Assessing South Africa's Potential to become a Low Carbon Society

A Backcasting approach to climate change mitigation assessment

By

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Abstract

This research work examines how South Africa can change from its current 'business as usual' (BAU) development path into a LCS developmental trajectory that takes into account behavioural change and sustainability over a 50-year period (2000-2050), using a goal-orientated approach as the point of departure for mitigation analysis. As such, two low carbon society visions are developed. One vision is that of a technology driven society with more emphasis on individual needs (scenario ZA50A). For ZA50A, convenience is a priority and Gross Domestic Product (GDP) grows at two per cent. Here, society is driven by technology advancements which have profound benefits for power generation. The second vision is that of a society sensitive to behavioural change and with a community-centered focus (scenario ZA50B). In the case of ZA50B, LCS forms part of social and cultural values and GDP grows at a rate of one per cent. There is greater emphasis on developing local energy resources and low carbon technologies. Sustainability is favoured over rapid economic growth. Interestingly, both visions demonstrate that 65% of emissions relative to the CO_2 levels of 2000 can be saved. Assessing these visions is only part of the problem, though: changing the current situation of 'business as usual' (BAU) by realising either of these visions is another problem altogether. However, the approach adopted here differs from the traditional forecasting mitigation analysis, which first assesses the current 'BAU' emissions profile, before it uses mitigation actions to arrive at the best possible situation. Instead, this thesis follows a normative approach, which begins by setting the visions for a LCS assessment, before using a backcasting analysis to project the emissions savings back to the current situation. The visions are quantitatively assessed by using an 'energy snapshot' (ESS) tool.

The added advantage of this approach is that assessment and solutions to obstacles are embedded in the backcasting analysis. Twelve potential LCS actions are thus developed for each scenario, and the relevant / their emissions savings potential is assessed by using the 'backcast model' (BCM).

Five LCS actions are common to both scenarios. Since LCS actions are targeted at influencing behaviour, they are mainly focused on service demand energy sectors, namely, commercial, industrial, residential as well as the transport (private and freight). Supply side energy sector is also assessed.

The analysis conducted here shows that it is possible to set a reasonable long-term emission reduction target of 65% relative to 2000 levels by 2050. This target is comparable with targets set elsewhere in the world. The ZA50B scenario performs better than ZA50A scenario due to low energy intensities and lower economic growth. However, both LCS scenarios show a potential for reducing emissions by over 50% by 2050. Most emissions savings are related to changes in the energy mix for power generation (over 60%), followed by the establishment of manufacturing and commercial sectors that are more climate conscious and the use of cleaner fuels for transport.

Penetration of LCS actions show that, for scenario ZA50A, the critical period for implementation is between 2010 and 2020 and that the impact of LCS actions under this scenario matures between 2030 and 2045. This differs slightly from scenario ZA50B, whose critical period of implementation is 2008-2018, with LCS actions reaching maturity between 2035 and 2045. In the ZA50B pathway, most of the LCS actions are implemented later due to long-term infrastructure development and limited availability of technologies.

Carbon decomposition analysis shows that, in the ZA50A scenario pathway, economic growth and demand for commercial space, goods and services contributes to increasing service demand. In the case of ZA50B pathway, in contrast, service demand remains constant due to assumed constant economic growth. In both pathways, energy intensity changes are reduced due to energy efficiency measures, mostly in the industrial and commercial sectors. This also reduces carbon intensity, coupled with the use of renewable energies for end-use applications such as solar water heating. Carbon intensity changes in the transformation sector are due mainly to the introduction of nuclear and renewable energies for power generation as well as carbon capture and storage for synfuels and power generation.

This thesis demonstrates that it is possible to follow a pathway that changes people's behaviour without compromising the quality of life that is currently being enjoyed. This is demonstrated by the selection of mitigation options explored in both ZA50A and ZA50B pathways. In the ZA50A pathway, options such as improved transport logistics, transport modal shift, clean vehicle fuels and climate sensitive private transport demonstrates how improved quality of life can be sustained whilst people adopt low carbon lifestyles. This is similarly the case for ZA50B, pedestrian friendly urban city design, adoption of waste minimization principles, minimum-carbon driven consumer spending attempt to do the same.

However, in order to achieve such a pathway, serious commitment and strong policy signals towards low carbon transition need to be demonstrated by the government. Consumer education about low carbon choices is also critical. A low carbon society is not only about mitigating climate change but it is also about making gradual changes in lifestyle. Therefore, the government is encouraged to implement a LCS curriculum for learners in the lowest grades at school, to ensure that LCS principles are grasped at an early age of human development.

