In all sectors the EMES targets are achieved by 2020 and thereafter are doubled by 2050.

For this scenario the city develops strategies that integrate its economic development and climate change policies, and promote the development of low carbon industries. Due to the new policies and incentives, the structure of the economy shifts towards service and commercial sectors, as these sectors are less energy intensive. By 2050, service and commercial sector contributes 95% to the economy, which is similar to current developed country cities like London, New York City and Washington DC (Dodman, 2009). The promotion of a "Green Economy" results in people finding employment in the growing green sector of the economy. Furthermore, the strict control of CO_2e emissions in the city, results in an increase in energy efficiency and an increase in the usage of renewable energy and cleaner technologies in all sectors.

Based on a study conducted by Imagine Durban (2009), it was established that businesses and industries in Durban can significantly reduce their energy consumption by implementing simple measures such as creating awareness to achieve behavioural change in the workplace, making lighting more efficient by installing timers and switching to chloro-fluorescent lighting (CFL's) , installing solar water geysers, improving the automation during process cooling, reducing the pressure required for compressed air and other factors. The manufacturing industries that were used were Toyota, SAB and Mondipak Corrugated. On average these industries achieved a 14% reduction in electricity consumption. In addition to this, Pick 'n Pay, which falls in the commercial sector achieved a 22% reduction in electricity consumption. This reduction in electricity consumption is expected to improve as industries and businesses implement more technologies and measures in the future. Based on this study, this scenario assumes that all industries reduce their electricity consumption by 14% and all commercial sectors reduce their electricity consumption by 22% by 2012. Thereafter the EMES target is achieved by2020, such that the industrial and commercial sector reduces their emissions by 30%. The switch to cleaner fuels and new technologies increases the energy efficiency by 60%, by 2050.

The quantity of coal, which is considered a 'dirty fossil fuel', utilised is reduced by 60%. The reduction in the consumption of coal is supplemented with an increase in the consumption of renewable energy, MRG and LPG. Renewable energy represents 20% of the fuel mix by 2050, including biomass. The impact of this is a slight decline in GDP for the first ten years, as industries use some of their profits to implement new technologies or adopt cleaner fuels. Thereafter, it begins to increase as industries begin to save energy due to their investments. GDP stabilises at 3% per annum by 2030, which is based on the LTMS final GDP growth rate (SBT, 2007).

In the residential sector, population growth is lower than the BAU Scenario, with population reaching 3.6 million by 2020 and declining to 3.2 million by 2050. However, the Municipality begins to build energy efficient low cost housing and many households begin to replace their electric geysers with solar water heating (SWH), as it becomes cheaper to use. More awareness about climate change is created, which results in a behavioural change in the city. Residents begin to improve the energy consumption of households as most households switch to CFL's for lighting, install timers for their geysers, switch off unnecessary appliances and other factors. Therefore, by 2050 the energy efficiency of this sector improves by 50% by 2050.

The municipality creates an urban fringe to limit urban sprawl and promote compact cities, with mixed zones in close proximity to encourage cleaner modes of transport (Schremmer and Stead, 2009). Bicycle paths and pedestrian walkways become more common. Behavioural change in the economy impacts on the transport sector, such that by 2050 13% of drivers switch to hybrid and electric vehicles and 10% of the fuel mix consists of biofuels. The public transport system is effective and successful and many people choose to use it rather than private vehicles.

The local authority becomes carbon neutral by 2050, by completely minimising its energy consumption, running all municipal vehicles on biodiesel and by generating electricity from their wastewater treatment plants in addition to their landfill sites. Their remaining CO_2eq emissions are offset by planting trees and providing low cost houses subsidies for SWH, insulating ceilings of low-cost houses and other energy efficiency and renewable technologies. The only emissions attributed to the local authority by 2050 are electrical distribution losses, through theft, unmetered usage of electricity and technical losses. Distribution losses also decrease as the municipality places more stringent measures on electricity distribution.

<u>A Natural Transition City</u>

The Natural Transition City Scenario assumes that climate change issues are no longer prioritised and there is a steady and constant supply of energy. This scenario also assumes that local municipal assistance is minimised in all sectors in the city, such that Durban does not achieve its development goals. Economic growth in the city naturally shifts from an industrialising economy towards a post-industrial society, which is a service and information economy, as identified by Bell (1976) and Jung *et al.* (2000). The scenario assumes a general decline in growth rates in the manufacturing sector and an increase in the financial and real estate, ICT, tourism and other business and service sectors. Growth in the ICT and tourism sectors increases the level of integration with other international cities. As in the Low Carbon city, by 2050 the commercial and service sector represents 95% of the economy.

Due to a minimal influence from national and local government, the economic growth takes a longer time to recover from the recession. Markets are left to free trade, with no government stimuli, therefore GDP growth is moderate. The decline in the manufacturing sector results in the job losses of semi- and un-skilled labourers (OECD, 1994). The resultant job losses increase the gap between the rich and the poor in the city. The transition towards a service and commercial sector creates an influx of a skilled workforce but also an increase in slums in the city. This has an impact on the housing sector of the economy

As local authority influence in this scenario is minimised, the city fails to produce the necessary housing for people residing in informal settlements and the number of households grows at a lower rate than the BAU Scenario. The high rate of unemployment increases the gap between the rich and the poor. Population grows at a higher level than the BAU scenario, at an average of 1% per annum. Due to an increase in informal households and upper class suburban areas, the city begins to sprawl and many houses are in need of basic services. The city takes a longer time to provide households with basic services; and by 2050, 95% households are electrified.

As the city sprawls, it places pressure on the road networks in the city, as people begin to commute longer distances to places of work, education and recreation (Schremmer and Stead, 2009). This increases the demand for transport in Durban, however, public transport systems do not improve significantly. As a result the demand for fuel grows at a higher rate than GDP growth, with no contribution from biofuels. As a result of the open market economy, the air and marine transport sector grows at double the rate of the economy, due to increased interactions with international economies.

Since climate change issues are no longer a concern and the supply of fossil fuels remain steady, the fuel mix in the economy remains the same.

Slow Go City

The Slow Go City assumes that climate change issues are recognised but are not prioritised. The Municipality, which is influenced by national regulation, prioritises the need for economic development and the creation of jobs over the mitigation of climate change. Like the Shell Scramble Scenario, nationally the main concern is to secure energy supply. Climate change mitigation and energy efficiency are postponed as a result of climate change related disasters and fossil fuel price increases (Shell, 2008).

The city does not evolve towards a post-industrial society, but rather experiences growth in all sectors including the manufacturing sector. This is because manufacturing industries are viewed as sectors that provide the country with a competitive advantage, as a result of higher energy costs in many other countries, and also as an important sector for providing jobs (Winkler, 2008 and Winkler and Marquard, 2007). This is achieved by providing the manufacturing sector with incentives to expand and by increasing government spending to stimulate growth in the economy (Mohr and Fourie, 2002 and Winkler, 2008). Manufacturing sectors that encourage the export of manufactured goods are targeted. Economic growth is initially rapid, due to government stimuli and follows the same growth pattern as the GWC scenario until 2015, and then declines to 2.5% per annum as the high fuel prices and the costs for implementing other technologies have an impact on the economy

Whilst there is no compulsion in GHG mitigation, industries begin to adopt energy efficiency measures and cleaner technologies due to an increase in electricity and in oil prices. The increase in the price of electricity and fossil fuels reduces the payback period for cleaner technology investments, making it more worthwhile for industries to invest in energy-saving technologies (Imagine Durban, 2009). However, due to the need to boost the economy and a lack of urgency in mitigating climate change, improvements in efficiency and the use of cleaner technologies occur at a slow pace. Therefore energy efficiency and technological improvements only begin in 2020 and by 2050 the economy becomes 40% more energy efficient and approximately 12% of the energy consumed in the economic sectors is from renewable sources, such as solar power, biomass and wind.

The increase in oil prices will also reduce the demand for oil, which would impact on the oil refineries, by reducing the production of liquid fuel products, which would reduce the energy consumed by the refineries.

The transport sector grows at a high rate until 2020, similar to the GWC scenario, but then also begins to decline as the high fuel prices encourage people to start using public transport, carpooling and switching to more efficient vehicles. By 2050, 8% of the fuel used in the transport sector is biofuels and approximately 5% of vehicles are hybrid or electric cars.

The local authority drives poverty alleviation and service delivery such that by 2020 all households are electrified and growth of households is at the same rate as the GWC scenario. Due to the creation of jobs in the city, the rate of rural-urban migration increases as people move to the city to find jobs. Energy consumption per household increases until 2015 as people become wealthier but thereafter remains the same, as high electricity prices make consumers more energy efficient. Many households switch from electric geysers to SWH and some households replace electric stoves with gas stoves for cooking. By 2050, approximately 5% of energy for households comes from renewable energy sources.

The energy consumption of the local authority sector also grows with the economy, as the municipality aims to improve service delivery in the city; however, the sector also begins to become more efficient as fuel prices increase, and begins to adopt more efficient practices. The Municipality adopts simple measures like installing light timers in buildings, switching to CFLs and LEDs in traffic signals, using biodiesel for municipal vehicles and generating energy from their landfill sites and wastewater treatment facilities.

<u>Required by Science</u>

The Required by Science (RBS) Scenario was adapted from the LTMS of South Africa. The RBS scenario is based on the IPCC guideline, which states that global emissions need to be reduced between 60% to 80% of 1990 levels by 2100. Therefore this scenario was created on the premise that emissions are reduced by 30% to 40% of their 2005/2006 level by 2050. As mentioned in Section 2.2, this scenario is not attainable without the implementation of technologies that are yet to be discovered and behavioural changes of the Durban society (SBT, 2007).

4.2.5 *Comparison, evaluation and analysis of scenarios*

The LEAP tool analysis function formulates a series of graphs, which illustrate the different scenarios based on the input parameters. The tool allows the user to focus on the emissions, energy consumption by fuel type and the GDP of an individual subsector or all the subsectors together. The tool also develops graphs that illustrate the differences in the scenarios.

The created scenarios are first evaluated to ensure that there are consistencies in the scenarios. The scenarios were then compared to determine the impacts of the different scenarios on GHG emissions.

4.3 The downscaling approach

According to van Vuuren *et al.* (2007: 115) 'downscaling' is defined as 'any process in which coarse-scale data is disaggregated to a finer scale while ensuring consistency with the original data set'. Therefore downscaling allows for the generation of data at smaller scales. This is important as different countries and cities are subject to different policies, land-use patterns and other factors that vary over short distances. Downscaling enables the portrayal of global IPCC scenarios on a local level, therefore depicting the GDP, population, energy consumption and CO_2e emissions for the different scenarios on a country and city level. For the purpose of this dissertation the downscaled data were taken from research done by van Vuuren *et al.* (2007) of the Netherlands Environmental Assessment Agency.

Downscaling methodologies range from conditional modelling to clearly defined algorithms. Conditional modelling uses finer scale models that are based on the outcome of coarse scale data. This technique requires detailed information of the small scale parameters, which is difficult to acquire. Another problem with this method is the lack of transparency, due to the complexity of the different models (van Vuuren *et al.*, 2007).

The other method of downscaling is through the use of algorithms. Three common downscaling approaches are used in downscaling. Linear downscaling assumes that the growth rates of the larger unit are the same as the growth rate of the smaller unit (van Vuuren *et al.*, 2007). For example, the growth rate of a country is the same as the growth rate of a city within the country. This method can only be applied if there is insufficient information to determine differences between the units. Also, this method would not be applicable if there are great differences between the larger and smaller units (van Vuuren *et al.*, 2007). Convergence downscaling assumes that changes in the smaller units will eventually converge with the regional rates, over a period of time. This method is applied in cases where there are significant differences in the smaller units, but previous data have shown a tendency towards convergence (van Vuuren *et al.*, 2007). External-input-based downscaling is used when other scenarios exist for the smaller units, which can be used to determine the position of the smaller unit within the region. The benefit of using this approach is that it allows for capturing of changes within the smaller unit in the scenario. However this technique is dependent on data availability (van Vuuren *et al.*, 2007).

The downscaling of the IPCC regional data to country-level data was based on independent work done by several authors and is not part of the IPCC SRES. Gaffin *et al.* (2004) created a database of downscaled GDP and population data on a country and grid level, based on the IPCC scenarios and Höhne and Ullrich

(2005) downscaled the GHG emissions. However, Gaffin *et al.* (2004) acknowledged many problems in the results due to the downscaling methodology applied and the lack of population scenarios for countries after 2050, which resulted in discontinuities in the population scenarios. The GDP results were abnormally high as a result of linear downscaling techniques used to determine country-level GDP. This was not plausible due to varying economic growth in countries within a region. Similarly Höhne and Ullrich (2005) used a linear downscaling technique to downscale GHG emissions to a country-level, which does not reflect differences in emissions in different countries within a region. The data produced were also inconsistent because socio-economic scenarios were not produced and related to the GHG data (van Vuuren *et al.*, 2007).

Van Vuuren *et al.* (2007), aimed to provide a new dataset of consistent downscaled data, taking into account the discrepancies of the previous downscaling approaches. The study used the scenarios based on the Integrated Model to Assess the Greenhouse Effect (IMAGE) model, which was one of the six models used to develop emission scenarios by the IPCC (Nakicenovic, 2000a). Van Vuuren *et al.* (2007) developed downscaled SRES scenario data for 224 countries, illustrating population, GDP per capita and GHG emissions per capita. The data therefore reflect A1, A2, B1 and B2 scenarios for the 224 countries from 2000 – 2010.

For downscaling population scenarios, an external-input based downscaling approach was applied, based on more recent UN country-level data. For GDP and emissions, van Vuuren *et al.* (2007) used the partial convergence approach, which assumes that all countries' GDP and emissions per capita, within a region, will partially converge in a year out of the 2000-2100 scenario period. The rate of convergence varies according to the different scenarios and regions. The A1 and B1 scenarios will have high rates of convergence due to tendencies towards globalisation and the A2 and B2 scenarios have a low degree of convergence. After developing country-level data, based on the above methodology, van Vuuren *et al.* (2007) state that the data can be downscaled from a national level to a grid level (0.5° x 0.5°) using a linear downscaling approach. This approach assumes that the rate of change within a grid of a country is the same as the changes in the country.

Alternative approaches can be used when downscaling to a grid-level or a city level, however this would require detailed information about the city or grid area. For example, in population projections, fertility, morality and migration patterns within a grid can be considered, however this minimises the transparency of the study. According to van Vuuren *et al*. (2007) GDP within a country will differ between rural and urban areas, especially in developing countries, therefore sub-national data will improve the scenarios.

The downscaling of the downscaled country-level IPCC scenarios was conducted in this study to enable a comparison between the SRES scenarios and the scenarios that were generated (Malone *et al.*, 2004). The country-level data, based on van Vuuren *et al.'s* (2007) research were published on the Netherlands Environmental Assessment Agency website, and were used to downscale South African data on population, GDP and emissions to a Durban level. However, van Vuuren *et al.* (2007) did not downscale energy consumption to a national-level, which was important for this study, in order to determine the CO_2 emissions in relation to energy consumption. Therefore the energy consumption for the GWC scenario of the LTMS was used and compared to a downscale of regional IPCC SRES data.

4.3.1 *Data sources*

The data for the downscaling were taken from:

- Statistics South Africa: South African population statistics;
- Netherlands Environmental Assessment Agency: South African population, gross value added (GVA) per capita and emissions per capita scenarios;
- eThekwini Economic Development Unit: population data for Durban (2000 – 2008), data per economic sector for South Africa (2000 – 2007) and Durban (1997 – 2008);
- GHG Data Collection and Emissions Inventory Report' (Antoni, 2007);
- eThekwini Municipality State of Energy Report (Mercer, 2006).

4.3.2 *Population*

The first step towards the downscaling of South African data to a Durban scale was to review previous trends in population growth for both country and city. This purpose of this was to determine if the growth patterns in the city and country were similar. Data for South Africa's population from 2000-2007 were obtained from Stats SA and population data for Durban were obtained from Denny Thaver of the eThekwini Economic Development Unit. It was established, based on population data from the eThekwini Economic Development Unit, that Durban's population represents 6.94%-7% of South Africa's population. Therefore, a linear downscaling methodology was chosen, as described by Gaffin *et al.* (2004) and van Vuuren *et al.* (2006). The algorithm used to downscale from a South Africa to Durban level was kept simple, as van Vuuren *et al*. (2006) describes a good downscaling method as one which is transparent, consistent with local data and consistent with the original dataset. The algorithm is shown in equation (1) below.

$$Pop_{Dbn} = Pop_{SA} * (A_{Dbn}/A_{SA}) \qquad (1)$$

Where:
Pop_{Dbn} represents Durban's population for the different years and scenarios.
Pop_{SA} is based on the South African downscaled data from van Vuuren *et al.* (2007) for the A1, A2, B1 and B2 scenarios.
A_{Dbn}represents population data for Durban's (Economic Development Unit, 2008).
A_{SA} is equal to the population data for South Africa.

4.3.3 *Gross value added*

Previous GDP statistics of South Africa and Durban were compared in order to determine if growth trends are similar in both areas (Economic Development Unit, 2008). From 2000 to 2007, Durban contributed between 10.3 and 10.8% to South Africa's total GDP. Durban's GDP growth also correlates with that of South Africa, such that when South Africa's GDP increases, so too does that of Durban. This allowed for a linear downscaling of GDP from a South African level to a Durban level. The downscaled scenario data for South Africa provided by the Netherlands Environmental Assessment Agency, were in US $ per capita, whilst the data provided by the Economic Development Unit were in Rands, adjusted to constant

2000 prices. Therefore the growth rates of GDP per person for the South African data, for five-year intervals from 2000 - 2100 were used to determine the changes in GDP per capita for Durban. The outcome was then multiplied by the population outcome of the different scenarios to establish total GDP for the city.

4.3.4 *GHG emissions*

GHG emissions are a function of socio-economic driving forces such as population, economic growth and technological change, as discussed in Chapter 2. Van Vuuren *et al.* (2006) used the IPAT equation (discussed in Chapter 2) as the downscaling outline for GHG emissions, as emissions are determined by economic growth, population and technology. Hence, van Vuuren *et al.* (2007) downscaled South Africa's GHG emissions from the Africa Latin American Middle East (ALM) Region, using the IPAT Framework. However, a linear downscale was chosen for the estimation of GHG emissions in Durban, so that it follows the patterns of population and economic growth downscaled data.

The South African downscaled data were used to determine the changes in GHG emissions in Durban. The South African and Durban emissions are likely to follow similar growth patterns, which are largely determined by national legislation and policy. For example, the Energy Efficiency Strategy of South Africa (DME, 2005) sets a target to reduce overall energy consumption by 12% by 2015. This target will have an impact on the energy consumption of Durban.

4.4 Conclusion

The methodology applied involved two main steps: creating different scenarios based on a range of possible development paths for the city using the LEAP tool and downscaling scenarios from the global SRES scenario to reflect future emissions for Durban based on global development paths. The LEAP scenarios involved developing a database of energy consumption for the different sectors within the city, inputting these values into the tool and developing development paths from the base year. The downscaled SRES scenarios were developed by linearly downscaling SRES scenarios for South Africa to a Durban level.

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5 RESULTS AND DISCUSSION

5.1 Introduction

The purpose of this dissertation was to create different development paths for the city of Durban and to compare the resultant GHG emissions scenarios of the various paths. Five scenarios were created, based on changes in the various drivers of emissions for the different sectors, such as population and the number of households, GDP, structural change, energy efficiency and technological change. A sixth scenario was created to illustrate the future emissions if the RBS guidelines are met. Thereafter, the IPCC global scenarios were downscaled to illustrate the implications of global development paths on the City of Durban. All scenarios assumed different storylines for the city with some commonalities in the changes of the drivers of GHG emissions.

This chapter will first present the results of each of the created scenarios. Thereafter the scenarios will be compared with each other and the IPCC downscaled scenarios. The comparison will allow for the identification of optimal development paths for the city.

5.2 Growth without Constraints Scenario

The GWC Scenario represents a city where there is no longer a concern for climate change mitigation and there is a steady and constant supply of fossil fuels for the next half century. There is an emphasis on economic growth in the city, and as a result a substantial increase in the drivers of emissions, such that the GDP of the economy grows by about 6.5 times from the base year by 2050. The rapid increase in economic growth in the city increases per capita annual income from an average of R32 500 per person in 2005 to R115 300 per person in 2050. During this period the population of the city doubles from 3.3 million inhabitants to 6.4 million by 2050, whilst the number of households increases 3.8 times from 823 000 households to 3.1 million households during the same period. This rapid growth in the economy and the residential sector of the city will lead to major increases in energy demand and CO_2 emissions.

Figure 5.1 illustrates future energy demand and CO_2e emissions if the city follows the GWC development path. Energy demand increases from 170 million GJ in 2005 to approximately 1 000 million GJ, which is about a 6 times increase in energy demand by 2050. As a result of the increase in energy demand but no changes in the energy type, CO_2e emissions increase from 19.6 million tCO_2e to 124 million tCO_2e, which is a 6.3 times increase in emissions. The growth in CO_2e emissions is slightly greater than the increase in energy demand as a result of all households switching to electricity. The increase in energy consumption and GHG emissions closely follows the increase in GDP during this period.

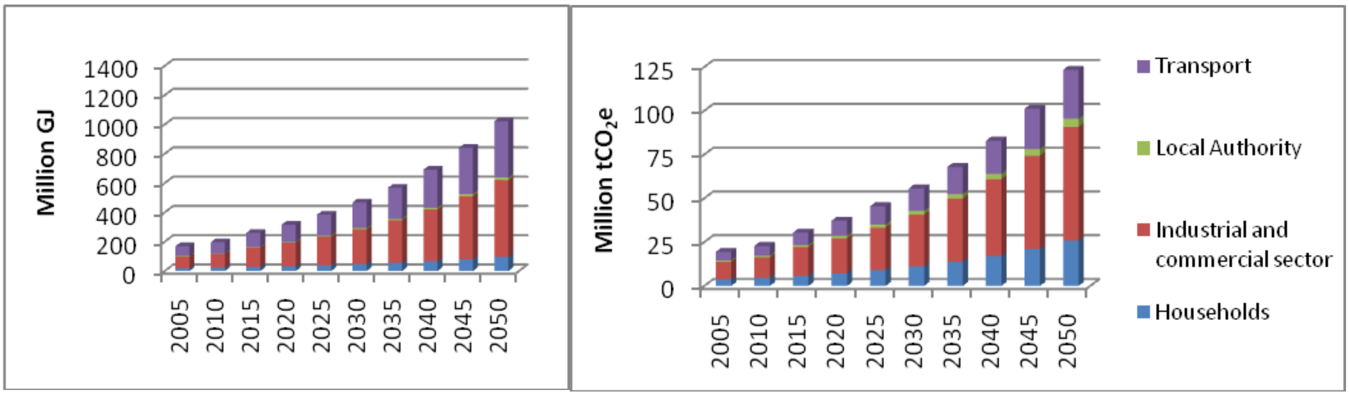


Figure 5.1: Energy demand (Million GJ) and CO_2e emissions (Million tCO_2e) by sector for the GWC Scenario from 2005 - 2050

The composition of energy demand and CO_2e emissions remains roughly the same, with a slight increase in emissions from the residential sector, which increases from 19% to 21% from 2005 to 2050 (Fig. 5.2). The reason for the increase in emissions in the residential sector is due to a decline in the number people per household, which increases the overall consumption of energy (Winkler, 2009) and the result of all households switching to electricity, which has a higher emission factor than other energy sources such as paraffin, LPG and biomass.

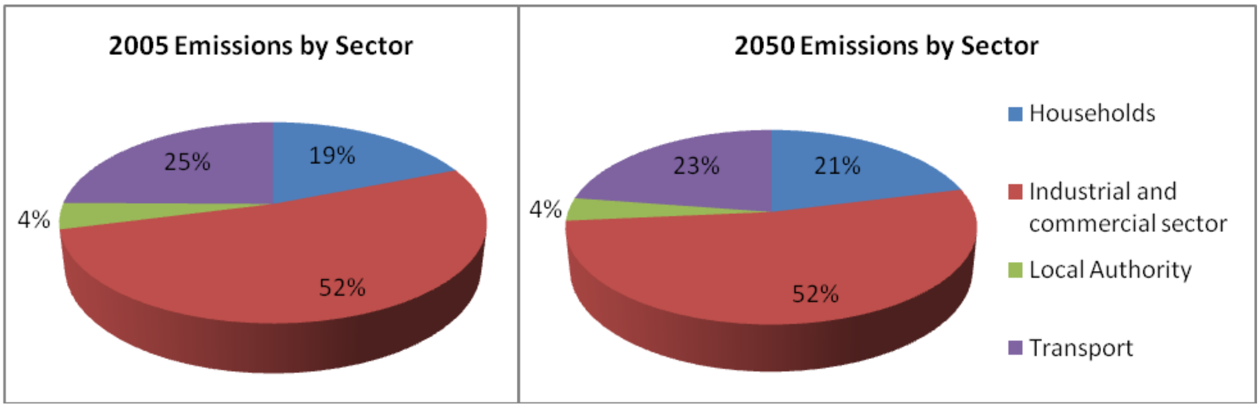


Figure: 5.2: Change in the composition of emissions from 2005 to 2050

If the city were to follow a GWC storyline, the demand for energy would grow exponentially (Fig. 5.3), similar to developed countries in the past (Meadows *et al.*, 1972). Oil products, which include mainly petrol, diesel, refinery gas and HFO, make up 59% of total energy demand, followed by electricity which makes up 27% of total energy demand. However, in terms of CO_2e emissions, electricity continues to be the highest emitter of GHG emissions, comprising 62% of total emissions, followed by oil products which emit a total of 32% of emissions. Other energy types that would be consumed are solid fuels, biomass and MRG. Solid fuels, which is coal, is the third largest energy source, in terms of energy demand and CO_2e emissions, whilst MRG and biomass are the smallest energy sources in this storyline. There is no use of renewable energy in this scenario, which is similar to Bangkok's BAU Scenario in which the main sources are liquid fuels, solid fuel, electricity, biomass and natural gas (Phdungsilp, 2008).

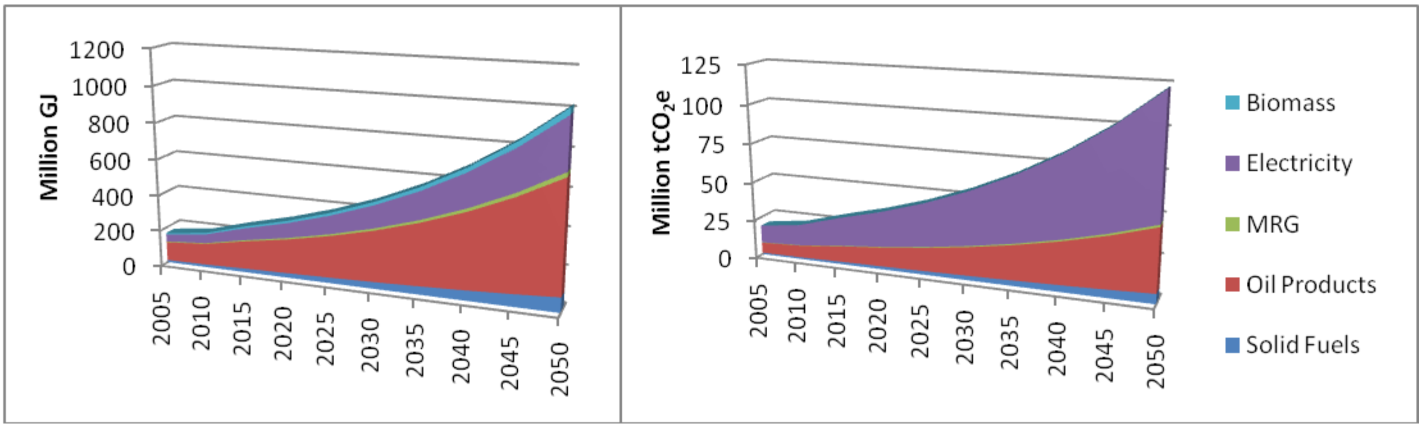


Figure 5.3: Energy demand (Million GJ) and CO_2e emissions (Million tCO_2e) by fuel type for the GWC scenario from the base year to 2050

This scenario can be compared to the LTMS GWC Scenario, which showed that emissions for South Africa will quadruple by 2050 (SBT, 2007). The higher emissions in the GWC Scenario for Durban are due to the city experiencing a higher economic and population growth rate in comparison to the national GWC Scenario. Similarly, when this scenario is compared to the high growth scenarios of the IPCC, IEA and EIA scenarios shown in Chapter 2, the emissions in this scenario are greater. Emissions increase 2.8 times in the IPCC A1C scenario and increase approximately 1.7 times the base year level by 2030 in the IEA and EIA scenarios. During the same time, the GWC Scenario for Durban increases about 3 times the base year value. This is as a result of high levels of urbanisation and development in developing country cities (Satterthwaite, 2005).

5.3 Business as Usual Scenario

The BAU Scenario was based on the assumption that existing policies and strategies are implemented and that governments would do nothing more during the projection period to impact on energy consumption (IEA, 2008a). This scenario therefore reflects a development path that includes the current action plans of the city, which are continued into the future. The current action plans of the city aim to increase economic growth, provide jobs and housing and improve energy efficiency to an extent. The GDP of the city increases to a slightly lower level then the GWC scenario from R115.1 to R660.4 billion by 2050, which is six times the base year value. Population grows moderately from 3.3 million people to 5 million people by 2050, and the number of households doubles during this period. Therefore, by 2050, the number of people per household decreases from 4 to 3.1.

The increase in GDP and the number of households impacts on the demand for energy and CO_2e emissions in the future. Energy demand increases 3.9 times from the base year and CO_2e emissions increase 3.5 times from the 2005 level (Fig. 5.4). The reason for a greater increase in energy demand as opposed to emissions is due to an improvement in energy efficiency and the quantity of renewable energy utilised in this scenario. The growth in energy demand and emissions is less than the economic growth of the city, which illustrates an overall decline in energy and carbon intensity in this scenario.

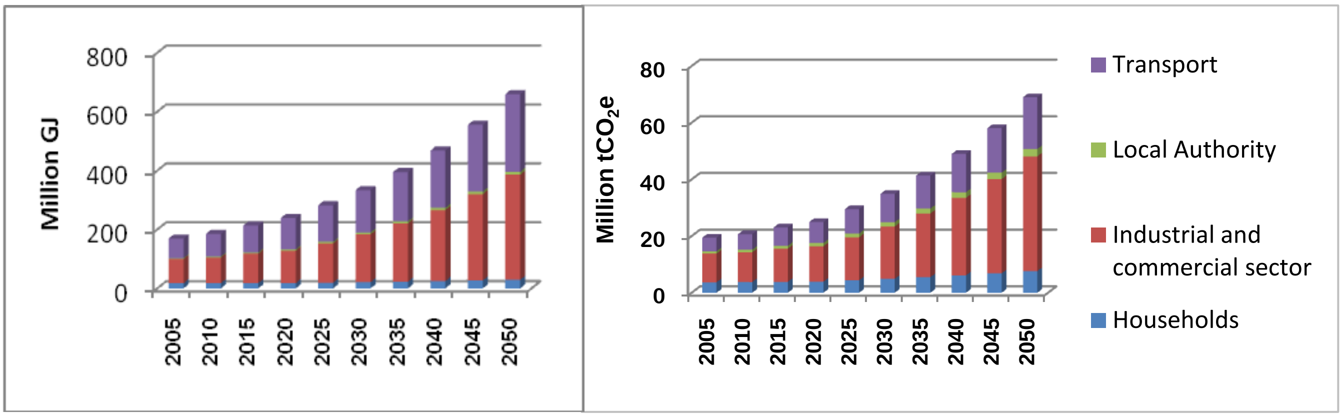


Figure 5.4: Energy demand (Million GJ) and CO_2e emissions (Million tCO_2e) for the BAU Scenario for the key sectors in the city from 2005 to 2050

The sector that has the highest energy demand and CO_2e emissions is the industrial and commercial sector, followed by the transport sector, and thereafter the household and local authority sectors (Fig. 5.4). The energy demand and CO_2e emissions per sector remains about the same, with some minor changes, for example the energy consumption per household decreases from 10% of total energy demand to 5% by 2050. This is explained by an increase in the energy efficiency and an increase in the use of SWH. The decrease in energy demand by the residential sector is met with an increase in energy demand in the industrial and commercial sector as a result of high GDP growth rates, which increases the demand for energy and CO_2e emissions per sector.

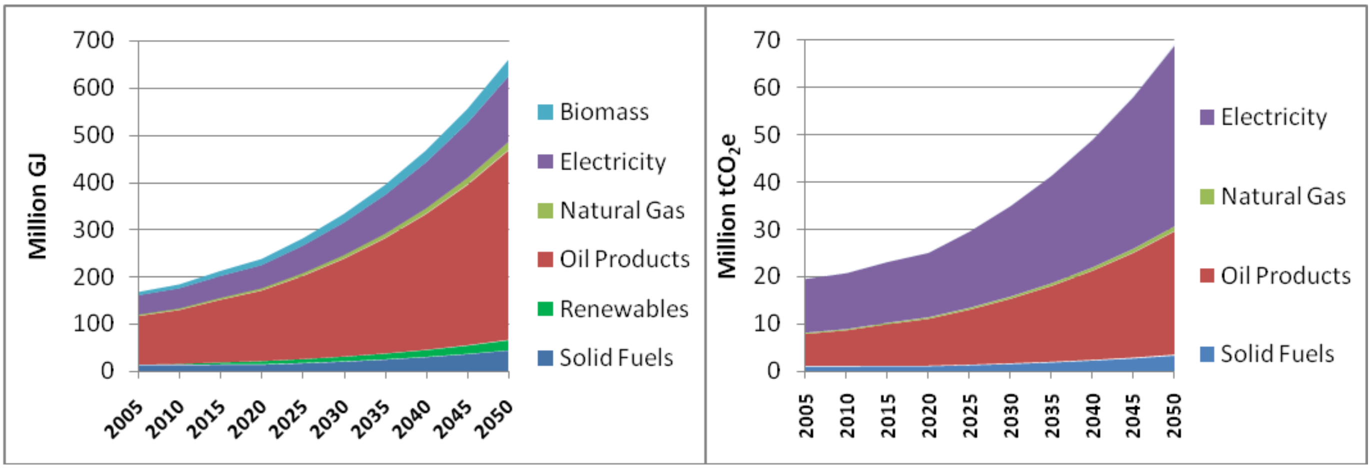


Figure 5.5: Energy demand (Million GJ) and CO_2e emissions (Million tCO_2e) by energy source for the BAU Scenario for 2005 to 2050

If the city continues on a BAU development path, the dominant fuel type will continue to be liquid fuels, followed by electricity (Fig. 5.5). The highest emissions per energy type will still be electricity, due to the high emissions factor of electricity. The main difference between the energy sources/fuel type of the GWC and the BAU Scenarios is the increase in the use of renewable energy, in the BAU Scenario. Renewable energy and biomass, which is also considered to be a renewable energy source consisting of biofuels, wood and bagasse (DME, 2003), makes up 9% of total energy demand, by 2050. This is a 5% increase from the base year, where the only significant quantity of renewable energy consumed in the city was biomass, which represented 4% of total energy consumed (Fig. 5.6).

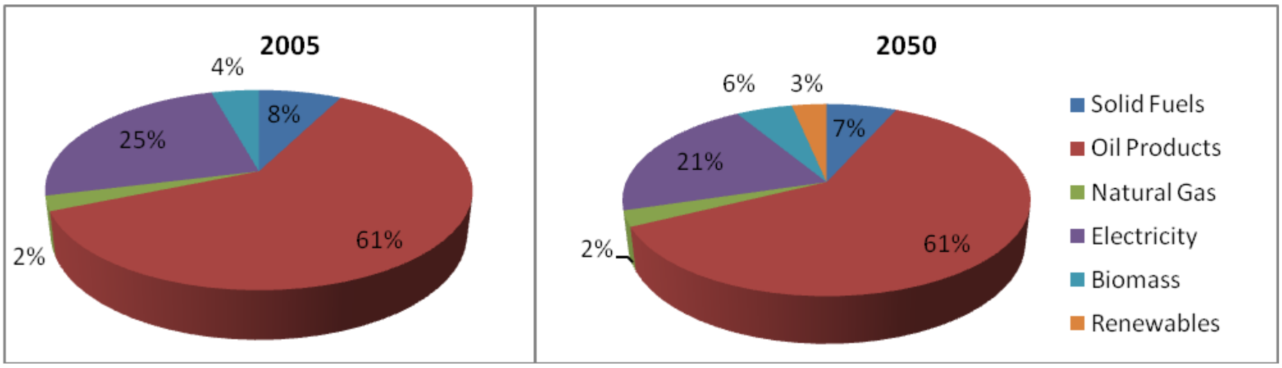


Figure 5.6: Change in composition of energy source from 2005 to 2050 for the BAU scenario

Emissions in the national LTMS Current Development Plans increase about 3.2 times from the base year to 2050, which is a similar to the 3.5 times increase in the BAU Scenario. The reason for the similarity between the two scenarios is that the EMES is based on national energy efficiency and renewable energy targets.

Many other global and local scenarios have also developed BAU Scenarios to allow for a comparison with other development paths that include mitigation measures. On a global level the EIA and IEA Reference Scenario is also based on the assumption of a continuation of existing government policies into the future. By 2035, emissions in these scenarios increase 1.6 times from the base year (EIA, 2009 and IEA, 2008a). Similarly, the BAU scenario increases 1.8 times the base year level by 2035.

On a local level this scenario can be compared with other BAU Scenarios, such as Mexico City, London, New York City, Milan, California and Bangkok, as shown in Table 5.1. Table 5.1 illustrates the increase in emissions from the base year of the various cities to the target year in each case. The table also shows the normalised percentage increase in CO_2e emissions, where the values have been normalised assuming a constant increase over the period so that they are directly comparable with the values for Durban. The target year for each city differed, therefore the increase in emissions for the various years was calculated for Durban. The increase in emissions from the base year to the target year is much greater in Durban in comparison with Milan, London, New York City and California, whilst the increase is very similar to the BAU Scenarios for Bangkok and Mexico City. This illustrates that even if existing targets are met, Durban is still far behind in reducing emissions as opposed to developed cities, whilst Durban's BAU emissions are similar to other developing cities. This is because the rate of urbanisation is more rapid in developing countries as opposed to developed countries. Furthermore, developed countries have only recently begun developing climate mitigation strategies (Croci *et al.*, 2009), whilst developed country strategy targets are far higher.

Table 5.1: Estimated BAU emission increases for other cities in comparison to that of Durban's BAU Scenario using a base year of 2005

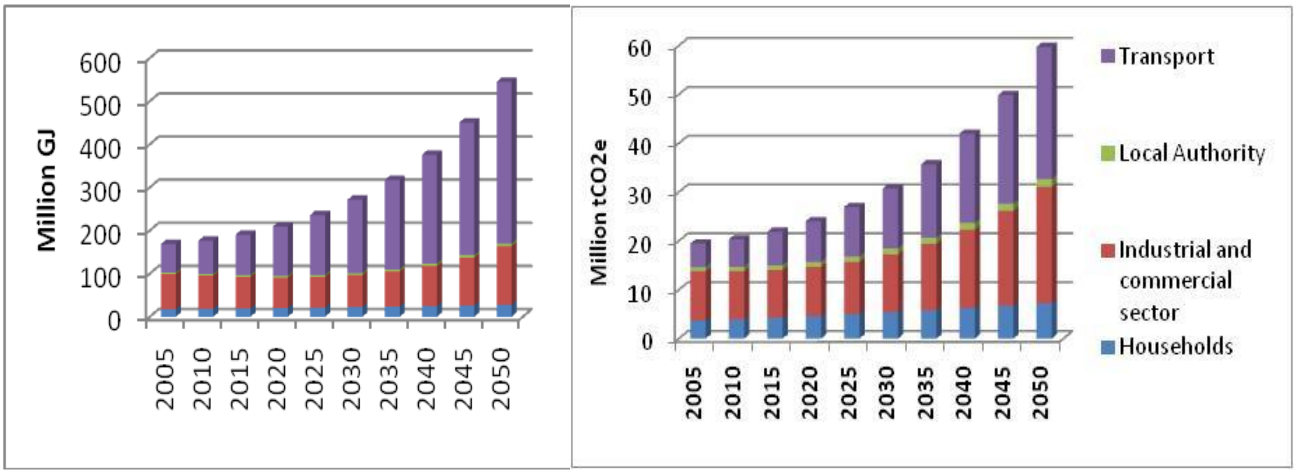
City	Base Year	Target Year	% Increase in CO_2e emissions	Normalised % increase in CO_2e emissions	% Increase in Durban's CO_2e for the relevant target year

Mexico City (Croci *et al.*, 2009)	2000	2012	11 low 25 medium 35 high	6 15 20	12
Milan (Croci *et al.*, 2009)	2005	2020	8	8	28
New York City (Bloomberg, 2007)	2005	2030	27	27	79
California (Ghandan and Koomey, 2005)	2000	2035	81	69	110
Bangkok (Phdungsilp and Dhakal, 2009)	2005	2012 2050	~14 ~240	14 240	12 250

5.4 Natural Transition City

The Natural Transition City assumes that municipal involvement in the city is reduced and that the economy is left to free markets. As a result the city moves towards a post-industrial economy, with a decline in the manufacturing sector and an increase in the service sector. The most significant difference between this scenario and the BAU Scenario is the structural change in the industrial and commercial sector and a lack of implementation of existing policies and strategies, due to minimal government involvement. The city's GDP increases to 4.5 times that of the base year value to R525.9 billion. The city's population increases to 5.1 million people and the number of households increases to 1 153 thousand households. The number of people per household increases from 4 to 4.4 people, as a result of an increase in informal settlements and structural job losses in the economy.

The energy consumption and GHG emissions increase as a result of an increased population, growth in the transportation sector and GDP growth. Energy consumption increases from 168.91 million GJ to 545.13 million GJ, which is 3.2 times more than the base year value (Fig. 5.7). CO_2e emissions also increases from 19.46 million tCO_2e to 61.15 million tonnes CO_2e, which is a 3.15 times increase. The sectoral contribution to CO_2 emissions, changes in this scenario, such that the transport sector



becomes the highest energy consumer by 2010 and the highest CO_2e emitter by 2030. By 2050, the transport sector contributes 44% to total emissions and the industrial and commercial sector contributes 41%, as shown in Figure 5.8. This is due to the changing structure of the economy and an increase in the energy demand in the transport sector primarily due to urban sprawl and also growth in marine and air transport. Furthermore, there is minimal improvement in public transport for this scenario, and therefore an increase in private vehicles usage increases emissions. The household sector's contribution to total emissions also decreases from 19% to 12% by 2050, which is as a result of an increase in the number of informal settlements and low income households in this scenario, where energy consumption is low, due to low income levels (Winkler, 2009).

Figure 5.7: Energy consumption (Million GJ) and CO_2e emissions (Million tCO_2e) by sector for the Natural Transition City from 2005 to 2050

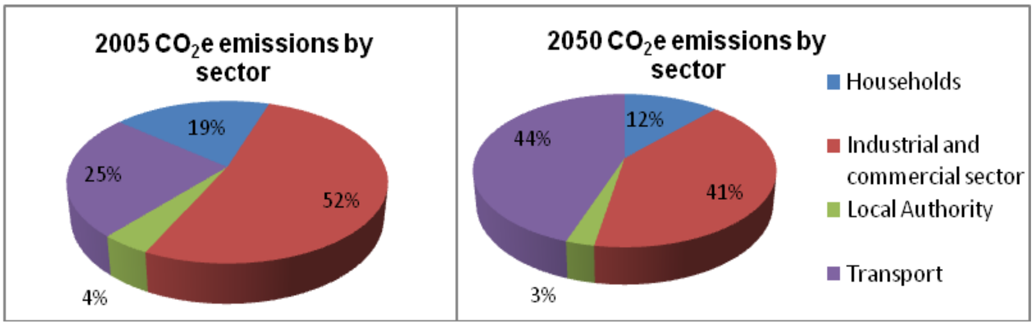


Figure 5.8: Change in the sectoral contribution to GHG from 2005 to 2050 for the Natural Transition City

The dominant energy sources in the Natural Transition City are oil products, which provide 76% of total energy by 2050. This is followed by electricity, which provides 21% of total energy by 2050. However, the highest contributors to CO_2e emissions are both oil products and electricity, due to the high emissions factor of electricity in South Africa (Fig. 5.9). There is a decrease in demand for solid fuels, due to a decline in the manufacturing sector, which is the largest consumer of coal. Natural gas remains about constant during the 45 year timeframe.

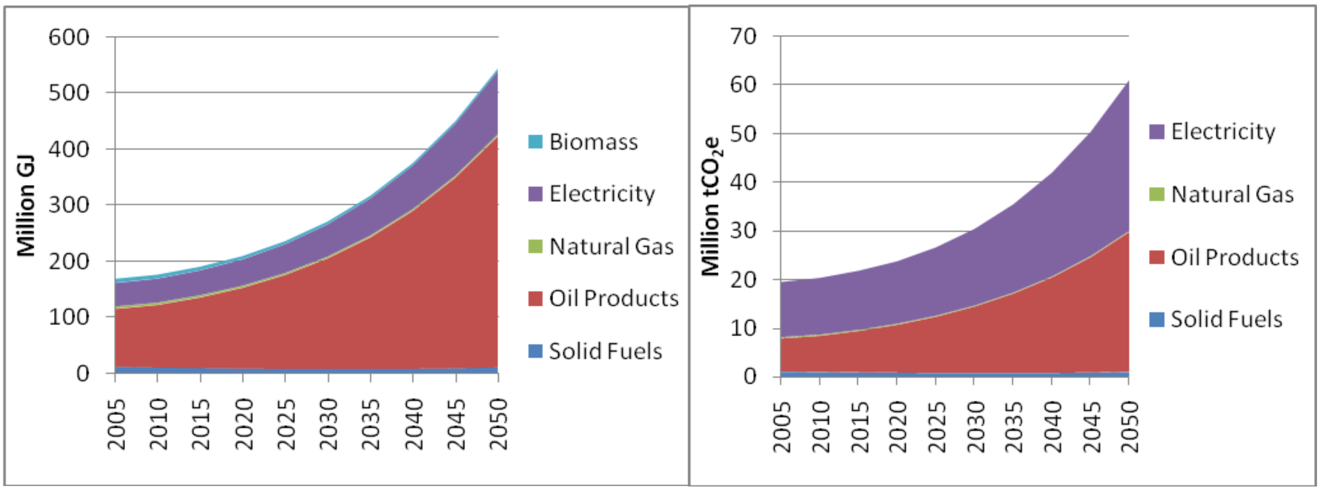


Figure 5.9: Energy demand (Million GJ) and CO_2e emissions (Million tCO_2e) by fuel type from 2005 to 2050 for the Natural Transition Scenario

The most significant difference between this scenario and the BAU Scenario is the structural change in the economy from a manufacturing economy to a service economy and an increase in the percentage contribution of the transport sector. The manufacturing sector is more energy intensive, requiring more energy per unit GDP output, compared to the commercial and service sector which requires less energy to produce the same quantity of GDP. Figure 5.10 illustrates the change in CO_2e emissions in the manufacturing and commercial sectors from 2005 to 2050. Whilst the manufacturing sector was the highest contributor to emissions in 2005, emissions from this sector decline slightly by 2050, resulting in a simultaneous decline in the amount of energy demanded from the various fuel and/or energy types. As a result, the demand for coal, refinery feedstocks, HFO and MRG also declines. Emissions from the commercial sector increase 5 times from the base year, as a result of rapid growth in the service, ICT and tourism sectors. The main energy source in this sector is electricity, followed by LPG, which is used in hotels and restaurants, and lastly coal.