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I, Jongikhaya Witi, Know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own'

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Abbreviations, Acronyms and Units

3Rs	Reduce, Reuse and Recycle
AGAMA	Agama energy (company)
AIDS	Acquired immunodeficiency syndrome
AR4	Fourth assessment report
AR5	Fifth assessment report
AsgiSA	Accelerated and shared growth initiative for South Africa
ASSA	Actuarial Society of South Africa
BAU	Business as usual
BCM	Backcasting model
C'	CO_2 emission without measures in transformation sector
C	CO_2 emission with measures in transformation sector
C&S	Centralization and standardization (spatial planning approach)
C/C'	Change of CO_2 intensity by measures in transformation sector.
C'/E	CO_2 intensity in end-use sector (without measures in transformation sector)
CAF	Constraint analysis framework
CAT	Compressed air technology
CBD	Central business district
CCGT	Combined cycle gas turbines
CCS	Carbon Capture and Storage
CCT	City of Cape Town
CDM	Cleaner Development Mechanism
CERs	Certified Emission Reductions
CFLs	Compact Fluorescent Light bulbs
CGER	Centre for Global Environmental Research
CO_2	Carbon Dioxide
COP	Conference of parties
COP-8	8^{th} Conference of Parties
CSAG	Climate Systems Analysis Group

CT case	Carbon tax case
CTL	Coal to liquids
D	Driving forces (service demand)
D&I	Decentralization and innovation (spatial planning approach)
DBSA	Developmental Bank of Southern Africa
DEAT	Department of Environment and Tourism
DME	Department of Minerals and Energy
DNA	Designated National Authority
DSM	Demand-side management
E	Energy Consumption
E/D	Energy Intensity
EBT	Energy Balance Table
ERI	Energy Research Institute
ERC	Energy Research Centre
ESS	Energy snap-shot tool
GDP	Gross domestic product
GHG	Greenhouse gas
Gnr	Generated
GTL	Gas to liquids
HIV	Human immunodeficiency virus
HFCVs	Hydrogen fuel cell vehicles
HVAC	Heating, ventilation and air conditioning
ICT	Information communication and technology
IEA	International Energy Agency
IEP	Integrated Energy Plan
IGCC	Integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
kWh/m^2	kilowatt-hour/square meter
LCS	Low Carbon Societies
LPG	Liquefied petroleum gas
LSM	Launch scenario module
LTMS	Long-term mitigation scenarios

LULUCF	Land use, land use change and Forestry
M-M	MARKAL-Macro
MtCO2-eq	Megatonnes of carbon dioxide equivalent
Mtoe	Million tons of oil equivalent
MW	Megawatt
NERSA	National energy regulator of South Africa
PBMR	Pebble-bed modular reactor
PPMv	Parts per million (by volume)
QI	Quantity and Impact
R&D	Research and development
RCEP	Royal Commission on Environmental Pollution
RE	Renewable energy
RETs	Renewable energy technologies
REFIT	Renewable energy feed-in tariffs
SANBI	South African National Biodiversity Institute
SANERI	South African National Energy Research Institute
SAPIA	South African Petroleum Industry Association
SEA	Sustainable Energy Africa
SD-PAMS	Sustainable Development-Policies and Measures
SRES	Special report on emissions scenarios
SS	Sustainable policies case
SSA	Statistics South Africa
SUV	Sports utility vehicle
SWHs	Solar Water Heaters
Trans.Prv	Transport (private)
Trans.Frg	Transport (freight)
UHE	Urban higher income electrified
UK	United Kingdom
UNPD	United Nations Population Division
UNEP	United Nations Environmental Program
WCED	World Commission on Environment and Development