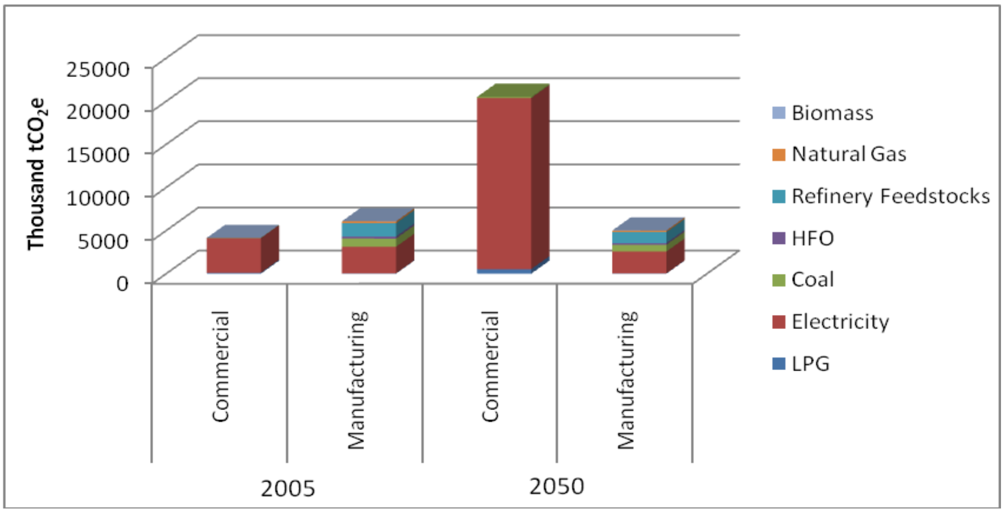


Figure 5.10: Comparison between 2005 and 2050 CO_2e emissions (Million tCO_2e) for the commercial and manufacturing sector in the Natural Transition Scenario

The transport sector becomes the largest contributor to energy demand and CO_2e emissions by 2050. Figure 5.11 illustrates the changes in emissions in the transport sector from 2005 to 2050 by sector and fuel type. The dominant fuels in this sector are diesel and gasoline and the dominant emitter is the road transport sector. Emissions from road transport increase 460% from the base year, while emissions from air and marine transport increase 890% from the base year. While the increases in emissions for air and shipping are higher than road transport, their total emissions remain insignificant, as they contribute only 2% to total emissions. Therefore, even if emissions from the air and shipping sector increase to ten times that of the base year value, they will still not be as significant as emissions from the road transport sector for Durban.

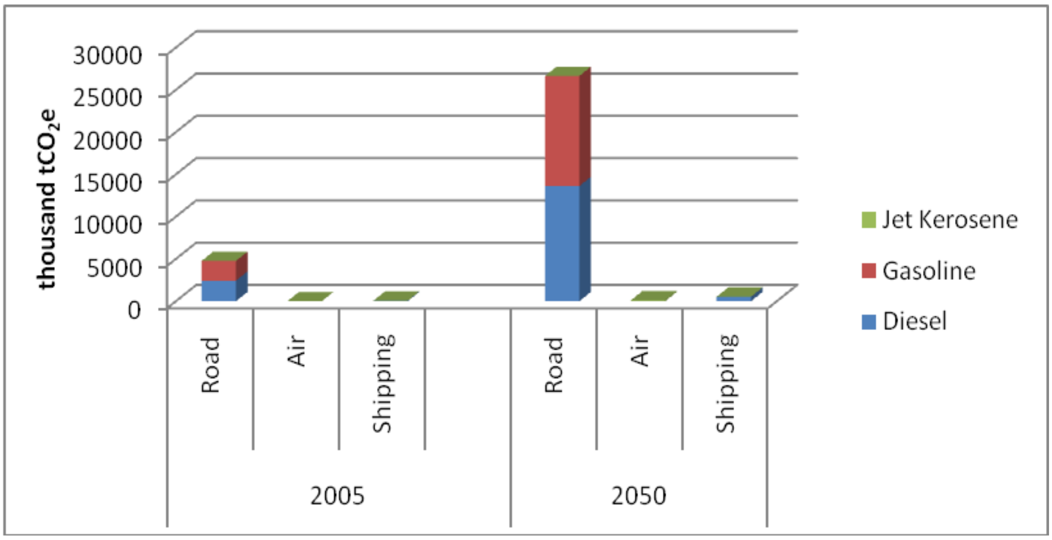


Figure 5.11: Comparison between 2005 and 2050 CO_2e emissions (thousand tCO_2e) for the transport sector, by subsector and fuel type

While this scenario does not have close similarities with other global and local scenarios, it does have some commonalities with the WEC Giraffe Scenario, in that both scenarios assume a low level of government intervention and high levels of global integration. However, the Giraffe Scenario assumes high levels of technological change, whilst the Natural Transition City assumes minimal technological change. Furthermore, the Giraffe storyline assumes that environmental awareness is improved regionally and locally, whilst the Natural Transition City assumes that environmental concerns are not prioritised (WEC, 2007).

5.5 Slow Go City Scenario

The Slow Go City Scenario assumes that the city is slow to administer mitigation measures for climate change, and instead focuses on promoting economic development in all sectors. However, by 2015 oil and other fossil fuel prices increase, including electricity and a series of climate change related disasters, making it vital for the city to use alternate energy sources and reduce emissions by becoming more energy efficient. This has an impact on economic growth, which grows rapidly by 62% to R186.7 billion, by 2015, and then grows at a slower rate as the economy is impacted on by high fuel costs and implementing efficiency measures and technological improvements. By 2050, the GDP of the city is R537.6 billion, which is five times the base year value. The population increases to 5.1 million people by 2050 and the number of households increases to 2 million. The provision of jobs in the economy and improved municipal service delivery reduces the number of people per household to 2.5.

The energy consumption and GHG emissions in this scenario increases approximately 2.5 times the base year value, as a result of more efficient use of energy (Fig. 5.12). The main difference in the sectoral contribution to emissions is that there is a slight decline in the percentage contribution to CO_2e emissions from the transport sector, from 25% to 20%. This is due to the increased energy efficiency and use of public transport in the transport sector as fuel prices increase. The percentage contribution to CO_2e emissions in the industrial and commercial sector increases from 52% to 55%, because of high economic growth rates and an initial slower response to climate change mitigation.

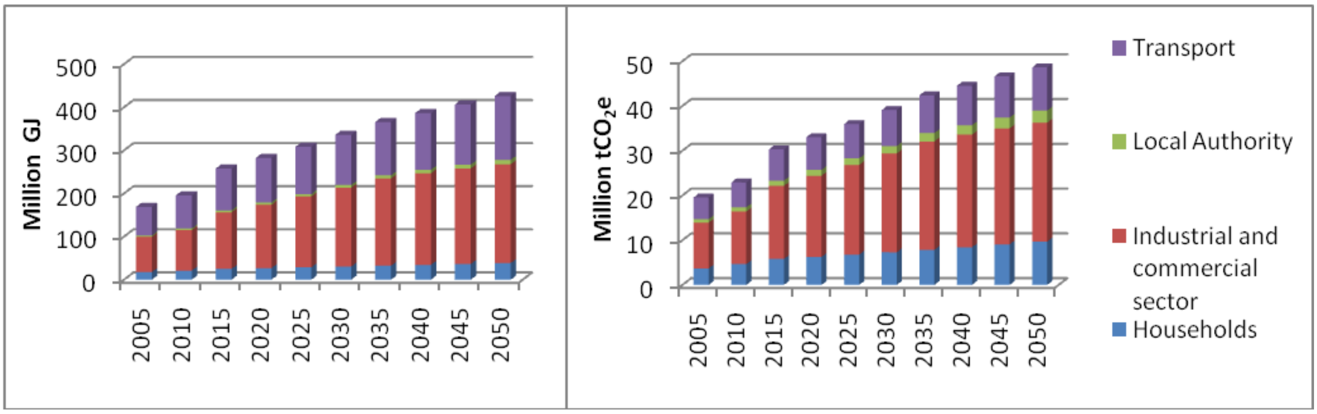


Figure 5.12: Energy consumption (Million GJ) and CO_2e emissions (Million tCO_2e) by sector for the Slow Go City from 2005 to 2050

Figure 5.13, which shows the energy demand and CO_2e emissions by energy source or fuel type, illustrates that the dominant energy source is still oil products by 2050, followed by electricity. Energy demand and CO_2e emission increase at a higher rate from 2010 to 2015, as a result of rapid economic growth (Fig. 5.13). This growth slows down thereafter and there is an increase in renewable energy sources and biomass. Energy from biomass and renewable energy make up 12% of total energy supply by 2050 and the contribution of natural gas increases from 2% to 6%. This is as a result of industries switching from coal and heavy fuel oil to natural gas, which has a lower emissions factor. Oil products usage decreases from 61% to 40%. The consumption of coal also decreases from 8% to 6% of total energy supply.

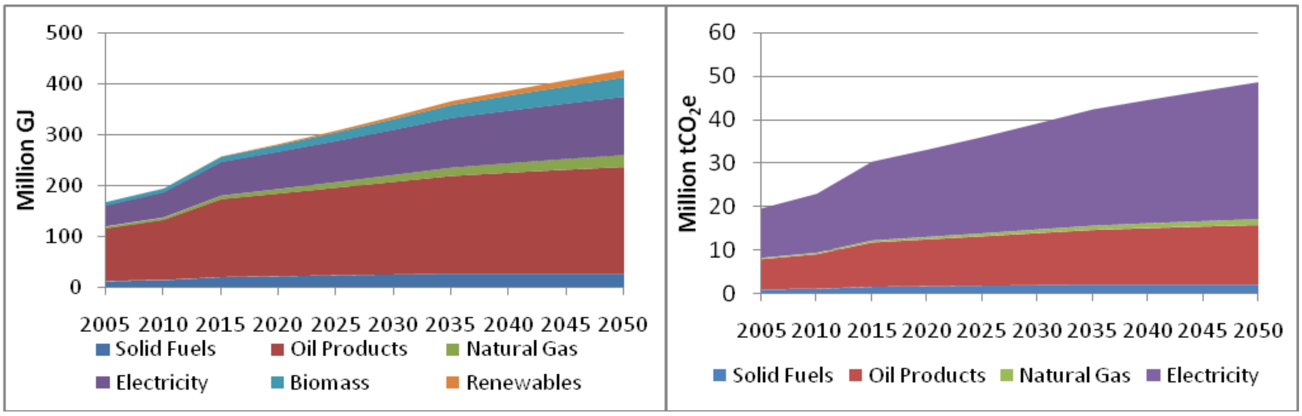


Figure 5.13: Energy consumption (Million GJ) and CO_2e emissions (Million tCO_2e) by energy type for the Slow Go City from 2005 - 2050

5.6 Low Carbon City

In this scenario, the city is quick to respond to climate change mitigation, as a result of global and national policies and targets. In addition to this, high costs of fossil fuels and electricity and taxes and incentives make it useful for the city to reduce emissions. As a result, GDP growth is slower in comparison to the other scenarios, and GDP increases 3.3 times from the base year by 2050. Population grows from 3.3 million in 2005 to 3.6 million in 2020, but then declines to 3.2 million in 2050. Therefore, annual income per person increases from R35 000 per person to R120 000 by 2050. The number of households grows to 1.07 million, therefore the number of people per household decreases to 3 people per household.

A result of immediate climate change mitigation, energy consumption and CO_2e emissions decline until 2020. Total emissions by 2025 are 15% less than the base year and total energy demand declines 6%. Thereafter energy demand and emissions begin to increase at a slow rate, as urban development outpaces carbon mitigation measures. Therefore, while efficiency is improving and there is an increase in the use of renewable energy, the city is also expanding and requiring more energy. By 2050, emissions are 1% less than the base year, at 19.45 million tCO_2e. Although, the industrial and commercial sector remains the highest emitter, emissions from this sector decline from 10.2 million tCO_2e to 8.9 million tCO_2e. Furthermore, emissions from the household sector increase from 3.7 million tCO_2e to 4.4 million tCO_2e as people become wealthier and demand more energy for the use of appliances (Fig. 5.14).

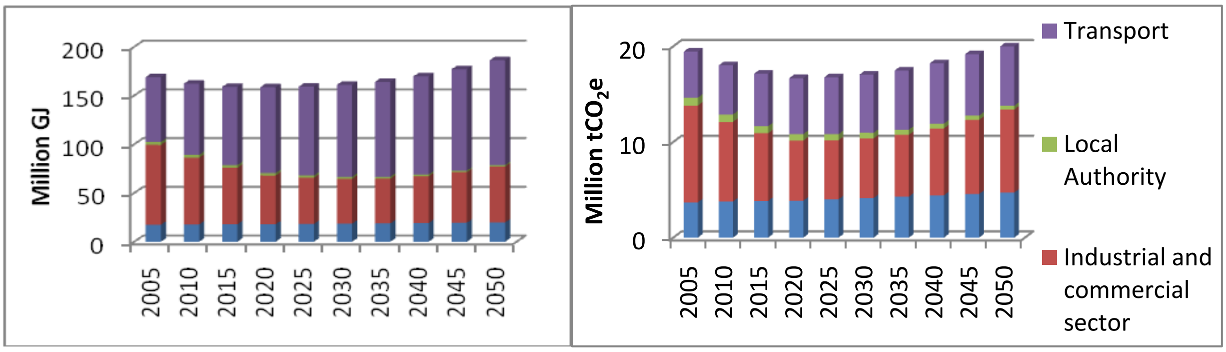


Figure 5.14: Energy demand (Million GJ) and CO_2e emissions (Million tCO_2e) for the Low Carbon City from 2005 to 2050

By 2050, the main energy source is still oil products; however, there is a slight decline in the consumption of oil products from 103.4 million GJ to 97.6 million GJ (Fig. 5.15). Electricity demand declines until 2020, and then slowly increases until 2050. Usage of solid fuels declines considerably from 12.7 million GJ to 1.8 million GJ in 2050. The quantity of renewable energy and biomass increases from 7.3 million GJ in 2005, to 36.3 million GJ and makes up 20% of total energy supply, by 2050. Electricity remains the highest CO_2e emitter, making up 65.4% of total emissions (Fig. 5.15). This is followed by oil products which contribute 32.5% to total emissions. Natural gas and solid fuels makes up the remaining 2% of emissions.

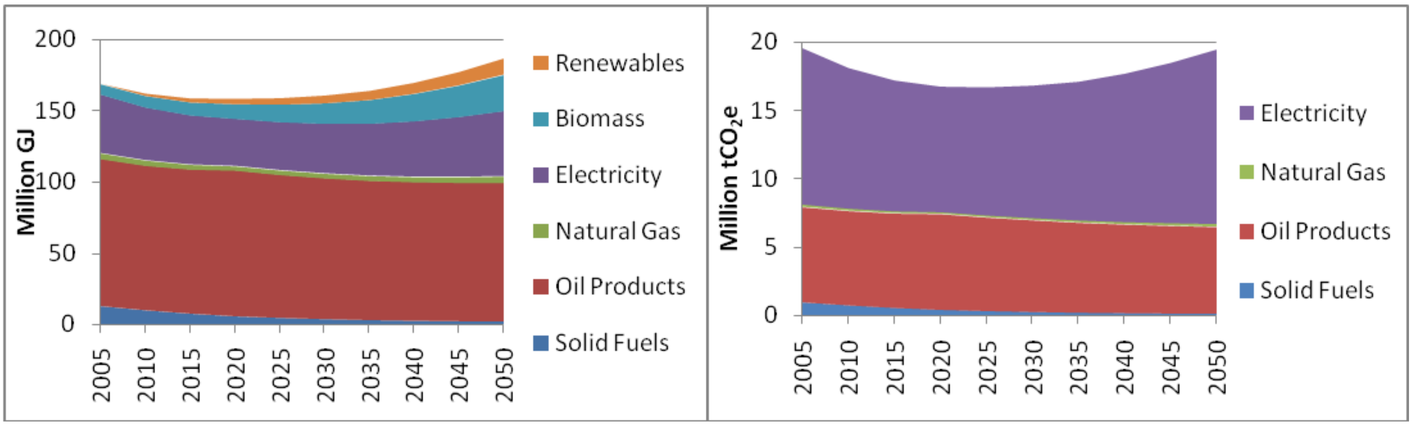


Figure 5.15: Energy consumption (Million GJ) and CO_2e emissions (Million tCO_2e) by fuel type for the Low Carbon City Scenario from 2005 to 2050

Many developed cities and some developing cities have begun implementing climate action plans, which set out reduction targets to become low carbon cities. Table 5.2 shows the carbon reduction targets set by some developing cities and other developed cities in comparison to the reduction in Durban's emissions if it follows the Low Carbon City development path. The table also shows the normalised percentage increase in CO_2e emissions, so that they are directly comparable with the values for Durban. The reduction targets in both the developed and developing cities are higher than Durban's reductions. New York City's reduction targets are way above the reductions in the Low Carbon City, whilst the reductions for Bangkok, which is considered a developing city, are closer to the Low Carbon City. This means that by achieving a 50% improvement in energy efficiency, increasing the use of renewable energy to 20% of the energy supply and changing the structure of the economy to reduce manufacturing, will still not be sufficient to reduce emissions to a level that is comparable with other cities globally. To allow for economic growth, more changes will be required to ensure a reduction in emissions.

One major difference between Climate Action Plans of other cities and Durban's Low Carbon City Scenario is their major reductions in emissions due to improvements in the energy supply (Bloomberg, 2007, Mayor of London, 2007 and Tokyo Metropolitan Government, 2007). Durban in this scenario, remains dependent on electricity from the national grid, and does not have control over the emissions as a result of independent electricity generation. One way of overcoming this is to promote a decentralised energy supply as proposed for London, which is opting to move away from a centralised energy to localised energy source, where excess heat can be used for heating and cooling (Mayor of London, 2007).

Table 5.2: Comparison between other cities emission reduction targets from base year to target year and Durban's Low Carbon City emissions from 2005 to indicated target year

City	Base Year	Target Year	Reduction Target (from base year)	Normalised increase in CO_2e emissions	% Decrease in Durban's emissions
Milan (Croci *et al.,* 2009)	2005	2020	-20%	-20%	-14%
Tokyo (Tokyo Metropolitan Government, 2007)	2000	2020	-25%	-19%	-14%
New York City (Bloomberg, 2007)	2005	2030	-30%	-30%	-14%
Bangkok (Croci *et al.,* 2009 and Phdungsilp and Dhakal, 2009)	2005	2012	-15%	-15%	-10%

5.7 Comparison of scenarios

The purpose of this study was to determine the implications of various development paths for the city of Durban on future emissions. Five main scenarios were developed based on different assumptions for the selected drivers of emissions. Figure 5.16 shows the CO_2e emissions for the different scenarios, including the RBS Scenario from 2005 to 2050.

If the city has to follow high levels of economic and population growth, with no implementation of climate change mitigation, emissions will increase 6 times the base year value (GWC Scenario). This is followed by the BAU Scenario, which depicts a development path based on existing policies and strategies, where emissions will increase 3.5 times the base year. While this is much lower than the GWC development path, the increase is still high in comparison to other cities' BAU Scenarios, such as London and New York City. The Natural Transition Scenario was developed to illustrate the impacts of a structural change towards a post-industrial society, with no mitigation of emissions. Emissions were lower than the BAU Scenario, therefore illustrating that structural change does play a significant role in reducing emissions. However, rapid structural change can also result in job losses, increasing the rate of structural unemployment and poverty in the city (OECD, 1994).

The Slow Go City describes a development path that is initially slow to respond to climate change mitigation, but makes significant changes at a later stage as a result of climate change disasters and high fossil fuel prices. Emissions peak in 2015 at a higher level than the BAU Scenario, as a result of high economic growth and no climate change mitigation. Emissions in this scenario are 42% less than the BAU Scenario by 2050, with no changes in the structure of the economy. This scenario illustrates that emissions can be reduced, whilst promoting growth in the manufacturing sector.

The Low Carbon City illustrates a development path with a lower economic growth rate, a transition to a service economy, increases in energy efficiency and in the consumption of renewable energy and a decline in population growth rates. As a result, emissions in 2050 are 1% less than the base year's emissions and are equivalent to a 50 million tCO_2e reduction from the BAU emissions. The Low Carbon City emissions are still higher than the RBS, which assumes a 40% reduction from the base year. In order to achieve a RBS emission level, emissions need to peak in 2020 at 20.6 million tCO_2e and then decline to 11.74 million CO_2e by 2050. According to the LTMS, to achieve this target in South Africa, would be too costly using existing technologies and would require the emergence of new technologies in the future (SBT, 2007).

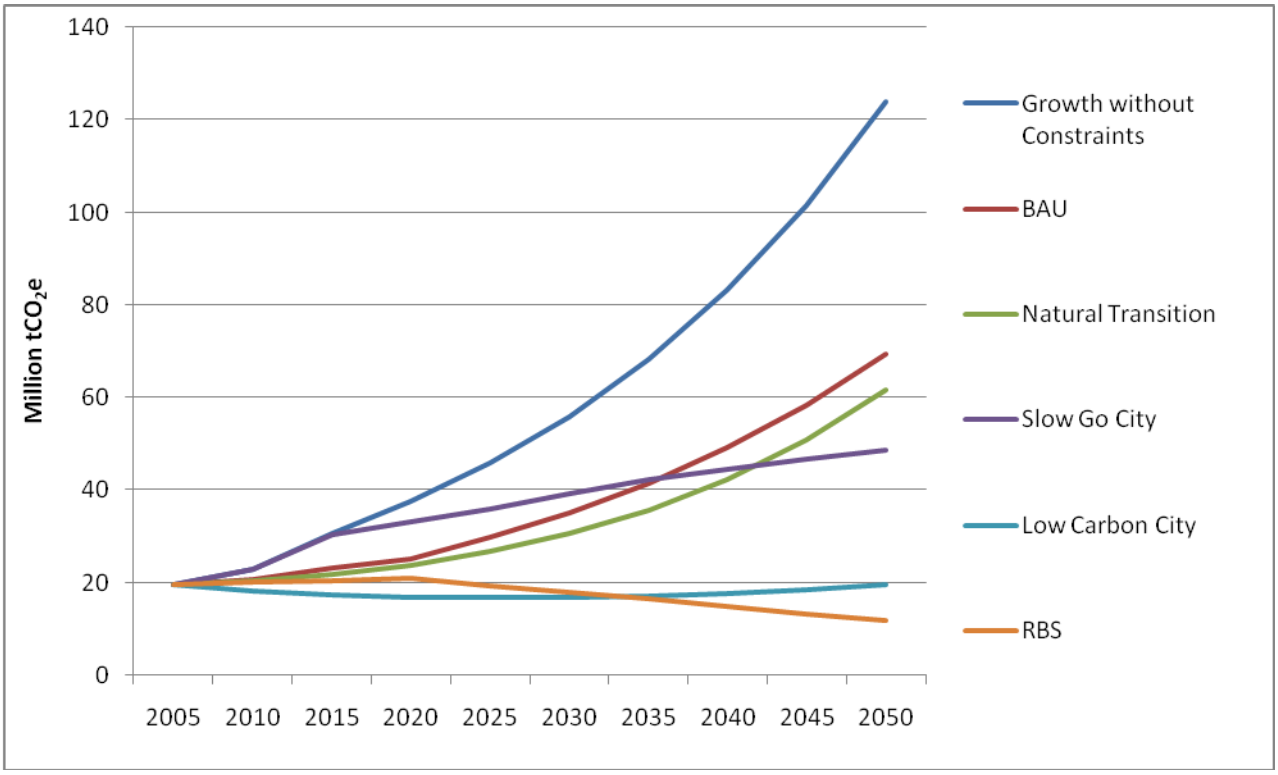


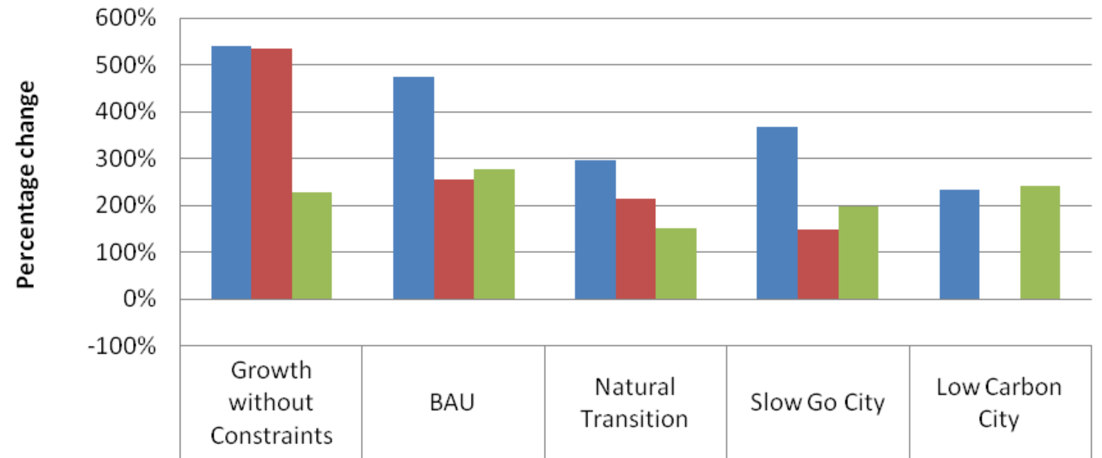
Figure 5.16: Comparison of CO_2e emissions (Million tCO_2e) for the different scenarios from the base year to 2050

5.7.1 *GDP, income per capita and CO_2e emissions*

Whereas GDP growth is considered a major driver of CO_2e emissions, it is possible to reduce emissions in a growing economy by changing other drivers of emissions. The GWC Scenario assumed that all other factors influencing emissions remained fixed and therefore the increase in GDP followed a similar path as an increase in CO_2e. Therefore, while GDP is the highest for this scenario, it results in a similar increase in emissions. This is similar to Turkey's scenarios, which were developed based on different levels of economic growth, due to a strong correlation between economic growth and emissions (Say and Yucel, 2006). Furthermore, the increase in income per capita is lower than the increase in GDP and CO_2e emissions due to a high rate of population growth. The BAU Scenario results in a high increase in GDP, with a smaller increase in emissions. Whilst GDP increases 474%, emissions increase 255%, which is due to energy efficiency improvements and renewable energy use in the city (Fig. 5.17). This scenario also has a high increase in income per capita.

The Natural Transition Scenario is the least beneficial path to pursue in terms of income per capita, which increases 153% from the base year. Further, a 295% increase in GDP in this scenario results in a 215% increase in emissions. The Slow Go City results in a 367% increase in GDP per capita, whilst CO_2e emissions increase 148% and income per capita increases 199%. This illustrates that this scenario will be efficient to pursue. Lastly, the Low Carbon City has a lowest increase in GDP at 234%; however emissions actually decline 1% and income per capita increases 241%. The income per capita is the second highest, following the BAU Scenario.

The comparison between GDP growth, income per capita and CO_2e emissions illustrates that in some cases GDP growth might not be beneficial to improving per capita income. For example, a higher per capita income may be achieved by pursing the Low Carbon City, which has the lowest GDP and a slight decrease in emissions, in comparison to the GWC Scenario, which has the highest GDP and CO_2e emissions but the only third highest increase in income per capita.



	Growth without Constraints	BAU	Natural Transition	Slow Go City	Low Carbon City
GDP	540%	474%	295%	367%	234%
CO2e emissions	534%	255%	215%	148%	-1%
Income per capita	227%	277%	153%	199%	241%

Figure 5.17: Percentage change in GDP, CO_2e emissions and income per capita from 2005 – 2050 for all scenarios

5.7.2 *Population and households*

Although population plays a role in driving emissions in the city of Durban, it is not as significant as GDP growth. This is because the highest emissions in the city are from the industrial and commercial sector, where population growth is not a significant driver. By 2050, the GWC Scenario has the highest population, number of households and CO_2e emissions in the household sector and the lowest number of people living per household (Fig. 5.17 and Table 5.3). The rapid growth in this scenario results in an increase of emissions from 3.7 million tCO_2e to 26 million tCO2e. The main reason for this growth is an increase in income and households and therefore people are using more electrical appliances. Furthermore, the number of people living per household has declined the most in this scenario, which according to Winkler (2009), increases the overall demand for energy.

The sector with the second highest emissions is the Slow Go City, with emissions increasing 162% from 2005 to 2050. The reason for this increase is due to high growth in the number of households in the city to approximately two million homes in 2050, mainly as a result of efficient municipal provision of housing. The BAU and Natural Transition Scenarios result in a similar emissions path, but for different reasons. The BAU Scenario experiences moderate population growth, but a higher increase in the number of households in the city. A growth in the number of households increases the demand for energy, even though there is an improvement in energy efficiency in this sector. The Natural Transition Scenario experiences energy efficiency improvements and a higher increase in population in comparison to the BAU Scenario, however the number of households increases at a slower rate. As a result the household emissions for both scenarios are almost the same. The Low Carbon City achieves the lowest increase in emissions, which increases 19% from 2005 to 2050. This is as a result of a slow increase and thereafter a decline in the city's population, which results in a smaller increase in the demand for housing. Furthermore, improvements in energy efficiency and the use of renewable energy also reduces the growth in future emissions for this scenario.

Therefore, the number of households in the city plays a major role in the growth of emissions in the household sector. However, if existing households implement small measures to reduce energy consumption and if future housing projects are designed to ensure energy efficiency (Tokyo Metropolitan Government, 2007), by including good insulation, solar water heating and housing architecture that would use natural energy, it is possible to develop new homes without significantly increasing emissions in the household sector.

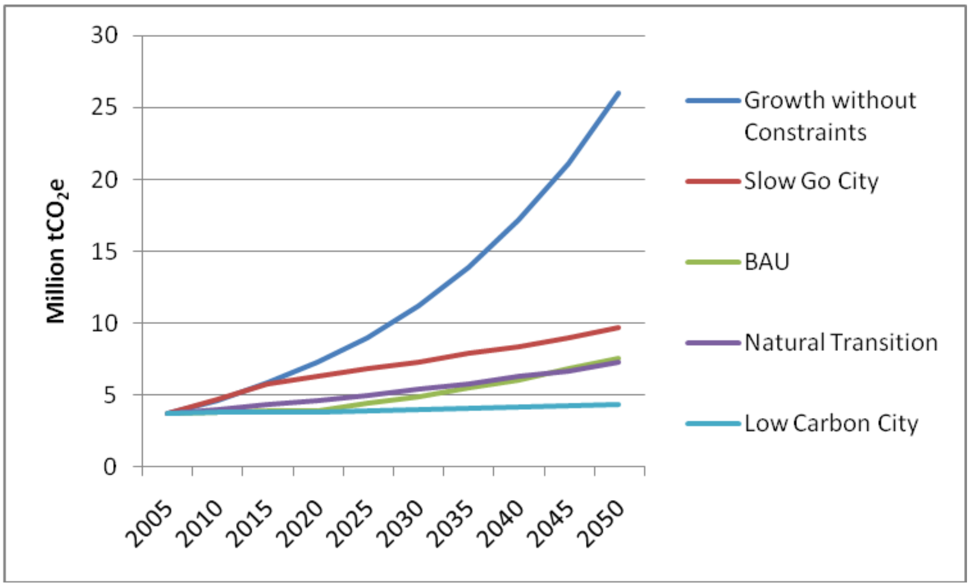


Figure 5.18: Household total CO_2e emissions (Million tCO_2e) from 2005-2050 for all scenarios

Table 5.3: Household emissions and drivers of household emissions

	2005	**2050**

	Base Year	GWC	Slow Go City	BAU	Natural Transition	Low Carbon City
CO_2e emissions for the household sector (million tCO_2e)	3.7	26.0	9.7	7.6	7.3	4.4
Population (thousands)	3267.3	6384.9	5112.6	4970.0	5112.6	3200.0
Number of households (thousands)	823.7	3114.9	2008.1	1609.7	1152.9	1070.0
Number of people per household	3.97	2.05	2.55	3.09	4.43	2.99

Household sector emissions in London are projected to increase approximately 18% by 2025 if no mitigation measures are implemented (Mayor of London, 2008). Durban's GWC Scenario experiences a 143% increase in household emissions during the same period. The reason for the large difference between projected emissions for Durban and London is due to the large increase in number of households and population for the Durban GWC Scenario and because Durban is a developing city. Cities in developing countries are growing at a faster rate than cities in industrialised countries, which results in an increase in developing cities' demand for energy (Jollands, 2008). However, the increase in household emissions for London is similar to Durban's BAU scenario, which experiences a 19% increase in emissions from 2005-2025.

5.7.3 *Fuel mix*

According to Winkler and Marquard (2007), changes in the fuel mix on the energy supply side can only happen over the long term due to power stations and refineries having a life-span of a few decades. Therefore, electricity and oil products remain the dominant energy sources for all scenarios, as shown in Table 5.4 and Figure 5.19.

Table 5.4 shows the actual change in energy demand for the various energy types for the different scenarios in comparison to the base year. Figure 5.19 shows the percentage contribution of the different energy types to the total energy supply. Oil products, comprising petrol, diesel, refinery feedstocks, HFO and LPG, are the largest energy source for all scenarios. An increase in demand for oil products is the greatest for the GWC Scenario and the smallest for the Low Carbon City. The large increase in the GWC Scenario is due to rapid growth with no restraints on liquid fuel, whilst the decline in demand for oil in the Low Carbon City is as a result of mitigation measures and high fuel costs. Oil products contribute approximately 60% to total energy supply for the base year and the GWC and BAU Scenarios (Fig. 5.19). This is because the GWC and BAU Scenarios are based on current trends. The Natural Transition Scenario shows an increase in the percentage contribution of oil products to 75% of total energy supply, which is due to a sprawling city that increases the demand for fuel for transport and as a result of a constant supply of oil products and no climate change mitigation. Oil products decline to 50% of energy supply in the Slow Go City as a result of high fuel prices and an increase in fuel efficiency and the use of alternative energy sources.

Table 5.4: Change in quantity of energy type demand from 2005

Energy Source (Million GJ)	2005 Base Year	2050				
		GWC	BAU	Natural Transition	Slow Go City	Low Carbon

						City
Oil Products	103.4	604.7	402.1	412.7	209.6	97.6
Electricity	41.5	274.7	138.5	112.5	114.1	46.2
Solid Fuels	12.7	81.4	44.1	11.8	26.5	1.8
Natural Gas	4.1	25.8	17.4	3.2	23.5	4.4
Biomass	7.3	35.4	35.4	4.8	38.2	25.4
Renewables	0	0	21.7	0	14.4	10.9
Total	**168.9**	**1022.0**	**659.2**	**545.0**	**426.3**	**186.3**

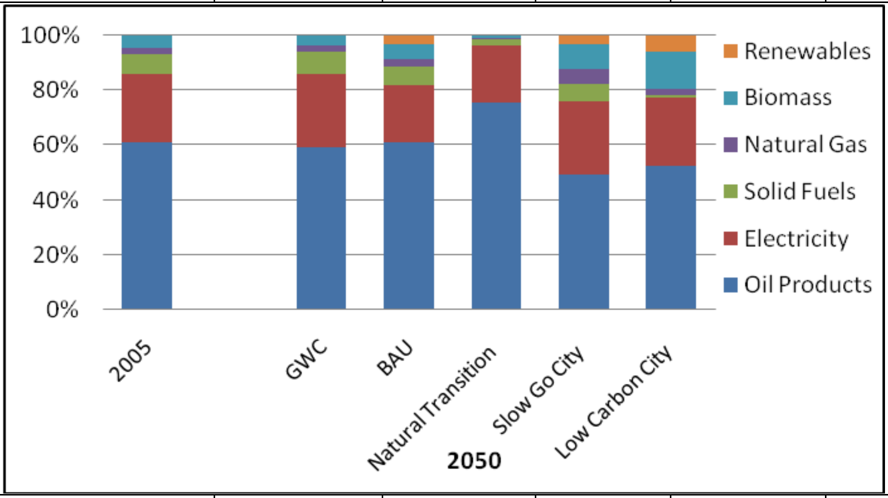
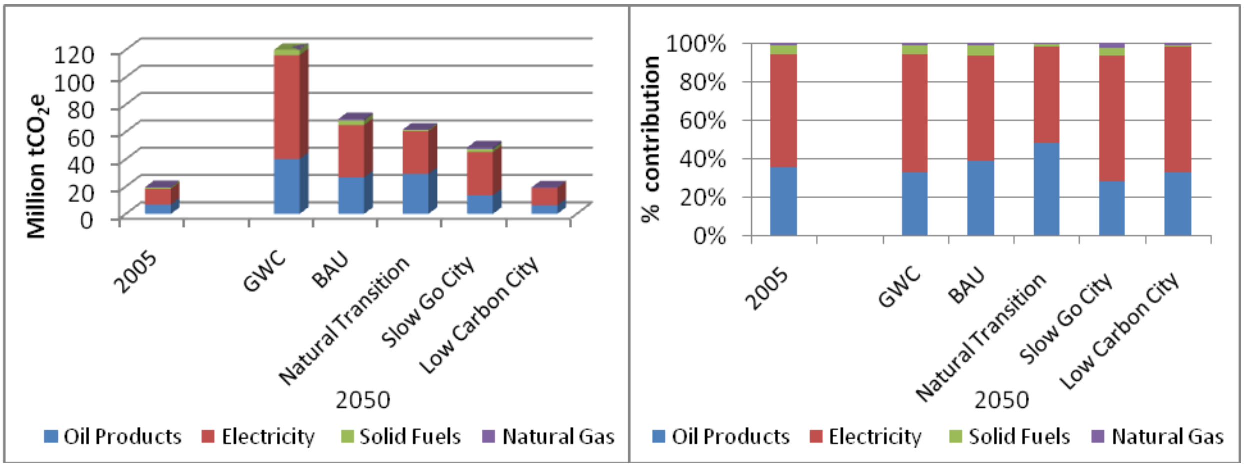


Figure 5.19: Percentage contribution of different energy sources for the different scenarios in 2050, in comparison to the base year (2005)

Electricity consumption increases for all scenarios as the city expands and households are electrified. Whilst electricity's contribution to final energy demand is from 21 – 27% for all scenarios, the rate of increase in demand differs. Solid fuels increase in the GWC, BAU and the Slow Go City, but decline for the Natural Transition and Low Carbon City Scenarios. This is because manufacturing still plays a significant role in the economy for the GWC, BAU and Slow Go City Scenarios and therefore a demand for coal remains, however, the increase in the quantity demanded is the highest for the GWC Scenario where there are no efficiency measures in place and the lowest for the Slow Go City, where there is a bigger improvement in mitigation. The percentage contribution of natural gas increases from 2% of total energy demand in the base year to 6% 2050 for the Slow Go City. This increase is as a result of industries switching to natural gas which is considered a cleaner fuel as opposed to coal. For the other scenarios natural gas remains at approximately 2% of total energy demand.

The contribution of biomass and renewable energy to the total energy supply is the largest in the Low Carbon City, at 20% of total energy supply. It is the smallest in the Natural Transition Scenario as there is a decline in the manufacturing sector that consumes the largest quantity of biomass and there is no demand for renewable energy.

The CO_2e emissions by energy source illustrates that the two main emitters of CO_2e for all scenarios are electricity and oil products, which together comprise over 90% of all emissions for all scenarios (Fig.5.20). Although oil products are the largest energy source for all scenarios, electricity is the highest emitter of CO_2e for all scenarios. Natural gas and solid fuels are the other contributors to emissions, with solid fuels emitting 5% of total emissions and natural gas emitting 1.5% of total emissions. Therefore it would be more important to target electricity and oil energy consumers for mitigation, rather than solid fuels and natural gas, because whilst solid fuels have a high CO_2e



emission factor they do not contribute a significant amount to total emissions.

Figure 5.20: Comparison between CO_2e emissions (Million tCO_2e and percentage) by fuel type for all scenarios from the base year to 2050

5.7.4 *Energy and carbon intensity*

Energy intensity is defined as the amount of energy required to produce a unit of output and carbon intensity is defined as the amount of CO_2e that is emitted per unit of output (DME, 2003). The energy intensity of an economy over time indicates changes in the quantity of energy required to generate a unit of output. Therefore a decline in the energy and carbon intensities over time illustrates an improvement in the energy efficiency of an economy.

Figure 5.21 illustrates the changes in energy and carbon intensity of the different scenarios from 2005 to 2050. The energy and carbon intensity of the GWC Scenario remains constant, due to no changes in the fuel mix, technology or structure of the economy. The energy and carbon intensities for the other scenarios decline. The Low Carbon City shows the largest reduction in energy and carbon intensity and the Natural Transition Scenario shows the smallest reduction. In the Low Carbon City, a combination of energy efficiency improvements, an increase in the use of renewable energy and structural changes in the City, has resulted in a decline in the carbon intensity from 0.17 tCO_2e/R '000 to 0.05 tCO_2e/R '000. The Natural Transition Scenario however does not make any energy efficiency improvements and the result of the reduction in carbon intensity is due to a shift from energy intensive industries to a low energy intensity service economy (Lightfoot and Green, 2001).

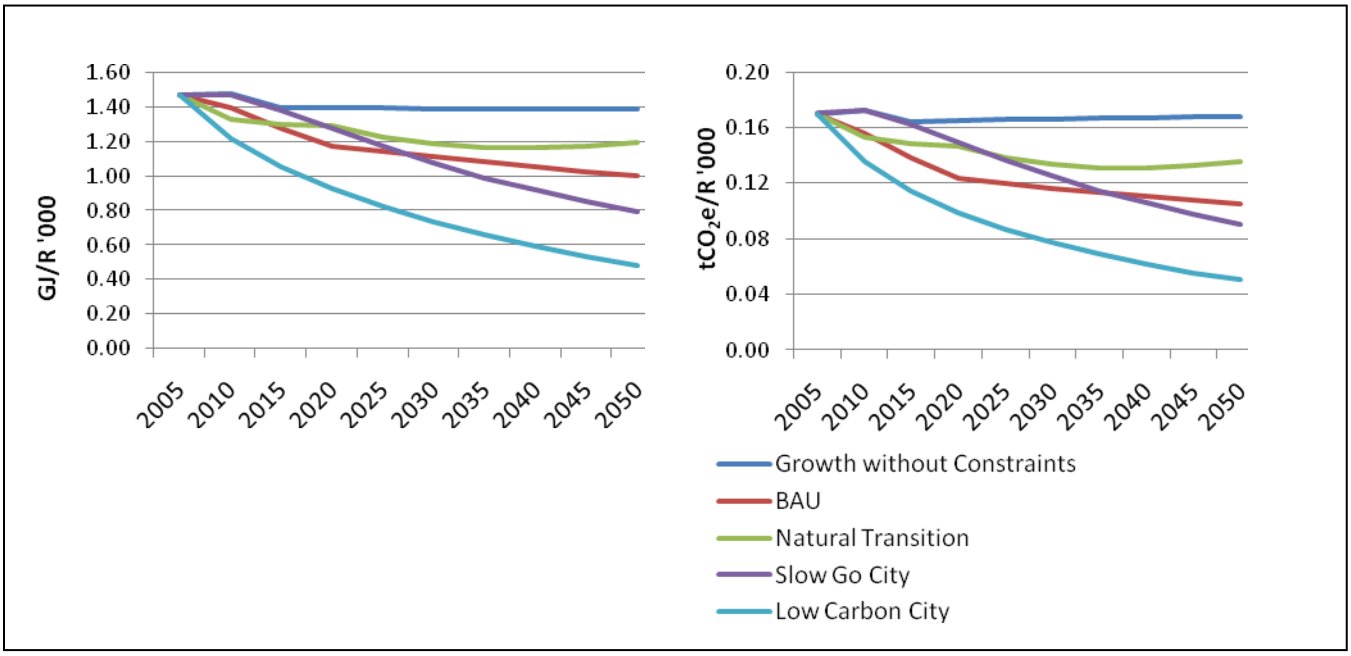


Figure 5.21: Energy (GJ/R'000) and carbon intensities (tCO_2e/R'000) of the different scenarios from 2005 to 2050

According to a study by Lightfoot and Green (2001), structural change in an economy can result in an annual decline in energy intensity between 0.16% and 0.30% from 1990-2100. The Natural Transition Scenario showed an annual average decline of 0.4% from 2005 – 2050. Furthermore the study stated that a combination of structural change and energy efficiency improvements could result in an annual average decline in energy intensity from 1% to 1.1% from 1990 – 2100 (Lightfoot and Green, 2001). The Low Carbon City showed an annual average decline of 1.5% from 2005 – 2050. Although the decline for Durban's scenarios is similar to Lightfoot and Green's global study, the rate of decline for Durban is higher. Possible reasons for a higher rate of decline in energy intensity the Natural Transition and Low Carbon City Scenarios is due to a short timeframe in this study and differences in assumptions for GDP and population growth in the scenarios.

A reduction in the energy intensity over time is prevalent in many economies and in most cases is related to an increase in income (Stern, 2004). For example, global energy intensity fell 0.2% per annum from 2000 – 2005 and the IPCC scenarios predict continued reductions in energy intensity in the 21st century (Fisher *et al.*, 2007, Garnaut, 2008). According to the DME (2003), the energy intensity in South Africa is declining due to a reduction in primary energy intensive sectors such as mining and agriculture. The UK has recorded a decline in the country's energy intensity over the past 30 years (UK Department of Trade and Industry, 2003). Similarly, Bangkok and Shanghai have shown a decline in energy intensity over time (Hammer, 2009 and Phdungsilp and Dhakal, 2009).

5.7.5 *Structural change*

According to Winkler (2008: 132) the "*most fundamental, approach to mitigation is to divert our economy away from its energy-intensive path*." This can be accomplished by investing in low-carbon sectors and shifting away from energy intensive sectors. To illustrate this, the Natural Transition development path was created to illustrate the implication of structural change in the economy with no energy efficiency improvements and the Low Carbon City was developed to illustrate the implication of structural change in addition to energy efficiency improvements and changes in the economies fuel mix.

Figure 5.22 illustrates the energy consumption and CO_2e emissions for the industrial and commercial sector, for the different scenarios. The total energy consumed for the GWC, BAU and Slow Go City Scenarios are higher than the Natural Transition and Low Carbon City Scenarios. Most of the energy demanded in these scenarios is for the manufacturing sector, which is energy intensive. The manufacturing sector makes up 80% of total energy consumed in the GWC, BAU and Slow Go City and 40% of total energy demand for the Natural Transition and Low Carbon City Scenarios. However, in terms of CO_2e emissions the manufacturing sector for the GWC, BAU and Slow Go City makes up 60% of total emissions and in the Natural Transition and Low Carbon City it makes up 20% of emissions. In addition to this, while the energy consumption of the Slow Go City is higher than the Natural Transition Scenario, the CO_2e emissions for both scenarios by 2050 are approximately the same. This implies that although the commercial and service sector has a low energy intensity, the carbon emissions per unit energy consumed is high for this sector, as a result of the sector's dependence on electricity, as shown in Figure 5.23. The carbon emissions per unit of energy consumed in the manufacturing sector is lower because of the high quantity of refinery feedstocks consumed by the oil refineries in Durban, which have a low emission factor in comparison to electricity (Fig. 5.23). Whereas structural change can reduce emissions, it is not as effective when the energy source of the sector that has a low energy intensity has a high carbon intensity per unit of energy consumed. Therefore is it important for structural change to be targeted in conjunction with

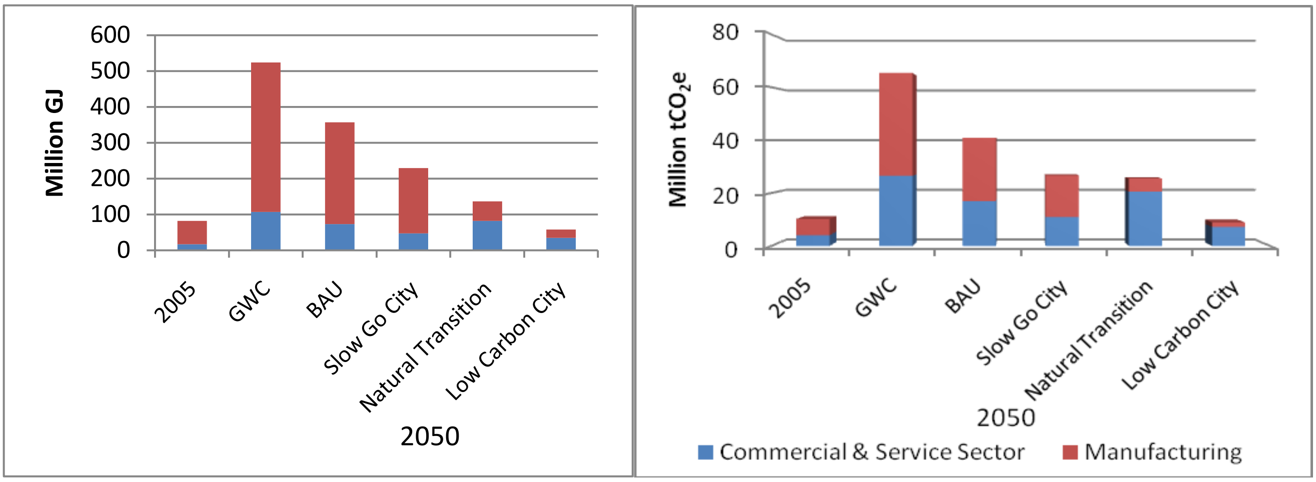


Figure 5.22: Comparison between energy consumption (Million GJ) and CO_2e emissions (Million tCO_2e) for the industrial and commercial sector for all scenarios for 2005 and 2050

energy efficiency and renewable energy goals.

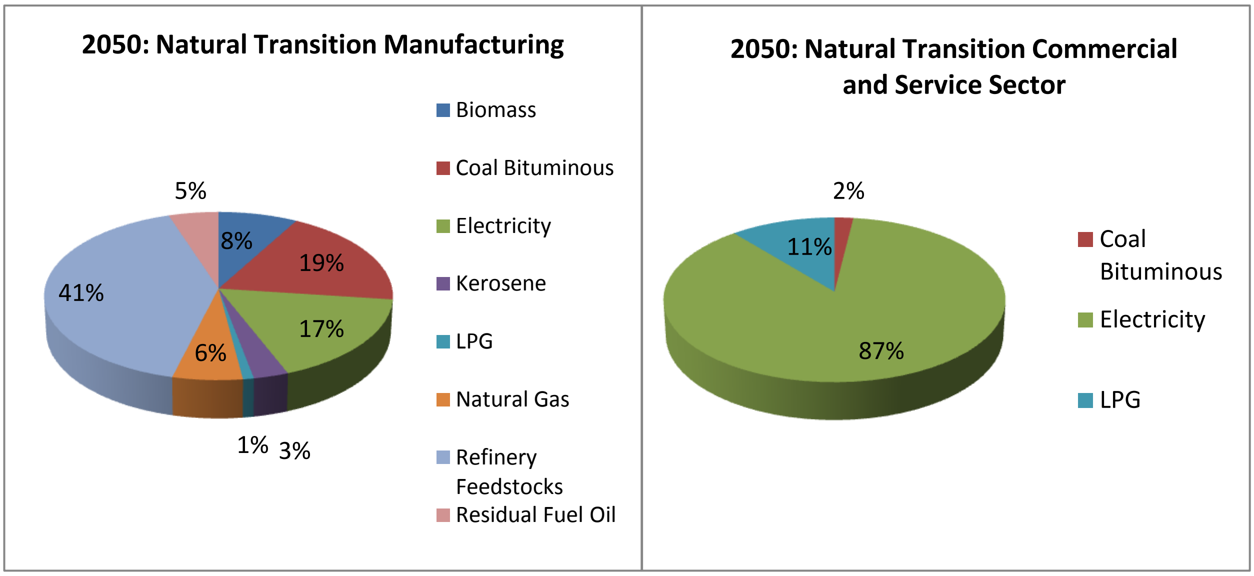


Figure 5.23: Forecasted percentage fuel mix for the manufacturing and commercial and service sectors for the Natural Transition Scenario for 2050

5.7.6 *Summary of drivers and emissions*

Table 5.5 shows a summary of emissions, energy consumption and drivers of emissions for all scenarios in comparison to the base year, most of which have been discussed in the sections above. One of the factors that was not mentioned in previous sections is CO_2e emissions per capita which is calculated based on local energy demand and consumption (Croci *et al.*, 2009). CO_2e emissions per capita increase for all scenarios. This implies that CO_2e emissions will grow at a faster rate than population growth, mostly due to high GDP growth rates. A general increase in CO_2e emissions per capita is comparable to other developing cities such as Tokyo, Seoul and Beijing that have experienced increases in CO_2e emissions per capita as the economy grows (Shrestha, 2007). The base year's CO_2e emissions per capita is approximately 6 tCO_2e per capita (Table 5.5), which is similar to Beijing, London and Milan that range from 5.5 – 6.9 tCO_2e per capita (Croci *et al.*, 2009 and Dodman, 2009). CO_2e emissions per capita is expected to increase up to 3.2 times from the base year in the GWC Scenario. CO_2e emissions per capita in the BAU Scenario increases 133% which is comparable to the Bangkok Reference Scenario that forecasts emissions per capita to increase approximately 150% from 2005 to 2050.

In general, high economic and population growth, with no climate change mitigation results in the highest emissions. However, this does not mean that reducing emissions would require a decline in economic growth, for example while the Low Carbon City has a lowest economic growth it has the second highest income per capita. Furthermore, structural change in the city plays a significant role in reducing emissions from the industrial and commercial sector, as in the Natural Transition and the Low Carbon City.

In addition to GDP growth, urban sprawl and oil price changes also impact on the transport sector, with emissions in the Natural Transition Scenario increasing 470% from the base year value. However, if the city switches to cleaner fuels, adopts more efficient driving methods and promotes compact cities as in the Low Carbon City, emissions from the transport sector will increase 19% from 2005 to 2050. This illustrates the variance in emissions in changes in emissions in the transport sector.

Table 5.5: Changes in drivers of emissions and emissions for the different scenarios from the base year to 2050

	2005	2050				
	Base Year	GWC	BAU	Natural Transition	Slow Go City	Low Carbon City
GDP (R Billion)	115.08	736.18	660.38	455.10	537.63	384.19
Population (thousands)	3267.26	6384.91	4970.00	5112.64	5112.64	3200.00
Households (thousands)	823.70	3114.89	1609.68	1152.91	2008.05	1070.00
People per household	4.0	2.0	3.1	4.4	2.5	3.0
Income per capita (R thousands)	R35.22	R115.30	R132.87	R89.01	R105.16	R120.06
Energy consumption (Million GJ)	168.91	1021.89	659.22	545.12	426.26	186.25
CO_2e emissions (Million tCO_2e)	19.57	124.05	69.47	61.67	48.63	19.46
% Renewable energy including biomass	4.0%	3.5%	8.7%	1.0%	12.0%	20.0%
Structural change		Remains the same	Remains the same	Dominant information and service sector and reduction in manufacturing	Remains the same	Dominant information and service sector and reduction in manufacturing
Energy intensity (GJ/R thousand)	1.47	1.39	1.00	1.20	0.79	0.48
Carbon intensity (tCO_2e/R thousand)	0.17	0.17	0.11	0.14	0.09	0.05
CO_2e emissions per capita(tCO_2e/capita)	6.00	19.43	13.98	12.06	9.51	6.08
Households emissions (Million tCO_2e)	3.7	26.0	7.6	7.3	9.7	4.4
Industrial and commercial emissions (Million tCO_2e)	10.2	65.4	40.9	25.5	26.6	8.9
Local authority Million tCO_2e)	0.8	4.7	2.6	1.6	2.7	0.4
Transport (Million tCO_2e)	4.8	27.9	18.3	27.3	9.7	5.7

5.8 Downscaled scenarios

The purpose of the downscaled scenarios is to illustrate future emissions for Durban based on global development paths. These scenarios reflect future population, GDP and CO_2 emissions if Durban had to follow a global development path as depicted in the IPCC scenarios. These scenarios do not include any future climate change policies that may be implemented, however they do include environmental policies that can impact on GHG emissions (IPCC, 2001). The purpose of downscaling scenarios was to account for global influences on a local level and to allow for a comparison with the scenarios created in LEAP to ensure consistency in the results (Malone *et al.*, 2004).

5.8.1 *A1 Scenario*

The A1 Storyline reflects a development path with high economic growth rates, slow population growth and high levels of global integration. As a result the population for Durban peaks at 3.8 million people in 2025 and declines to 3.5 million by 2050. This is comparable to the global A1 Scenario, however whilst population peaks in 2050 and declines thereafter in the global scenario, the population for Durban peaks in 2025. A possible reason for this is the impact of HIV/AIDS (Haw and Hughes, 2007), but also as income per capita increases in the city, population growth declines (IPCC, 2001). GDP during this period increases approximately 500% and CO_2e emissions increases between 3.3 and 4.2 times the base year depending on the fuel mix of the scenarios.

The A1 Scenario is comparable to the GWC and the BAU Scenarios. The GDP for the A1 Scenario increases to R704.9 billion by 2050, which is in between the GWC and BAU Scenarios (R736 billion and R660 billion). The GWC scenario is similar to the A1F storyline, in that both scenarios experience high economic growth rates and a dependence on fossil fuels. The main difference in the storylines is that the GWC Scenario experiences high levels of population growth, whilst population declines for the A1F Scenario. The A1B Scenario and BAU Scenario both have high economic growth rates, with a balance between renewable fuels types and slow population growth rates.

As shown in Figure 5.24, the CO_2e emissions for the GWC are the highest by 2050, followed by the A1f Scenario. The reason for a significantly higher growth for the GWC Scenario is because the scenario assumes that there is no technological change, which would reduce the energy intensity of the economy from 2005-2050. Emissions for the BAU Scenario are initially lower than the A1 Scenarios, but by 2050, are between the A1B and A1T Scenarios. This comparison illustrates that the high economic growth scenarios developed in LEAP are similar to the high growth IPCC scenarios but they have a wide range, ranging from 124 million tCO_2e to 65 million tCO_2e.

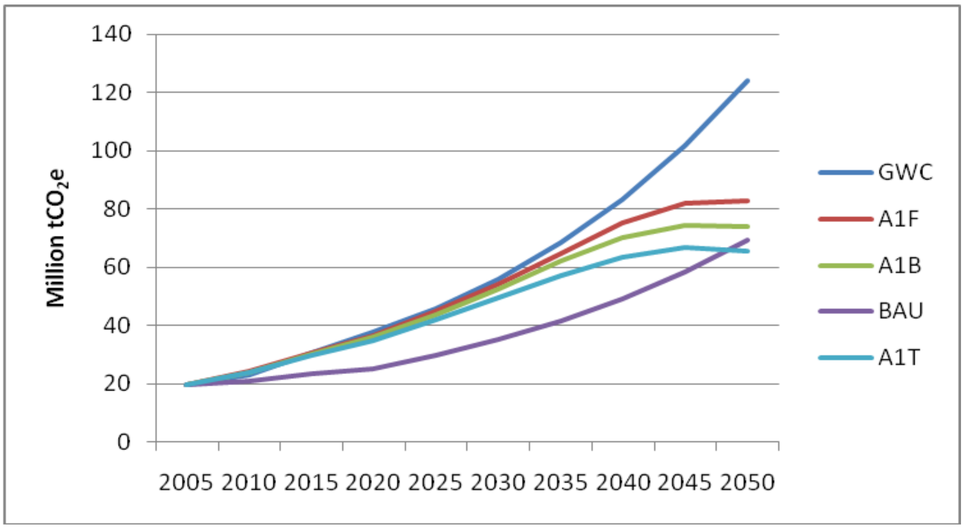


Figure 5.24: Comparison between CO_2e emissions (Million tCO_2e) for the A1 Scenarios and the GWC and BAU Scenarios from 2005 to 2050

5.8.2 *A2 Scenario*

The A2 Storyline represents a future with closed economies, high population growth rates and low levels of technological change. As a result, population increases 40% to 4.7 million people by 2050. GDP growth is slow, with GDP increasing 260% from 2005. Due to the moderate GDP growth, GHG emissions increase approximately 3.3 times from the base year.

The A2 Scenario is similar to the Natural Transition Scenario in that both scenarios experience high population growth rates, moderate GDP growth and slow technological change. However, the city does not move towards a service economy in the A2 Scenario as it does in the Natural Transition Scenario.

As shown in Figure 5.25, the resulting emissions for both the scenarios follow a similar path. The emissions for the Natural Transition Scenario are lower than the A2 storyline as a result of the structural change in the economy.

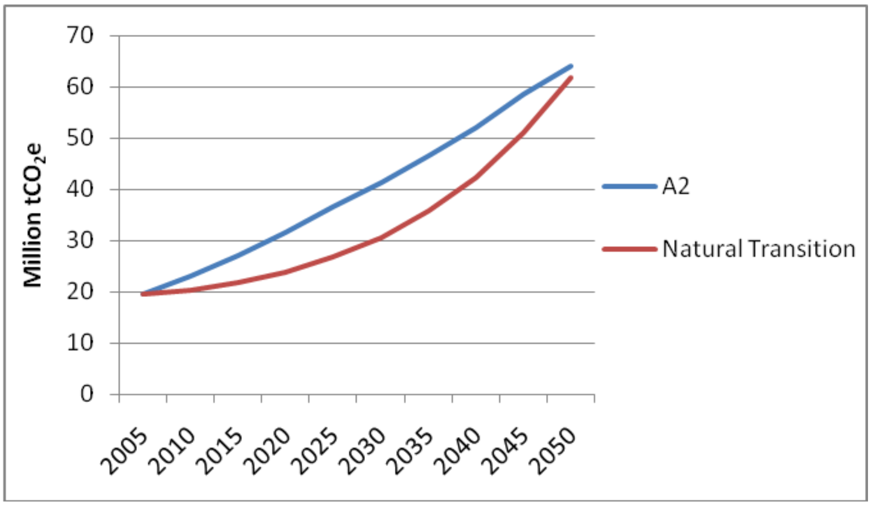


Figure 5.25: Comparison of CO_2e emissions (Million tCO_2e) for the A2 and Natural Transition Scenarios from 2005 to 2050

5.8.3 *B1 and B2 Scenarios*

The B1 Storyline illustrates a development path characterised by high levels of environmental awareness, high rates of economic growth towards a service and information economy and low population growth. Population and GDP levels are the same as the A1 Scenario but CO_2e emissions are 38% lower than the A1 Scenario by 2050. GHG emissions increase 2.4 times from the base year. The main difference between the A1 and B1 storylines is the high level of environmental and social awareness and the shift to low carbon industries.

The B2 Scenario is similar to the A2 Storyline, but is characterised by an increase in environmental awareness and an emphasis on providing local solutions for sustainability. Therefore, population and GDP is similar to the A2 Scenario, however CO_2e emissions are about 40% less than A2 emissions by 2050. CO_2e emissions increase approximately 2.3 times from the base year, from 19.57 million tCO_2e in 2005 to 44.66 million tCO_2e in 2050.

The emissions for the B1 and B2 Scenarios can be compared with the Natural Transition and Slow Go City Scenarios (Fig. 5.26). However there are not many similarities between the drivers of emissions for these scenarios. The main similarity between the Natural Transition and the B1 Scenario, is that both scenarios assume a shift towards a service and information economy. The Slow Go City is similar to the B1 Scenario as both scenarios enhance the implementation of cleaner and more efficient technologies. By 2050, emissions for the Natural Transition Scenario are the highest, followed by the Slow Go City and the B1 development path, which follow a similar emissions path to the Slow Go City. The emissions for the B2 Scenario are slightly lower than the other scenarios, which is due to moderate economic growth and local concerns for environmental protection. The Low Carbon City emission curve is also illustrated in Figure 5.26, to show the difference in emissions of the moderate GHG emissions pathways and the low carbon emissions path. The Low Carbon City also has some similarities with the B1 Scenario, in that both scenarios assume structural change in the economy towards services and both scenarios adopt cleaner technologies. However, by 2050, emissions for the

Low Carbon City are approximately 60% lower than the moderate emissions scenarios. This is because the Low Carbon City assumes direct climate change mitigation occurs, whilst the B1 Storyline only includes environmental policies that can have an impact on emissions (Nakicenovic *et al*., 2000).

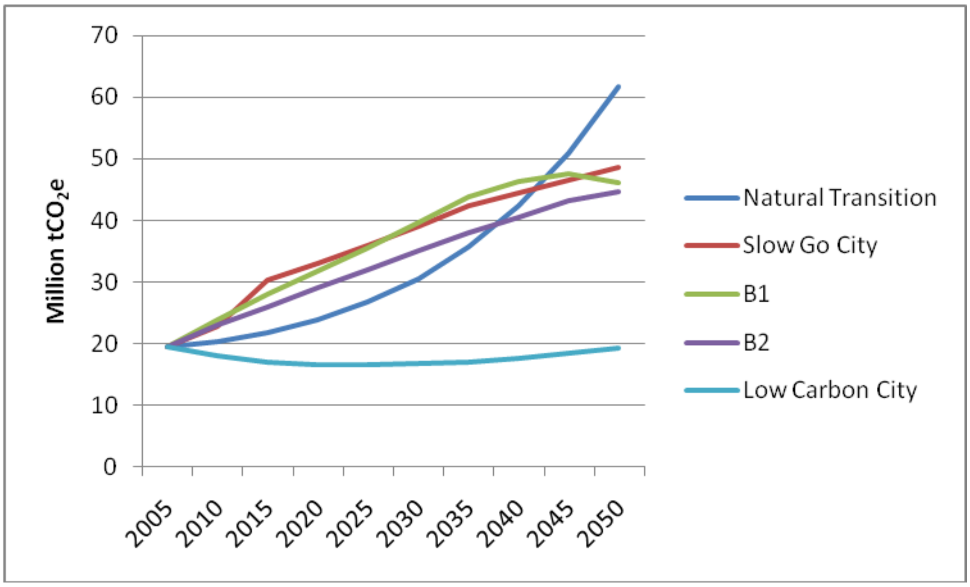


Figure 5.26: Comparison between moderate emission paths (Natural Transition, Slow Go City and the B1 and B2 Scenarios and the Low Carbon City, from 2005 to 2050

5.8.4 *Conclusion*

The different development paths had a range of impacts on emissions. Rapid economic growth, with no climate change mitigation in the GWC Scenario, results in a 6.3 times increase in emissions from the base year to 2050. In the BAU Scenario, emissions will increase 3.5 times from the base year. If there is a transition to a post-industrial society, with no climate change mitigation, emissions will increase 3 fold from 2005 to 2050. The National Transition Scenario illustrated that if Durban moves towards a service sector economy, which are predominantly low carbon sectors, with no climate change mitigation, emissions will increase 3.15 times the 2005 levels. If the city is slow to respond to climate change as in the Slow Go City, emissions will increase 2.5 times from the base year. The Low Carbon City Scenario a results in reduction in emissions of 1% from 2005. These were compared to the IPCC downscaled scenarios, which followed a similar pattern. The scenarios are comparable to developing city scenarios, but illustrate that the city is lagging behind developed cities. The IPCC downscaled scenarios fall within the range of the scenarios created in LEAP. However, whilst some of the LEAP scenarios include climate change mitigation assumptions, the IPCC scenarios only include environmental concerns that impact on a reduction in emissions. As a result the Low Carbon City emissions are much lower than the IPCC Scenarios. Furthermore, emissions for the GWC Scenario are greater than the A1F Scenario because the GWC Scenario assumes that there is no technological change in the economy that would improve efficiency. Therefore, while the IPCC Scenarios do provide a range of possible future emissions, it is also possible for emissions to be higher than the IPCC range. This is similar to a model developed for the USA, which found that the range of the IPCC scenarios is too narrow .

In order to make an impact in the reduction of emissions, it is essential for the city to target the commercial and industrial sector, which is the sector that emits the highest GHG emissions. However all these scenarios are still insufficient for achieving the RBS emissions target of a 60-80% reduction from 1990 levels. Achieving this reduction would require more than a 50% improvement in energy efficiency, structural change in the economy to low energy intensive sectors and a 20% contribution of renewable energy to total energy supply.

6 CONCLUSION

6.1 Introduction

Cities are key emitters of energy-related GHG emissions globally and this is expected to increase as the rates of urbanisation increases, therefore it is important to target cities for mitigation. In order to effectively mitigate climate change in cities, it is imperative that planners and policy makers know the implications of the city's development path and alternate development paths on GHG emissions. With economic development and job creation being a priority in many developing cities, there is often a conflict between growth and reducing GHG emissions. The aim of this dissertation was to develop GHG emissions scenarios, which portray the implications of different urban development paths on future energy demand and emissions, for the city of Durban. This would enable policy makers and planners to make informed decisions on future development.

The chapter will first outline the results of the study, in order to meet the specified objectives. It will thereafter identify recommendations for future work in this field.

6.2 Summary of results

The first objective of the study was to interpret the city of Durban's GHG inventory and to determine the key drivers of emissions in the city. This was achieved by examining the methodology and results of the city's GHG inventory and State of Energy Report and determining where the missing gaps are. From this it was established that the industrial sector emits the highest quantity of GHGs. The key driver in this sector is economic growth. However, another important driver of emissions in this sector was structural change. Studies have shown that changing the structure of the economy from an energy intensive economy to a service economy can reduce emissions, while resulting in the same amount of economic growth. Therefore GDP growth and structural change were selected as the main drivers of emissions in the industrial and commercial sector.

The next highest GHG emitter was the transport sector, whose main driver of emissions is GDP per capita. This is because as the wealth of the community increases, people who previously used public transport buy a private vehicle, while other switch to larger vehicles, which increases emissions. Another key driver in this sector is economic growth, which will increase emissions in the freight transport industry. The transport sector is also driven by fuel price, which can impact on the sector if there are significant increases or decreases in the price.

The residential sector of the city is driven by income per capita, population and the number of households. As peoples' wealth increases it drives their demand for appliances, which increases the demand for energy and emissions per household. Furthermore, population also increases emissions in this sector as it increases the demand for households, which increases the consumption of electricity and other energy sources in the sector and therefore emissions.

Lastly, the local authority sector is the lowest emitter of emissions, but it is also the sector that has the highest potential to reduce emissions. This is because local authorities influence emissions directly and indirectly through, the provision of services, by governing their own activities and by interacting with communities and industries to encourage energy efficiency. Therefore the local authority can influence emissions by the campaigns they have and the regulations they publish.

Other drivers of emissions that were considered for all sectors were changes in the fuel mix of the different sectors and the level of technological change in the different sectors. Different energy sources have different emissions factors, therefore if there is a switch to less CO_2e emitting fuels it could reduce emissions. Furthermore technological change can result in a shift towards more energy efficient products.

6.2.1 *The creation of scenarios*

The changes in the drivers of emissions formed the basis for creating different scenarios. Once the main drivers of emissions for the different sectors were identified, the future development plans for the city were determined. The city's IDP and its Economic Development Strategy were used to establish the development goals of the city. It was determined that the City set an economic growth rate of 1% above the National target. In addition to this the city plans to promote development in the automotive sector, agriculture, creative industries, ICT and tourism, clothing and textiles and the wood, paper and pulp industries. Therefore, the current development plan for the city is based on high GDP growth and an even distribution of growth in energy intensive industrial sectors, which includes the clothing and textile and wood, paper and pulp subsector and commercial sectors, which include the ICT, tourism and creative industry subsectors. This formed the basis of the creation of the BAU Scenario, which was based on existing development trends. In addition to this, the scenario assumed that the transport sector will grow as a result of the King Shaka Airport and the harbour expansion, resulting in more freight being carried to and from these ports. In terms of population the scenario assumed the population growth rate of the ASSA model and that the City achieves its housing provision targets of 17 000 households per annum until 2017. In terms of GHG mitigation, the City plans to reduce emissions by 27.6% of the GWC level. This was also factored into this scenario.

The GWC Scenario was developed on the basis that there is no longer a concern for climate change mitigation and there is a steady and constant supply of fossil fuels for the next half century. There is an emphasis on economic growth in the city and as Durban becomes wealthier there is an increase in demand for transport and houses.

The Natural Transition City assumes that municipal involvement in the city is reduced and that the economy is left to free markets. As a result the city moves towards a post-industrial economy, with a decline in the manufacturing sector and an increase in the service sector. The most significant difference between this scenario and the BAU scenario is the structural change in the industrial and commercial sector and a lack of implementation of existing policies and strategies, due to minimal government involvement. The aim of this scenario was to illustrate the implication of only structural change towards a service economy on emissions.

The Slow Go City Scenario assumes that the city is slow to administer mitigation measures for climate change, and instead focuses on promoting economic development in all sectors. Nationally, the country focuses more on securing energy supply rather than improving energy efficiency. However, by 2015 oil and other fossil fuel prices increase, including electricity and a series of climate change related disasters, making it vital for the city to use alternate energy sources and reduce emissions by becoming more energy efficient. The purpose of this scenario is to illustrate the implications on emissions if the city is slow to respond to climate change, but is very efficient in the future, as a result of energy prices increases and climate change disasters.

The Low Carbon City was created to illustrate the implications on future emissions of Durban if it becomes mandatory for the city to reduce emissions. The economy continues to grow but at a slower rate than the BAU Scenario, however growth is in the service sector due to policies that promote green economic growth. The city achieves a 60% improvement in energy efficiency by 2050 and renewable energy supplies 20% of the total fuel mix by 2050, compared to minimal renewable energy consumption in the existing GHG inventory of Durban. The purpose of this scenario was to illustrate the future emissions as the city begins to use cleaner and renewable energy, becomes more energy efficient and the structure of the economy changes to low carbon economic sectors.

The last scenario, the RBS Scenario, was adapted from the LTMS of South Africa. The RBS Scenario is based on the IPCC guideline, which states that global emissions need to be reduced between 60% - 80% of 1990 levels by 2100. Therefore this scenario was created on the premise that emissions are reduced by 30% - 40% of their 2005/2006 level by 2050. However this scenario is not attainable without the implementation of technologies that are yet to be discovered and behavioural changes in the Durban society.

6.3 The scenarios

The results of the scenarios showed that if Durban were to continue to grow at high economic levels, emissions in the city would increase six times the base year by 2050. This was compared to the LTMS, whose GWC Scenario resulted in a quadrupling of emissions by 2050. The increase in emissions for Durban was greater, as a result of a higher economic growth rate assumed for Durban. A six times increase in emissions is unsustainable and would have many other implications for the city, such as an increase in air pollution and health impacts.

The BAU Scenario showed that if Durban were to continue to grow based on its existing growth path, and meets all its energy strategy targets, emissions will still increase approximately 3.5 times the base year level. It was shown that this increase is similar to BAU Scenarios in developing cities such as Bangkok and Mexico City, however it is much greater than BAU Scenarios for developed cities New York City. The main reason for this is Durban and other developing cities are growing at a faster rate than developed cities and also many developed cities do not have energy-intensive industries. The BAU Scenario shows that if the city continues on its current development path, GHG emissions will continue to increase and that the city needs to implement more effective strategies to reduce emissions.

The National Transition Scenario illustrated that if Durban moves towards a service sector economy, with no climate change mitigation, emissions will still increase 3.15 times the 2005 levels, which is slightly less than the BAU Scenario. However, the economic growth of the city is not as rapid as the BAU Scenario. This scenario illustrated that whilst structural change does result in a lower increase in emissions in comparison to an increase in GDP, it is still insufficient for effectively reducing emissions. furthermore, structural change in the economy will not sufficiently reduce emissions.

The Slow Go City results in late but rapid climate change mitigation occurring as a result of energy price increases and a series of climate change disasters. As a result the economy grows rapidly until 2015 and then slows down. Emissions increase 2.5 times from the base year, with a rapid increase in emissions until 2015, followed by a decline in the growth of emissions. While the growth of emissions is not as high as the GWC, BAU and Natural Transition Scenarios, emissions still increase to levels much greater than the IPCC recommended levels.

The rapid response to climate change mitigation in the Low Carbon City, resulted in a 15% reduction in emissions by 2025 from the base year. However, as the economy grows there is an increase in the demand for energy, which outpaces the mitigation measures, and results in a 1% decline in emissions from 2005, by 2050.

The result of the Low Carbon City illustrates that even with rapid improvements in energy efficiency, the energy mix consisting of 20% renewable energy sources and large scale structural changes in the economy to low carbon service sectors, the city will still not be able to meet the RBS target of a 30-40% reduction in base year emissions from 2005 levels.

The downscaled scenarios were then compared with the created scenarios, and illustrated that while there are similarities in the scenarios, the created scenarios included issues that were specific to a South African city context. Therefore while downscaling scenarios from a regional level can be useful for understanding the implications of different development paths on a local level, they do not ideally represent the specific city.

In general all scenarios besides the Natural Transition Scenario, portray the industrial and commercial sector as the sector with the highest emissions throughout the scenario period, followed by the transport sector. In the Natural Transition Scenario the transport sector becomes the highest CO_2e emitted by 2030 as a result of the urban sprawl and a decline in industrial and commercial emissions as the sector shifts towards low carbon enterprises.

6.4 Recommendations and way forward

6.4.1 *Recommendations for achieving a low carbon future*

Scenarios that focus on high levels of environmental awareness, structural change, technological improvement and low population growth rates result in lower emissions for Durban. Therefore it is vital that the city of Durban and other developing cities, shift towards growth in low carbon economies and stimulate behavioural change in the City in order to become more energy efficient. While it is a difficult task to achieve a rapid reduction in emissions, it is possible to reduce emissions, but it would require assistance from all levels. As found in the study by Ghandaan and Koomey

(2005), in order to reduce emissions to an optimal level, a combination of national and local policies and initiatives are required, along with individual and community involvement.'*...there are steps we have to take to change the legacy we will leave our children: adjustments to our growth path we have to make as a global community, as nations working together, as citizens of a shared humanity, in response to the challenge of climate change and environmental responsibility*.' (Manuel, 2008, Budget Speech)

In Durban, as in many other developing country cities, the industrial sector is the highest CO_2e emitter and will continue to be so for a long period. Therefore it is crucial that this sector is targeted for reducing emissions in the future. The city should promote and subsidise industries that are low carbon or produce renewable energy and energy efficient appliances. This would ensure that the economy grows and is sustainable. The transport sector is also a significant contributor to emissions and can potentially become the sector with the highest CO_2e emissions if no strategies are put in place to reduce emissions in this sector. As a result the transport sector is also an important sector to target to implement emission reduction strategies. While the residential sector is a minimal contributor to emissions in the present day, emissions can potentially increase in this sector as people become wealthier and the population increases. Therefore it is imperative that the city begins to promote energy efficiency measures and the use of solar and other renewable energy appliances in the household sector.

The city of Durban and other developing cities, should also continuously be involved in and subsidise research and development of new technologies that are more energy efficient or use renewable energy sources, so that they can be implemented quickly and easily. This will enable cities to close the gap between the RBS emission pathway and the actual emissions. Also by developing their own technologies, the production and implementation costs of the technologies would be less.

It is important for policy makers in developing country cities, such as Durban, to understand the implication of their IDPs and Economic Development Strategies on future emissions. In many cities, development is prioritised with no understanding of the implications, as shown in the BAU scenarios of Durban, Bangkok, Mexico City. However, it is possible to promote development that is sustainable, by ensuring that new developments are climate friendly. Policies that integrate climate change measures and economic development are essential to creating a low carbon economy. Furthermore, it is vital that people in cities are educated about the implications of climate change to ensure that there is behavioural change in cities.

6.4.2 *Recommendations for further studies*

Integrating a cost-benefit analysis (CBA) with the scenarios, would improve the scenarios, by determining the costs of introducing renewable energy sources and energy efficiency technologies, versus the monetary value of energy saved by implementing these measures to determine the pay-back period for these technologies. Ideally the CBA should take into account externalities which could impact on the city that do not have a monetary value. For example an increase in health problems as a result of climate change and the usage of fossil fuels. Hence, while the payback period for implementing cleaner and renewable energy is in many cases long term, by taking into account the negative externalities that are avoided,

The LEAP tool also consists of a function that determines the level of air quality pollutants such as particulates, nitrogen oxides (NOx) and sulphur dioxide (SO_2) that is emitted through the use of different energy sources. Further studies could include developing scenarios that encompass both air quality pollutants and climate change GHG emissions. This would allow for scenarios to be developed that would aid in reducing both GHG emissions and air pollutants.

Furthermore, these scenarios can be improved by developing back-casting scenarios, similar to the scenarios developed in the UK and China, where a future target is set and different scenarios are created to meet the future target. The advantage of this is that it will allow policy makers to set a desired outcome for the future and then determine what strategies would be required to achieve that outcome.

Scenario forecasting can also be applied to other cities in South Africa, to develop a detailed analysis and comparison between different cities in the country. It can also be used on a larger scale for comparing cities globally. This would add value to the research as it would illustrate the impacts of different urban structures and development paths on emissions

Lastly, these scenarios can also be improved by increasing the level of detail in the various sectors. Sector specific scenarios can be developed for the city which can portray the impact of specific strategies on emissions in the sector. For example, strategies that specifically target the transportation sector, will require that the sector be divided into various subsectors, such as vehicle type, fuel type and vehicle kilometres travelled. However in order to achieve this more data is required and further research is necessary to determine exactly in which sectors and subsectors the various energy sources are being consumed.

The future is uncertain, therefore to ensure that planning takes into account a range of possible development paths, emission scenarios should be created for all developing country cities and should be applied in policy making processes.

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APPENDICES

Appendix 1: Electricity Data

Appendix 2: Other energy sources

2.1 Coal Data

2.2 Liquid Fuels

2.3 Methane Rich Gas

2.4 Bagasse

Appendix 3: GDP Summary

7 APPENDIX 1: ELECTRICITY DATA

Company/Institution	Annual consumption 2006/7 (GWh)	Annual consumption 2007/8 (GWh)
DOW AGROSCIENCES SA (PTY) LTD	8.77	7.05
DENNY MUSHROOMS (PTY) LTD	5.01	5.24
D & A TIMBERS (PTY) LTD	1.65	1.22
FARMERS BROKERS (C0-OP) LTD	1.34	1.34
SA SUGAR ASSOCIATION	2.04	1.92
SA SUGAR ASSOCIATION	1.35	1.15
WESTDAWN TRADING (PTY) LTD	5.29	5.23
Total Primary Sector: Agric, forest, mining	25.43	23.14
SA BREWERIES LTD	50.78	50.39
ISEGEN SOUTH AFRICA (PTY) LTD	43.52	42.46
CLOVER SA LIMITED (QUEENSBURGH	30.88	29.53
UNILEVER SOUTH AFRICA HPC(PTY)	25.74	26.06
HULETT REFINERIES LIMITED	22.20	20.04
BEACON SWEETS & CHOCOLATES (PT	17.44	18.99
BEACON SWEETS & CHOCOLATES LTD	16.82	18.86
BEACON SWEETS & CHOCOLATES(PTY	19.35	16.57
FRESH PRODUCE TERMINALS (PTY)L	15.46	15.49
B B CEREALS (PTY) LIMITED	18.86	15.03
ABI THE SOFT DRINK OF THE	14.50	14.94
UNILEVER SOUTH AFRICA FOODS	12.16	12.26
NATIONAL BRANDS LTD	11.78	11.69
NATIONAL FRESH PRODUCE MARKET	11.13	10.31
NEW AGE BEVERAGES LTD	10.14	10.23
ILLOVO SUGAR LIMITED - MEREBANK	12.61	9.96
PIONEER VOEDSEL (PTY) LTD	5.57	7.17
COMMERCIAL COLD STORAGE PTY LT	7.24	7.16
NCP YEAST (PTY) LTD	6.35	6.47
CHESTER WHOLESALE MEATS KZN	5.46	5.47
EVEREST FLEXIBLES (PTY) LTD	7.87	5.24
UNITED NATIONAL BREWERIES SA L	5.76	5.00
UNILEVER SOUTH AFRICA FOODS	5.47	4.92

ALBANY BAKERS & CONFECT PTY LT	4.93	4.65
POLYOAK (PTY) LTD T/A DAIRYPAC	5.81	4.52
FRY GROUP FOODS (PTY) LTD	3.33	4.37
QUALITY PRODUCTS (PTY) LTD	3.78	4.36
DIAGEO SOUTH AFRICA (PTY) LTD	1.94	4.02
NATIONAL BRANDS LTD	3.33	3.78
DAIRYBELLE (PTY) LTD	2.97	2.84
FLAVOUR CRAFT (PTY) LTD	2.83	2.70
PERMATRADE 20 (PTY) LIMITED	1.41	1.17
B B CEREALS (PTY) LTD	2.82	2.56
A Y MOOLA T/A ACE FOOD PRODUCT	0.99	0.80
BALLARD'S PIES CC	1.64	2.20
BROMOR FOODS (PTY) LTD	2.44	2.47
CHARLES SMITH SUPERFOODS(PTY)L	0.57	0.59
CLOVER SA (PTY) LTD	1.86	0.26
DISTELL (PTY) LTD	0.70	0.69
DISTELL (PTY) LTD	2.90	2.24
DOSTEX BUTCHERIES (PTY) LTD	0.57	0.53
DOSTEX BUTCHERIES (PTY) LTD	0.53	0.49
DURBAN ICE CREAM PTY LTD	0.55	0.98
FRESHMARK (PTY) LTD	2.45	2.20
IMANA FOODS (SA) (PTY) LTD	1.86	2.22
IQLAAS FOODS (PTY) LTD	1.39	1.28
LIBERTY LIQUORS (PTY)TD	0.44	0.40
M G BIELOVICH T/A MDENI MEATS	0.74	0.78
NATIONAL BRANDS LIMITED	1.01	1.01
NESTLE SA (PTY) LTD	2.91	0.63
DRYSDALE GRANT & CO (PTY) LTD	4.34	4.92
PARMALAT SA (PTY) LTD	-	1.44
PIONEER FOODS (PTY) LTD	1.52	1.18
POLYOAK(PTY)LTD T/A DAIRYPACK	3.48	0.67
POWER BAKERY (PTY) LTD	2.52	2.36
SA BREWERIES BEER DIVISION	0.83	0.90
SA BREWERIES LIMITED	0.98	1.09
SARA LEE (SOUTH AFRICA((PTY) L	0.31	1.82
SIMPLY CEREAL (PTY) LTD	0.91	1.28
THE CHICKERY (PTY) LTD	0.53	0.52
ILLOVO SUGAR LIMITED	1.62	1.63
TONGAAT HULETT SUGAR LIMITED	0.1075	0.1075
Total Manufacturing: Food, beverages and tobacco	**450.98**	**436.91**
FRAME TEXTILE GROUP A DIVISION	121.83	113.49
HOSAF FIBRES (PTY) LTD	34.18	35.94
FRAME TEXTILE DIVISION OF	19.70	16.22
SPUNCHEN INTERNATIONAL(PTY) LT	19.78	19.73
NINIAN & LESTER (PTY) LTD	9.97	8.38
FRAME TEXTILE CORPORATION(ULTE	5.88	5.35
CROSSLEY HOLDINGS (PTY) LTD	5.65	5.11
RADIUS TRADING (PTY) LTD	7.57	3.83

JMV TEXTILES (PTY) LTD	3.05	3.29
FIRST GARMENT RENTAL (PTY) LTD	3.09	3.06
DURBAN CLOTHING MANFRS (PTY) L	2.53	2.51
CELROSE LIMITED	3.46	3.51
SHAVE AND GIBSON GROUP (PTY) L	1.41	3.30
A&A TEXTILES & GEN AGENCIES P/	0.57	0.37
CAMBRIDGE SHIRT MANUFACTURERS	1.21	0.51
DBAPPAREL SA (PTY) LTD	1.84	1.70
DYEFIN TEXTILES (PTY) LTD	2.87	0.25
FRAME TEXTILE GROUP A DIVISION	0.78	0.47
HOPEWELL FOOTWEAR (PTY) LTD	0.51	0.72
NORTH SAFETY PRODUCTS (AFRICA)	2.05	1.98
PALM FOOTWEAR MANUFACTURERS P/	0.95	1.09
PRESTIGE CLOTHING MANUFACTURER	2.41	2.21
STAFLEX (PTY) LTD	0.1790	0.1168
BEIER INDUSTRIES (PTY) LTD	5.97	5.73
Total Manufacturing: Textiles, clothing & leather goods	**257.44**	**238.86**
MONDI PAPER CO LTD	865.03	782.95
NAMPAK FLEXIBLE PACKAGING KZN	26.82	25.71
CTP LTD (printers and publishers)	17.31	17.73
S A PAPER MILLS (PTY) LTD	16.94	16.72
MEGAPAK A DIV OF METAL BOX P/L	9.78	9.65
NAMPAK TISSUE (PTY) LTD	9.33	9.46
NAMPAK CARTONS & LABELS	6.82	7.00
AFRIPACK LIMITED	6.39	6.87
HIRT AND CARTER (PTY)LTD	6.93	6.37
UNIVERSAL PRINT GROUP (PTY) LT	6.32	6.32
UNIVERSAL WEB (PTY) LTD	5.00	5.31
MONDI PACKAGING(SA)PTY LTDT/A	5.24	5.10
RAFALO PAPER MILLS (PTY) LTD	5.40	4.97
NEW ERA PACKAGING KZN (PTY) LT	4.93	4.96
DIVERSE LABELLING CONSULTANTS	2.97	3.16
HYPACK A DIV OF NAMPAK PRODUCT	6.08	5.77
CORRELL TISSUE (PTY) LTD	2.79	2.47
LITHOTECH MANUFACTURING PINETO	3.01	0.25
NAMPAK FLEXIBLE KZN	1.25	1.20
SYLKO (PTY) LTD	-	0.23
FERROPRINT (PTY) LTD	0.1697	0.1697
NAMPAK PRODUCTS	0.1792	0.1792
FERROPRINT (PTY) LTD	2.61	2.94
Manufacturing: Wood, paper and printing	**1011.32**	**925.49**
SHELL & BP SA (PTY) LTD	260.96	302.71
ENGEN PETROLEUM LTD	149.23	137.75
ENGEN PETROLEUM LTD	108.61	100.80
DUNLOP TYRES INTERNATIONAL P/L	36.51	39.75
UNILEVER SA (PTY) LTD	5.72	5.85
AIR LIQUIDE (PTY) LTD	18.75	23.09

WAYNE RUBBER A DIV OF CONSHU L	19.55	22.07
SHELL & BP SA (PTY) LTD	18.72	18.61
INDUSTRIAL & CONSUMER PLASTICS	15.85	17.37
SMITHS PLASTICS (PTY) LTD	12.20	13.93
PLASTOP KWAZULU-NATAL (PTY) LTD	6.83	11.59
XACTICS (PTY) LTD	11.24	10.70
TETRA PAK SA (PTY) LTD	7.34	7.93
TROPIC PLASTIC PACK INDS PTY LTD	7.30	7.88
ASTRAPAK KZN (PTY) LIMITED	7.25	7.84
FLEX-O-THENE PLASTICS PTY LTD	7.13	7.73
PAK 2000 (PTY) LTD	6.70	7.13
ASTRAFLEX (PTY) LTD	5.05	6.39
INDUSTRIAL OIL PROCESSORS P/L	5.65	5.20
ENGEN PETROLEUM LIMITED	4.27	4.22
SWAN PLASTICS CC	4.05	4.18
AUNDE-TAP (PTY) LTD	4.91	3.95
CRAY VALLEY RESINS SA (PTY) LT	-	3.85
RUBBERTEK (PTY) LTD	2.69	3.01
REVERTEX CHEMICALS (PTY) LTD	3.12	2.90
CALTEX OIL (SA) (PTY) LTD	3.05	2.53
SI GROUP-SOUTH AFRICA (PTY)LTD	3.13	3.17
COLGATE PALMOLIVE (PTY) LTD	8.67	9.34
EVA INDUSTRIES (PTY) LTD	0.37	3.44
ABE CONSTRUCTION CHEMICALS (PT	0.84	0.77
AUTOMOULD (PTY) LIMITED	1.41	1.60
BLACKBURN ENTERPRISES (PTY) LT	1.48	1.33
CONTINENTAL COMPOUNDERS (PTY)L	-	1.45
DM PLASTICS (PTY) LTD	1.90	1.99
ENGEN PETROLEUM LIMITED	0.56	0.52
ENGEN REFINERY A DIVISION OF	0.68	0.60
EVEREST FLEXIBLES (PTY) LTD	-	0.42
EVEREST FLEXIBLES PTY LTD	-	1.25
FFS REFINERS (PTY) LTD	1.65	1.80
H & R SA (PTY) LTD	1.04	1.04
INEOS SILICAS S A (PTY) LTD	2.42	2.15
KOHLER PACKAGING LTD T/A KOHLE	1.80	1.81
NELESCO 655 (PTY) LTD	0.56	0.38
PAK 2000 (PTY) LTD	0.34	0.34
PAKCO (PTY) LTD	2.44	0.25
POLYFLEX (NATAL) (PTY) LTD	0.42	0.45
PROGRESSIVE PLASTICS CC	0.74	0.65
SHANCO (PTY) LTD	1.33	1.54
VAN RYN RUBBER HOLDINGS (PTY)L	1.85	1.83
ZETACHEM (PTY) LTD	1.46	1.42
ZIMOPLAST INDUSTRIES CC	0.97	1.18
EVA INDUSTRIES (PTY) LTD	0.1628	0.1628
HEBCOOLER CC (polystyrene products)	2.0350	0.1504
Total Manufacturing: Petrol, chemical, rubber &	**770.95**	**820.01**

plastic		
A E C I CHLOR-ALKALI & PLASTIC	115.12	135.51
NPC-CIMPOR (PTY) LTD	45.11	43.63
TIOXIDE SA (PTY) LTD	35.43	36.12
PLASCON DECORATIVE COASTAL P/L	7.18	7.15
TROPIC PLASTIC & PACKAGING P/L	4.18	5.03
PFG BUILDING GLASS (PTY) LTD	4.19	3.73
BURCAP PLASTICS (PTY) LTD	4.49	3.62
BURCAP PLASTICS IML (PTY) LTD	3.79	3.07
COATES BROTHERS (SA) LTD	1.24	1.09
CREIGHTON PRODUCTS (PTY) LTD	1.00	1.24
GARSTAN PLASTICS CC	-	0.51
J.J PRECISION PLASTICS (PTY) L	-	0.57
MUCH ASPHALT (PTY) LTD	1.26	1.41
ROCLA (PTY) LTD	0.60	0.64
TSM STAMPING DIVISION LTD	0.93	0.61
VITAFOAM SA (PTY) LIMITED	1.35	0.66
Other Non-metallic minerals	**225.86**	**244.60**
METAL BOX SA LIMITED (BEV DIV)	18.46	24.15
DIVPAC NATAL A DIV OF METAL BO	15.20	15.85
NON FERROUS METAL WORKS SA (PT	11.94	10.80
GRIEF SOUTH AFRICA PTY LTD	8.26	6.59
NAMPAK CORRUGATED CONTAINERS	6.51	6.22
SCAW SOUTH AFRICA (PTY) LTD	6.04	5.55
NON-FERROUS METAL WORKS (SA)(P	5.64	5.38
PHOENIX GALVANIZING (PTY) LTD	4.94	4.94
METAL BOX (SA) LTD T/A NAMPAK	3.46	3.79
TRELLICOR (PTY) LTD	4.06	3.12
DURBAN GALVANIZING (PTY) LTD	3.07	2.81
AFRICAN GABIONS (PTY) LTD (steel wire mesh)	0.82	0.87
ARCELORMITTAL SOUTH AFRICA LTD	0.67	0.62
AVENG (AFRICA)LTD	0.88	1.08
COLLIER TOOL & DIE CC	1.02	0.86
FASCOR A DIV OF HAGGIE ENG P/L	1.62	1.65
FASCOR A DIV OF HAGGIE ENG P/L	0.33	0.44
GEDORE TOOLS SA (PTY) LTD	0.36	0.36
HANNSA TOOL AND DIE (PTY) LTD	1.82	1.74
LAFARGE BRAAS ROOFING (PTY) LT	2.41	2.00
PHOENIX GALVINIZING (PTY) LTD	1.45	0.56
PREMIER SPRING INDUSTRIES	1.80	0.63
ROHM & HAAS S A (PTY) LTD	2.00	2.00
STEELBANK MERCHANTS (PTY) LTD	1.02	0.81
VOIGT & WILLECKE (PTY) LTD	3.05	2.37
RHEEM SOUTH AFRICA (PTY) LTD	3.5666	0.1668
Metal products, machinery	**110.40**	**105.35**
DEFY APPLIANCES (PTY) LTD	22.37	16.96
FRANKE KITCHEN SYSTEMS (PTY) L	4.05	3.89
MERLIN GERIN SA (PTY) LTD	3.63	2.79

ALVERN CABLES (PTY) LTD	0.60	0.64
HM LIEBOWITZ (PTY) LTD	1.55	0.59
BSN MEDICAL (PTY)LIMITED	7.92	7.13
DERIVCO (PTY) LTD	4.05	4.30
UEC TECHNOLOGIES (PTY) LTD	3.40	3.02
UEC TECHNOLOGIES (PTY) LTD	3.11	2.98
BUSINESS CONNEXION (PTY) LTD	1.88	1.65
BUSINESS CONNEXION (PTY) LTD	1.31	1.44
DIMENSION DATA (PTY) LTD	0.68	0.77
UEC TECHNOLOGIES LIMITED	1.18	1.20
INTERNATIONAL HLTH CARE DISTRS	0.7946	0.1653
Electronic machinery and appliances	**56.52**	**47.53**
TOYOTA SA MOTORS (PTY) LTD	165.55	135.81
FELTEX LTD (car seats and components)	12.83	14.14
SMITHS MANUFACTURING (PTY) LTD	11.99	11.60
FEDERAL MOGUL FRICTION PRODUCT	10.80	9.76
FEDERAL-MOGUL ENGINE BEARNGS	13.07	9.27
AUNDE SOUTH AFRICA (PTY) LTD	2.20	7.62
G.U.D. HOLDINGS(PTY) LTD	5.33	5.49
TOYOTA SA STAMPING DIV	5.12	5.20
SMITHS MANUFACTURUNG (PTY) LTD	3.93	4.15
TSA AUTOMOTIVE COMPONENTS	7.45	3.65
G U D HOLDINGS(PTY) LTD	5.48	5.22
CATALER SA LTD	2.78	2.24
G U D HOLDINGS(PTY) LTD	0.20	0.21
HENRED FRUEHAUF TRAILERS PTY L	0.75	0.78
HM LIEBOWITZ (PTY) LTD	1.55	0.59
NMI D S M PTY LTD T/A CHRYSLER	0.16	0.61
NMI DBN SOUTH (PTY) LTD	0.53	0.51
NMI DBN SOUTH MOTORS (PTY)LTD	0.71	0.64
NMI DURBAN SOUTH MOTORS (PTY)L	1.25	1.16
NMI DURBAN SOUTH MOTORS (PTY)L	0.74	0.77
NMI DURBAN SOUTH MOTORS (PTY)L	0.19	0.45
NMI DURBAN SOUTH MOTORS (PTY)L	0.45	0.20
NMI DURBAN SOUTH MOTORS(PTY)LT	1.20	1.12
PALM MOTORS PTY LTD T/A KEY	1.17	1.28
ROCKHAM INDUSTRIES (PTY) LTD	0.91	0.64
SMITHS MANUFACTURING (PTY) LTD	3.35	2.39
Total Transport Equipment	**259.68**	**225.51**
BAKKER AND STEYGER PTY LTD	5.69	4.67
Total Furniture	5.69	4.67
Total Manufacturing	**3 148.84**	**3 048.93**
AFROX LIMITED (gas supply and equipment)	1.11	1.10
Electricity, gas and hot water supply	1.11	1.10
UMGENI WATER (WIGGINS)	17.78	24.58
DURBAN METRO WATER SERVICES	11.92	12.54
UMGENI WATER DBN HEIGHTS	10.02	10.73
DURBAN METRO WATER SERVICES	8.39	7.88

DURBAN METRO WATER SERVICES	7.32	7.38
DURBAN METRO WATER SERVICES	6.36	6.84
OTV RSA ENVIRONMENT (PTY) LTD	6.95	6.63
DURBAN METRO WATER	4.93	5.14
ETHEKWINI WATER AND SANITATION	-	3.97
UMGENI WATER BOARD	3.41	3.53
AQUAFUND (PTY) LTD	1.48	0.81
Collection, distibution and purification of water	**78.55**	**90.04**
COROBRIK (PTY)LTD	11.13	11.24
JT ROSS PTY LTD	2.81	2.54
HENDOK (PTY) LTD	9.21	8.23
PIETER M DUYS (PTY) LTD (engineering)	3.50	3.76
GRINAKER -LTA BLDG EAST TRDING	0.50	0.55
Construction	**27.17**	**26.32**
RYCKLOF-BELEGGINGS (PTY)LTD (Musgrave Centre)	21.79	20.74
GOLDEN POND TRADING 350 (PTY)L	12.92	11.19
MAKRO SA (PTY) LTD	5.37	5.34
SIMPLY TRADING 28 PTY LTD T/A	3.90	3.88
MASSSTORES (PTY) LTD T/A	3.73	3.72
PICK N PAY WHOLESALERS (PTY) L	3.47	3.30
CENTILLION TRADING (PTY) LTD	3.01	3.09
METRO CASH & CARRY LTD	2.58	2.77
ANDGOV TRADING DEALS CC	1.27	1.12
BEVISBROOK TRADING (PTY) LTD	1.26	0.90
CHARIS TRADING CC	0.77	0.78
FAVORS CASH & CARRY (PTY) LTD	1.09	1.01
GROWTHPOINT SECURISATION WARE-	0.82	0.93
HYPERCHECK (PTY) LTD	1.29	1.30
HYPERCHECK (PTY) LTD	0.56	0.69
JEENA'S WAREHOUSE CC	1.03	1.11
MACSTEEL TRADING (PTY) LTD	1.02	0.89
METRO TRADE CENTRE (PTY) LTD	2.27	2.14
NORTHERN JUNGLE TRADING 264 PT	0.77	0.71
OHLANGA CASH AND CARRY	0.98	0.92
RICHDENS LINKHILLS CC	1.78	1.83
SALMON DUNNINGTON & SONS CC	-	0.26
SIMPLY TRADING 28 (PTY)LTD	2.49	2.35
SOLWA WHOLESALERS (PTY) LTD	1.64	1.36
SOLWA WHOLESALERS (PTY) LTD	0.65	0.66
THOMBELL CC TRADING AS	0.73	0.73
TRADEFIRM 15 (PTY) LTD T/A	1.50	1.57
TRANS NATAL MEAT WHOLESALERS P	1.00	0.97
Wholesale and commission goods	**79.67**	**76.25**
OLD MUTUAL LIFE ASS CO OF SA (Gateway Shopping Centre)	74.40	78.61
PARETO LIMITED (THE PAVILION)	59.80	59.08
PICK N PAY HYPERMARKET (PTY) L	13.02	12.80
UMLAZI MEGA CITY (PTY) LTD	0.94	12.36

OLD MUTUAL PROPERTIES (Gateway)	8.41	8.19
SPAR KZN A DIVISION OF THE SPA	8.28	7.95
SHOPRITE CHECKERS (PTY) LTD	-	7.81
KLOOF SHOPPING CENTRE SHAREBLO	4.00	4.03
PICK `N PAY RETAILERS (PTY) LT	4.12	3.96
SHOPRITE CHECKERS (PTY) LTD	4.05	3.91
PICK 'N PAY RETAILERS (PTY) LT	3.93	3.73
MT EDGECOMBE PLAZA (PTY) LTD	3.91	3.69
PICK 'N PAY RETAILERS (PTY) LT	3.82	3.63
WOOLWORTHS PTY LTD - BR 333	3.56	3.53
PICK 'N PAY RETAILERS (PTY) LT	2.98	3.28
PICK 'N PAY RETAILERS (PTY) LT	3.48	3.12
EDGARS STORES LIMITED	3.80	3.00
SHOPRITE CHECKERS(PTY)LTD	3.00	2.88
SHOPRITE CHECKERS (PTY) LTD	2.61	2.73
BARROWS DESIGN & MANUFACTURING	3.33	3.04
BRETT FOUR CC T/A CAMBRIDGE ME	2.55	3.75
ACKERMANS LIMITED	2.19	2.46
BODY CRPRTE VICTORIA ST MARKET	1.67	1.24
BODY CRPRTE VICTORIA ST MARKET	0.84	0.73
CHECK ONE SUPERMARKET (PTY) LT	1.38	1.32
CHECK ONE SUPERMARKET (PTY) LT	0.71	0.59
CHECK ONE SUPERMARKET (PTY) LT	0.34	0.35
CHECKONE SUPERMARKET (PTY) LTD	0.38	0.40
CLICKS ORGANISATION (PTY) LTD	1.74	1.74
EDGARS CONSOLIDATED STORES LTD	2.79	2.06
GAME DISCOUNT WORLD	2.35	2.24
GAME DISCOUNT WORLD (PTY) LTD	1.40	1.33
GOLDEN SUN SUPERMARKET CC	0.52	0.52
HILLMAX RETAIL SOLUTIONS PTY L	0.25	0.24
KENSINGTON SQUARE (PTY) LTD	1.74	1.81
KENSINGTON SQUARE (PTY) LTD	1.49	1.63
KENSINGTON SQUARE (PTY) LTD	1.37	1.27
KENSINGTON SQUARE (PTY) LTD	0.70	0.69
KIRSTEN'S SUPERMARKET CC	1.03	0.95
KLOOF SUPERMARKET (PTY) LTD	11.53	1.00
LEISURELAKE SUPERMARKET P/L	1.24	1.09
MASSTORES (PTY) LTD	1.10	2.13
MG BIELOVICH T/A BLUFF MEAT	0.27	1.97
MG BIELOVICH T/A BMS SELECT FO	0.16	2.28
MG BIELOVICH T/A MNDENI MEATS	1.62	1.34
MILADYS STORES	1.14	1.11
MODEL HELP U MARKET (PTY) LTD	0.52	0.54
NORTH BEACH TRADERS T/A	0.95	1.11
OK BAZAARS (HILL ST PINETOWN)	2.10	1.97
OK BAZAARS LTD	0.20	0.20
PICK 'N PAY RETAILERS (PTY) LT	2.37	2.13
PICK 'N PAY RETAILERS (PTY) LT	1.14	0.87

PICK N PAY WHOLESALERS PTY LTD	1.97	1.85
SA RETAIL PROP LTD S/STN 1	0.78	0.77
SA RETAIL PROP LTD S/STN 3	1.83	1.51
SA RETAIL PROPERTIES LTD	1.98	1.76
SA RETAIL PROPERTIES LTD	-	1.42
SHOPRITE & CHECKERS PROPERTIES	0.74	0.50
SHOPRITE CHECKERS	1.58	1.64
SHOPRITE CHECKERS (PTY) LTD	2.30	2.49
SHOPRITE CHECKERS (PTY) LTD	2.55	2.40
SHOPRITE CHECKERS (PTY) LTD	2.23	2.29
SHOPRITE CHECKERS (PTY) LTD	1.69	1.84
SHOPRITE CHECKERS (PTY) LTD	1.54	1.65
SHOPRITE CHECKERS (PTY) LTD	1.64	1.60
SHOPRITE CHECKERS (PTY) LTD	1.52	1.56
SHOPRITE CHECKERS (PTY) LTD	1.59	1.55
SHOPRITE CHECKERS (PTY) LTD	1.19	1.19
SHOPRITE CHECKERS (PTY) LTD	0.21	0.21
SHOPRITE CKECKERS (PTY) LTD	1.86	1.73
TAKE 'N PAY (PTY)LTD	1.00	1.08
THE HUB (FLO BENGTSON)	1.75	1.68
WARDKISS (PTY) LTD (retail paint and hardware store)	0.41	0.41
WARNER BEACH SUPERMARKET CC	2.37	2.28
WEDDERS SUPERMARKET CC T/A BLU	1.46	1.43
WOOLWORTHS (PTY) LIMITED	0.61	0.50
WOOLWORTHS (PTY) LTD	2.17	2.10
WOOLWORTHS (PTY) LTD	0.57	0.56
WOOLWORTHS (PTY) LTD BR. 330	0.87	0.89
BARRY MOORE'S SUPERMARKET CC	0.1494	0.1494
OK BAZAARS 1929 LTD (CODE 412)	0.1625	0.1239
SHOPRITE CHECKERS (PTY) LTD	0.1602	0.1602
ETLIN INTERNATIONAL TRADING P\	4.67	3.26
Retail trade and repairs	**304.74**	**317.01**
STANGER & ROSSBURGH STATION	140.47	151.10
TSOGO SUN KZN (PTY) LTD	26.83	27.43
AFRISUN KZN (PTY) LTD T/A SIBAYA	20.25	19.20
SOUTHERN SUN HOTEL INTERESTS P	10.41	9.79
AFRICAN AMERICAN PROP HOTELS P	10.42	9.66
ROYAL HOTEL	8.92	8.49
HOLIDAY INNS HOTEL CORP PTY LT	7.77	8.24
HOLIDAY INN GARDEN COURT	6.68	5.83
HOTELS INNS & RESORTS (SA)P/L	5.48	4.99
UMHLANGA SANDS HOTEL	5.26	4.89
CABANA BEACH SOUTHERN SUN CORP	5.39	4.86
PROTEA HOTEL GROUP (PTY) LTD	3.49	3.41
BEVERLEY HILLS HOTEL	3.52	3.12
CITY LODGE HOTELS LIMITED	1.45	1.20
CITY LODGE HOTELS LTD	1.87	1.85

COASTLANDS HOL. APARTMENTS P/L	1.79	1.70
GOODERSON LEISURE CORP (PTY) L	2.39	2.30
GOODERSON LEISURE CORP (PTY) L	1.79	1.74
INTERPARK LIMITED (ROYAL HOTE	0.15	0.37
KARRIDENE RESORT T/A PROTEA	2.24	1.94
PARK VIEW HOTEL (PTY) LTD	1.15	0.99
TRUE BLUE HOTELS (PTY) LTD	0.58	0.61
Hotel and restaurants	**127.81**	**122.59**
NATIONAL PORTS AUTHORITY OF SA	52.68	56.82
PETRONET-A DIV OF TRANSNET LTD	26.93	29.22
PETRONET-A DIV OF TRANSNET LTD	23.38	27.47
SA RAIL COMMUTER CORPORATION	19.04	10.54
SPOORNET(A DIVISION OF TRANSNE	8.81	8.50
SA RAIL COMMUTER CORPORATION	9.48	6.49
VECTOR LOGISTICS LTD	5.49	4.96
METRO MANAGER (SPOORNET)-DURBA	3.23	3.63
TRANSNET LIMITED	3.83	3.43
PETRONET-A DIV OF TRANSNET LTD	5.17	2.67
SHIPBUILDERS DURBAN (PTY) LTD	3.07	3.38
CARGO CARRIERS LIMITED	0.27	0.24
GRINDROD (PTY) LTD	1.38	1.31
M3 CARRIERS CC	1.11	0.63
MAN TRUCK AND BUS (SA) (PTY) L	1.30	1.18
MEDITERRANEAN SHIPPING CO P/L	1.82	1.83
REGIONAL OFFICER NPA	1.18	1.27
REMANT ALTON LAND TRANSPORT	2.03	1.89
RENNIES CARGO TERMINALS (PTY)L	1.19	1.22
RENNIES CARGO TERMINALS (PTY)L	0.44	0.40
RENNIES DISTRIBUTION SERVICES	1.50	1.21
SPOORNET (PROPERTY MANAGEMENT	2.11	1.64
AIRPORTS COMPANY LTD	18.35	10.83
KZN COLD STORE (PTY) LTD	1.93	1.68
REEFER STORAGE (PTY) LTD	4.67	5.15
THE COLD CHAIN (PTY) LTD	4.71	4.29
Air, land and water transport	**205.07**	**191.88**
TELKOM SA LTD	11.11	11.71
SA POST OFFICE LIMITED	6.68	4.98
MOBILE TELEPHONE NETWORKS P/L	2.63	2.73
TELKOM SA LTD	2.96	2.64
MOBILE TELEPHONE NETWORKS (PTY	1.80	2.18
MOBILE TELEPHONE NETWORKS P/L	1.12	1.42
SA POST OFFICE LTD	2.11	1.86
SA POST OFFICE LTD	0.34	0.34
SIEMENS LIMITED	0.51	0.69
TELKOM SA LTD	2.38	2.31
TELKOM SA LTD	2.41	2.15
TELKOM SA LTD	1.61	1.70
TELKOM SA LTD	1.70	1.63

TELKOM SA LTD	1.41	1.37
TELKOM SA LTD	1.25	1.25
TELKOM SA LTD	1.12	1.13
TELKOM SA LTD	0.93	0.90
TELKOM SA LTD	0.78	0.81
TELKOM SA LTD	0.70	0.70
TELKOM SA LTD	0.52	0.52
TELKOM SA LTD	0.47	0.50
TELKOM SA LTD	0.39	0.50
TELKOM SA LTD	0.46	0.45
TELKOM SA LTD	0.41	0.44
TELKOM SA LTD	0.42	0.42
TELKOM SA LTD	3.40	0.42
TELKOM SA LTD	0.34	0.34
TELKOM SA LTD	0.32	0.33
TELKOM SA LTD	0.17	0.33
TELKOM SA LTD	0.27	0.28
TELKOM SA LTD	0.20	0.22
TELKOM SA LTD	0.23	0.22
TELKOM SA LTD	0.20	0.20
S A POST OFFICE LTD 4060	0.1965	0.1496
TELKOM SA LTD	0.1166	0.1436
TELKOM SA LTD	0.1743	0.1282
Telecommunications and post	**51.85**	**48.09**
INVESTEC BANK LIMITED	1.07	16.85
NEDBANK LIMITED	7.04	6.61
EASY DOES IT INVESTMENT(PTY) L	6.01	6.08
SA MUTUAL LIFE ASSURANCE SOC	6.35	6.06
ITHALA DEVELOPMENT FINANCE	2.60	4.52
ABSA BANK LTD (CC 4272)	3.59	3.91
SANLAM ASSURANCE	4.21	3.81
S A RESERVE BANK	3.49	3.18
8 MILE INVESTMENTS 204 PTY LTD	5.06	2.97
DANDELTON INVESTMENTS (PTY) LT	2.78	2.72
UNILEVER S A HOME & PERSONAL	2.96	2.70
ARNOLD PROPERTIES (PTY)LTD	4.65	4.47
ERASURE INVESTMENTS P/L IN LIQ	3.41	3.74
ABSA BANK LIMITED	1.45	1.21
ABSA BANK LTD (C/C 4277)	0.73	0.56
ALEXANDER FORBES GROUP (PTY) L	1.35	1.29
DELOITTE & TOUCHE	2.36	1.96
F N B CORPORATE A DIVISION OF	2.16	1.86
FIRST NATIONAL BANK OF SA LTD	0.84	0.60
FIRST NATIONAL BANK OF SOUTHER	1.51	1.32
FIRST NATIONAL BANK OF SOUTHER	0.19	0.22
FIRST NATIONAL BANK S A LTD	2.50	2.24
GOODY INVESTMENTS CC	0.95	0.77
ITHALA DEVELOPMENT FINANCE	1.12	1.15

ITHALA DEVELOPMENT FINANCE COR	2.20	1.34
KAYDEN INVESTMENTS (PTY) LTD	0.81	0.77
LEODES INVESTMENTS (PTY) LTD	0.55	0.50
LILANE SYNDICATE INVESTMENTS C	0.83	0.47
MAXSHELL 27 INVESTMENTS (PTY)L	0.79	0.79
MAXSHELL 27 INVESTMENTS (PTY)L	0.81	0.77
ONE VISION INVESTMENTS 256(PTY	0.42	0.28
OUTWARD INVESTMENTS (PTY) LTD	1.22	1.12
OUTWARD INVESTMENTS (PTY) LTD	1.08	1.05
PMMT INVESTMENTS CC	0.90	0.81
PRICEWATERHOUSE COOPERS INC	1.46	1.40
S A MUTUAL LIFE ASSRNCE SOCIET	1.92	1.72
SANLAM ASSURANCE	0.51	0.50
SECPROP 30 INVESTMENTS (PTY) L	1.26	1.19
THE PALACE SHAREBLOCK LTD	1.39	1.38
HERALD INVESTMENTS (PTY) LTD	0.1659	0.1552
PANGBOURNE PROPERTIES LTD	0.1563	0.1563
Finance and Insurance	84.87	95.23
EMIRA PROPERTY FUND	23.35	31.52
PARAMOUNT PROPERTY FUND LTD	26.62	28.89
SA RETAIL PROPERTIES	21.22	20.77
GROWTHPOINT PROPERTIES LTD	19.64	20.46
VUKILE PROPERTY FUND LTD	14.99	12.52
VUKILE PROPERTY FUND LTD	11.75	11.89
GROWTHPOINT PROPERTIES LIMITED	11.09	11.18
APEX HI PROPERTIES LTD	10.78	10.39
SIYATHENGA PROPERTIES ONE	10.51	10.08
TECHNIKON MANGOSUTHU	10.63	10.02
SA RETAIL PROPERTIES LTD	10.47	9.97
METBOARD PROPERTIES LTD	6.34	8.99
ATLAS PROPERTIES LTD	8.43	7.74
VUKILE PROPERTY FUND LTD	8.44	7.13
OASIS CRESCENT PROPERTY FUND	7.18	6.73
NDAWONYE PROPS 1003 CC	6.46	6.20
DUBYLA PROPERTIES CC	7.18	5.59
SA RETAIL PROPERTES LTD	5.40	5.58
RMB PROPERTIES (PTY) LTD	5.58	5.56
APEX HI PROPERTIES LIMITED	4.91	5.55
ARTEMIS PROPERTIES (PTY) LTD	5.47	5.26
SWISH PROPERTY FOUR (PTY) LTD	4.84	4.74
ARENA PROPS 19 (PTY) LTD	3.72	4.65
PALTROW ADMINISTRATION (PTY) L	1.00	4.64
CORRUSEAL PROPERTIES (PTY)LTD	0.38	4.33
NIEUCO PROPERTIES (PTY) LTD	4.31	4.19
APEX HI PROPERTIES LIMITED	4.88	4.17
THE BODY CORPORATE OF DURDOC	4.02	4.11
SA RETAIL PROP LTD S/STN 2	2.11	2.51
APEX HI PROPERTIES LTD	3.45	3.24

APEX HI PROPERTIES LIMITED	1.92	2.37
APEX HI PROPERTIES LTD	1.69	1.85
APEX HI PROPERTIES LTD	2.11	1.79
APEX HI PROPERTIES LTD	1.54	1.47
APEX HI PROPERTIES LTD	1.37	1.22
APEX HI PROPERTIES LTD	0.48	0.50
APEXHI PROPERTIES LTD	1.74	1.74
APEXHI PROPERTIES LTD	1.79	1.71
ARTEMIS PROPERTIES (PTY) LTD	-	0.48
BLEND PROPERTY 7 (PTY) LTD	0.61	0.54
CAPITAL PROPERTY FUND	2.92	2.14
CAPITAL PROPERTY FUND	2.41	1.16
CBS PROPERTY TRUST	2.00	1.83
CLINTSAND INVEST.SHARE BLOCK L	1.22	1.20
DANDELTON INVESTMENTS (PTY) LT	1.90	1.43
DANDELTON INVESTMENTS (PTY)LTD	0.80	0.83
DANKIRA PROPERTIES (PTY) LTD T	0.67	0.60
DOLPHIN VIEW BODY CORPORATE	0.86	0.80
ECHOLAKE INVESTMENTS 35 CC	-	1.18
EDEN CRESCENT SHAREBLOCK LIMIT	1.46	1.30
EMIRA PROPERTY FUND	-	0.90
EMIRA PROPERTY FUND	-	0.49
FOUNTAINHEAD PROPERTY TRUST	2.04	2.10
FULLOUTPUT 161 (PTY) LTD	0.48	0.81
GROWTHPOINT PROPERTIES (PTY) L	0.72	0.69
I FOUR PROPERTIES THREE (PTY)L	0.92	0.91
J T ROSS PROPERTIES (PTY) LTD	1.76	1.55
LANNON PROPERTIES T/A	2.69	1.09
LILANE PROPERTY INVESTMENTS PT	0.44	0.30
M&R PROPERTY SERVICES (PTY) LT	0.90	0.86
MAGNOLIA RIDGE PROP 268 (PTY)L	1.17	0.99
MANCHESTER PARK BODY CORPORATE	1.05	1.07
MEBRO (PTY) LTD T/A UNIVERSAL	0.96	1.05
METBOARD PROPERTIES LTD	1.07	1.16
MILLDENE PARK RETIREMENT VILLA	0.65	0.60
NORTH BEACH PROPS SHAREBLOCK L	0.76	0.68
OLD MUTUAL PROPERTIES (NBS)	2.25	2.13
PANGBOURNE PROPERTIES LTD	0.92	0.42
PARAMOUNT PROPERTY FUND LTD	4.18	2.15
PENTA SHIPPING PROPS (PTY) LTD	1.16	1.17
RISING TIDES PROPERTY TRUST	0.44	0.42
SAN MARINA INVESTMENTS (PTY) L	1.53	1.54
SIYATHENGA PROPERTIES ONE	1.34	1.30
THE BODY CORP OF MARINE SANDS	0.96	0.89
THE BODY CORPORATE OF THE	2.65	2.48
TIKDAV INVESTMENTS CO	1.64	1.54
TREMOR PROPERTIES SHAREBLOCK L	1.39	1.28
VIDYA PROPERTIES (PTY) LTD	1.10	0.64

BODY CORPORATE OF WINDERMERE	0.1531	0.1531
RYCKLOF BELEGGINGS (PTY)LTD	4.28	3.25
FULLOUTPUT 161 (PTY) LTD	0.1283	0.1283
Real Estate Activities	332.37	339.49
GALBORN (PTY) LTD	84.75	67.86
DRAKE AND SCULL FM SA (PTY)LTD	35.61	34.34
DURBAN MARINE THEME PARK P/L	29.53	30.69
NATAL NEWSPAPERS (PTY) LIMITED	10.11	9.84
CHANGING TIDES 74 (PTY) LTD	9.56	9.68
SILVERAY STATIONERY (PTY) LTD	9.27	9.55
ZIMCO GROUP (PTY) LTD T/A	5.51	5.43
POINT CIRCLE (PTY) LTD	4.33	2.93
IDAHO (PTY) LTD T/A BLUE WATER	2.61	2.60
THE LANGFORD CONSORTIUM	3.21	3.11
TRI WASTE CC	5.61	5.74
ASM & JM JADWAT T/A JADWAT	1.20	1.43
BETTERBONDERS PTY LTD	-	0.40
BOSCHRAND BELEGGINGS (PTY) LTD	0.97	0.95
CHROME RITE ENGINEERING (PTY)L	1.48	0.89
DHL EXEL SUPPLY CHAIN SA PTY L	2.56	1.79
DOVES & ADLAM REID LTD	0.53	0.49
FREIGHTMAX PTY LTD	-	1.04
FUNLAND ENTERTAINMENT CC	0.72	0.72
M.BIELOVICH T/A BMS DURBAN NOR	-	0.43
MARSHALLS PARKING (PTY) LTD	0.70	0.60
NPA.REGIONAL LAUNDRY DBN & COA	0.79	0.88
POINT YACHT CLUB	0.43	0.43
PROCLARE (PTY) LTD	2.07	2.24
PROCLARE (PTY) LTD	0.71	0.62
RAFFLES HEALTH RACQUET & FITNE	1.36	1.64
RIVERSIDE PARK TRADING 198 (PT	0.78	0.88
SHEPSTONE AND WYLIE ATTORNEYS	1.11	1.00
SIPAN 1 (PTY) LTD	1.07	0.86
SIPAN 1(PTY) LTD	0.55	0.66
SMALL BUSINESS DEVELOPMENT COR	0.42	0.38
STAND 2253 DURBAN (PTY) LTD	0.64	0.57
STYLER PRODUCTS (PTY) LTD (pot plants & landscaping)	0.45	0.44
TARGET INVESTMENTS (PTY) LTD	0.66	0.82
THE HIGHWAY MAIL (PTY) LTD	1.31	1.25
THE SHELCOLL 5 TRUST	1.13	0.89
TRIGGER 4000 INVESTMENT CC	-	0.51
VIRGIN ACTIVE SA (PTY) LTD	1.80	1.86
VIRGIN ACTIVE SA (PTY) LTD	1.97	1.70
VIRGIN ACTIVE SA (PTY) LTD	1.43	1.54
VIRGIN ACTIVE SA (PTY) LTD	1.45	1.41
VIRGIN ACTIVE SA (PTY) LTD	1.18	1.05
VIRGIN ACTIVE SA (PTY) LTD	1.23	1.01

VIRGIN ACTIVE SA (PTY) LTD	1.09	0.98
VIRGIN ACTIVE SA (PTY) LTD	0.65	0.63
TERRAFIRMANENT (PTY)LTD	4.68	4.34
THE OCEAN TRUST	-	0.92
TOTALISATOR AGENCY BOARD (TAB) NATAL	0.75	0.46
XPANDA SECURITY (PTY) LTD	2.45	2.28
ZEALAND INVESTMENTS (PTY) LTD	1.33	1.84
Other Business Activities	**241.74**	**224.62**
ETHEKWINI MUNICIPALITY	1.94	10.81
CITY SERVICES DEPT.	3.82	3.48
WATER AND WASTE DEPT	3.45	3.45
DURBAN ELECTRICTY	2.76	3.42
CITY ESTATES DEPT (RENNIE HSE)	3.09	3.03
DEP OF PUBLIC WORKS	4.31	2.94
ETHEKWINI MUNICIPALITY	2.75	2.69
ETHEKWINI MUNICIPALITY	-	2.65
CITY ELECTRICAL ENGINEER	4.60	1.88
CITY HEALTH DEPARTMENT	0.91	0.95
DEPT OF LOCAL GOVT.& TRADIONAL	0.92	0.80
DEPT OF POSTS & TELECOMM	0.51	0.43
DEPT OF PUBLIC WORKS	0.63	0.45
DEPT OF PUBLIC WORKS: REGIONAL	0.38	0.64
DURBAN CITY POLICE	1.61	1.45
DURBAN METRO WATER & WASTE	1.96	1.86
DURBAN METRO WATER (KINGSBURGH	1.16	1.14
DURBAN METRO WATER SERVICES	2.21	2.15
DURBAN METRO WATER SERVICES	1.65	1.81
DURBAN METRO WATER SERVICES	1.00	0.70
DURBAN METRO WATER SERVICES	0.46	0.39
DURBAN WATER & WASTE	1.68	1.94
DURBAN WATER & WASTE	0.68	0.52
DURBAN WATER & WASTE	0.29	0.40
ETHEKWINI ELECTRICITY	-	0.45
ETHEKWINI MUNICIPALITY	-	2.33
ETHEKWINI MUNICIPALITY	-	2.30
ETHEKWINI MUNICIPALITY	-	2.23
ETHEKWINI MUNICIPALITY	-	2.05
ETHEKWINI MUNICIPALITY	-	2.04
ETHEKWINI MUNICIPALITY	-	1.67
ETHEKWINI MUNICIPALITY	-	1.02
ETHEKWINI MUNICIPALITY	-	0.98
ETHEKWINI MUNICIPALITY	-	0.90
ETHEKWINI MUNICIPALITY	-	0.85
ETHEKWINI MUNICIPALITY	-	0.59
ETHEKWINI MUNICIPALITY	-	0.50
ETHEKWINI MUNICIPALITY-	0.50	1.76
ETHEKWINI MUNICIPLITY	-	0.73
ETHEKWINI WATER SERVICES	0.98	2.45

METRO WASTE WATER MANAGEMENT	1.91	1.78
METRO WASTE WATER MANAGEMENT	1.14	1.04
METRO WASTE WATER MANAGEMENT	0.44	0.45
PROVINCIAL DEPT OF HEALTH	2.17	2.06
REAL ESTATE DEPARTMENT	2.58	2.13
SECRETARY FOR WORKS KWAZULU GO	0.90	0.80
THE DEPT OF HOUSING	2.90	0.43
THE DEPT OF HOUSING	2.77	0.37
THE DEPT OF HOUSING	2.61	0.36
THE DEPT OF HOUSING	2.32	0.34
THE DEPT OF HOUSING	2.49	0.34
THE DEPT OF HOUSING	2.29	0.33
THE DEPT OF HOUSING	2.37	0.33
THE DEPT OF HOUSING	1.07	0.29
THE DEPT OF HOUSING	1.28	0.21
UMGENI WATER	0.50	0.43
UMGENI WATER BOARD	0.78	0.80
THE DEPT OF HOUSING	1.2277	0.1573
THE DEPT OF HOUSING	0.9578	0.1356
THE DEPT OF HOUSING	0.9409	0.1190
TRANSPORT DEPT	0.1655	0.1655
Public Admin & Defence Activities	**78.06**	**85.92**
UNIVERSITY OF KWAZULU NATAL	26.44	28.09
UNIVERSITY OF NATAL	21.71	12.65
DURBAN INSTITUTE OF TECHNOLOGY	8.08	7.65
UNIVERSITY OF KWAZULU -NATAL	5.81	5.25
DURBAN INSTITUTE OF TECHNOLOGY	4.92	4.78
UNIVERSITY OF KWAZULU-NATAL	4.44	4.27
UNIVERSITY OF KWAZULU-NATAL	3.01	3.22
THE INDEPENDENT INSTITUTE OF EDUCATION	0.79	0.76
UNIVERSITY OF SOUTH AFRICA	2.25	1.94
Education	**77.44**	**68.62**
THE MEDICAL SUPERINTENDENT	17.66	18.06
NETCARE KZN (PTY) LTD T/A	13.78	13.30
MEDICAL SUPERINTENDANT	10.22	9.80
MEDICAL SUPERINTENDENT	8.23	8.29
ENTABENI HOSPITAL LTD	7.62	7.64
COMMUNITY SERV. HSING NINGIZIM	7.77	7.53
HIWAY MEDICAL CENTRE LIMITED	6.74	5.64
THE MEDICAL SUPERINTENDENT	7.32	7.19
SOUTH AFRICAN NATIONAL BLOOD	7.13	7.06
AMALGAMATED HOSPITALS LTD	2.28	6.69
THE MEDICAL SUPERINTENDENT	6.51	5.84
UMHLANGA MEDICAL CENTRE T/A	5.02	4.80
CITY HOSPITAL LIMITED	4.07	4.18
NETCARE HOSPITALS (PTY) LTD	4.02	4.02
KING GEORGE V HOSPITAL	2.67	3.94
MAHATMA GANDHI MEMORIAL HOSPIT	3.04	3.00

AMALGAMATED HOSPITALS LTD	2.75	2.70	
CHATSMED GARDEN HOSPITAL	2.10	2.15	
ISIPINGO HOSPITAL LIMITED	2.50	2.31	
KING GEORGE V HOSPITAL	0.91	0.57	
KZNPA HILLCREST HOSPITAL	1.44	1.49	
MCCORD HOSPITAL	1.63	1.70	
MEDICAL RESEARCH COUNCIL	0.77	0.71	
NETCARE KZN (PTY)LTD T/A	2.30	2.32	
OSINDISWENI HOSPITAL DEPT HEAL	2.36	2.18	
SPARKPORT PHARMACY & MEDICINE	0.61	0.59	
ST MARYS HOSPITAL	1.69	1.02	
THE MEDICAL SUPERINTENDENT	1.29	1.48	
VICTORIA HOSPITAL LIMITED	2.31	2.24	
Health and Social Work	**136.72**	**138.44**	
DEPT OF PUBLIC WORKS - REG MNG	15.09	14.45	
ICC DURBAN (PTY) LTD	10.28	10.31	
S A B C	3.90	3.79	
KWAZULU-NATAL PERFORMING ARTS	3.69	2.92	
CORPORATE SERVICES	3.94	3.50	
Other Service Activities	**36.90**	**34.98**	
TOTAL (GWh)	**5 035.75**	**4 701.20** **18 128 687.65**	**4 701.20**
Total (GJ)	18 128 687.65	16 924 310.71	

Split Between Industrial and Commercial Sector

Bulk Commercial Electricity Users = Trade + Financial and real estate services + Transport Services + Public admin and services + Other business

= 6 735 513.9 GJ

Other Commercial Electricity use = 6 795 462.6 GJ

Total Commercial Electricity use = 6 735 513.9 + 6 795 462.6 = 13 530 976.5 GJ

Total Industrial Energy use = 11 469 650.7 GJ

Total Electricity: Industrial & commercial sector = 13 530 976.5 + 11 469 650.7 = 25 000 627 GJ

8 APPENDIX 2 – OTHER ENERGY SOURCES

8.1 2.1 Coal Data

Details of the specific companies and institutions are confidential

Sector	GJ
Primary sector	232 900
Petroleum, chemical and rubber products	721 490
Wood and wood products	4 548 720
Food, beverages and tobacco products	3 971 170
Textiles, clothing and leather goods	765 830
Other Manufacturing	2 005 875
Trade	-
Financial and real estate services	-
Transport services (	13 700
Public admin and services	241 120
Other business and services	7 398
Total	**12 508 203**

8.2 2.2 Liquid Fuels

Liquid Fuel Data 2005/2006						
	DIESEL	**HFO**	**IP**	**JET**	**LPG**	**PETROL**
Megalitres	**888.72**	**73.78**	**111.01**	**86.96**	**119.30**	**949.24**
Gigajoules	33 860 156	3 069 259	5 099200	2 974 099	3 185 254	32 463 964

LPG breakdown

Sector	Gigajoules	Percentage
Manufacturing	637 050.85	20%
Commercial	1 751 889.84	55%
Residential	796 313.56	25%
TOTAL	**3 185 254.25**	**100%**

Transport Fuels Breakdown

Road Transport	Litres	Gigajoules
Diesel	869841886	33140976
Petrol	948894823	32452203

Total Gigajoules		**65593179**
Ship Transport		
Diesel	18876121	719180
Petrol	343898	11761
Jet Fuel	295523	10136
Total Gigajoules		741078
Aviation Transport		
Jet Fuel	86666442	2972659
Fraction of fuel burnt in Durban airspace	4246656	145660
% of fuel sold, burnt in Durban airspace	4.90%	

8.3 2.3 Methane Rich Gas

Total MRG Consumption (as per GHG Inventory, Mthoko Mbatha) : **4 000 000 GJ**

8.4 2.4 Bagasse

Industry	**tonnes**	**GJ**	**source**
Tongaat Hulett	380 000	2 508 000	Allan d. Ferguson
Illovo	420 000	2 940 000	
TOTAL	**800 000**	**5 448 000**	
CV bagasse = 6600 MJ/ton			
These numbers vary from year to year depending on crop size etc.			

APPENDIX 3: GDP SUMMARY [9]

GDP Sector Summary	2006 (thousand Rands)	% GDP
Primary sector	1 574 296	1.37%
Petroleum, chemical and rubber products	5 820 460	5.06%
Wood and wood products	3 122 837	2.71%
Food, beverages and tobacco products	4 539 269	3.94%
Textiles, clothing and leather goods	2 257 670	1.96%
Other Manufacturing	10 763 969	9.35%
Trade	19 129 611	16.62%
Financial and real estate services	17 725 245	15.40%
Transport, storage and telecommunication	18 594 146	16.16%
Community, personal and social services	21 032 417	18.28%
Other business and services	10 514 853	9.14%
Total	**115 074 772**	**100%**

GDP by sector (Recorded and Forecast)

(thousand R)

	Agriculture	Mining	Manufacturing	Electricity	Construction	Trade	Transport	Finance	Community services	Total Industries	Taxes less Subsidies	Total (GDP)
1996	1307719	386028	19018598	2663169	2438855	11742395	10678167	13773026	15437553	77445511	7715918	85161429
1997	1297446	447308	19369826	2761990	2585600	11866318	11268139	14356407	15159485	79112520	8387837	87500357
1998	1299071	404148	19363166	2597025	2298103	12061189	11774333	14651876	15734781	80183693	8349083	88532776
1999	1263258	258047	19596339	2612574	2166331	12953556	12166174	15587769	15556806	82160854	8235228	90396082
2000	1310509	212988	21478974	2800571	2273844	14140817	13056071	15847931	15736352	86858058	8528552	95386610
2001	1304376	264408	22343687	2832444	3074629	15361874	13685548	16889144	16003110	91759219	9148796	100908015
2002	1379486	203775	22727032	3104112	2435408	15757647	15012018	17806657	16106911	94533044	9122504	103655548
2003	1423335	195154	22668274	2714917	2539870	16936019	16040306	18587325	16575322	97680522	9291444	106971966
2004	1431835	188920	23747180	2812910	2832258	17939577	16752307	20166039	16892913	102763940	9737252	112501192
2005	1521067	184392	25030898	2898917	3204435	19186471	17613432	21486166	17416750	108542527	10217760	118760286
2006	1393363	187042	26312751	2970518	3573306	20692267	18889580	22833417	18210063	115062307	10913063	125975370
2007	1466838	184776	27489607	3065710	4169786	21905280	20086116	24562410	18936556	121867080	11371563	133238643
2008	1770403	157198	27978007	3025280	4709059	22133236	20986616	25866727	19685684	126312211	11598053	137910264
2009	1787783	145147	26543852	2926131	4761328	21414112	20440452	25179444	19799825	122998074	11728545	134726619
2010	1813694	147601	26916191	2978329	4889352	21822362	20858520	25745845	20228482	125400377	11943607	137343984
2011	1868793	153053	27951355	3095972	5210633	22797002	21773009	26872545	20964361	130686724	12413987	143100711
2012	1930981	159070	29192608	3241350	5548045	23959929	22868150	28233238	21860599	136993969	12987081	149981050
2013	1988977	165893	30586932	3411575	5881625	25233839	24099947	29772625	22854863	143996277	13630540	157626817