CHAPTER 1

1 Introduction

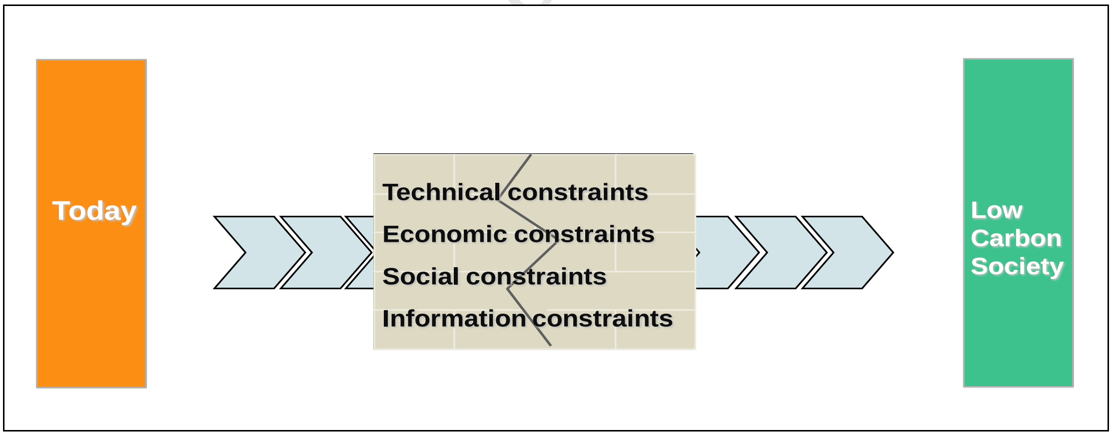
On a global scale, countries have been concerned with increasing global atmospheric concentrations of carbon dioxide (CO_2), which threatens to increase the global average temperature of the planet. Countries have responded by conducting climate change mitigation assessments to assess their own potential to reduce carbon emissions. Lessons from previous assessments indicate the need to pay closer attention to behavioural change and sustainability. It has been widely recognized that behavioural change is an important if not a critical factor to consider if economies and societies are to mitigate and adapt to the impacts of climate change. The Intergovernmental Panel on Climate Change (IPCC) at its 27th session, held in Valencia in 2007, called for the inclusion of behavioural scientist in its mitigation and adaptation working group when undertaking its Fifth Assessment (AR5) of climate change. This is particularly relevant for developing countries such as South Africa. Consequently, a new climate change mitigation theme focusing on creating low carbon society (LCS) has emerged to address sustainability and behavioural change. Hence, a number of countries including Germany, India and Japan have embarked on LCS studies to assess their potential to become low carbon societies.

In line with this trend, this study assesses the potential for South Africa to become a low carbon society. In doing so, it develops two contrasting visions or development paths for South Africa by 2050. One vision is technology driven with a society that focuses on individual self-sufficiency. The second vision is orientated towards behavioural change and emphasises the role of the community. For each vision, twelve LCS actions are deliberately chosen to reflect the nature of each vision. The mitigation potential of each of the LCS scenario pathways is investigated using a backcasting approach, which is then compared with mitigation goals that have been determined by using a forecasting approach.

LCS assessment, which is a new approach to mitigation analysis, provides an opportunity to influence or change behaviour. At the core of LCS is the promotion of consumption patterns and behaviour that are in line with low carbon emissions. This is also well in line with the definition of sustainable development. Sustainable development is defined by the World Commission on Environment and Development (WCED) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). A fundamental benefit of a LCS assessment is that it goes beyond the identification of a mitigation option by assessing potential obstacles that can hinder the implementation of a mitigation option. It is also important to highlight the obstacles associated with implementing mitigation options. Figure 1.1 shows the analysis needed in order to shift towards a low carbon society in the future, taking into account, technical, economic, and social constraints, as well as information constraints.

Figure 1.1: Low Carbon Society: Constraint Analysis

Source: (CGER 2007: 12)



Particularly in the developing world, things such as institutional arrangements, capital outlay, and awareness about technology options, the capacity to produce and operate mitigation technologies are often lacking (Skea & Nishioka 2008: 8). This presents a problem when one has to do long-term mitigation planning, as there are always uncertainties about when mitigation technologies are likely to be implemented due to such obstacles. In essence, it means that long-term planning should find a way of accounting for measures to address obstacles associated with options for mitigating climate change.

Other prominent problems associated with implementing mitigation options stem from the fact that some technologies may be in a developmental stage. In such cases, it may also be difficult to predict when these technologies are to be introduced. The technologies may require a piloting stage and they may be expensive initially due to efforts by service providers to cover the research and development (R&D) costs. All these obstacles must be identified to ensure an accurate understanding of when mitigation options are likely to be implemented, how much they would reduce greenhouse gases (GHGs), and how much they would ultimately cost.

As South Africa has to meet certain developmental objectives whilst facing climate risk at the same time, it needs to ensure that it adopts a sustainable development approach. Furthermore, there is common agreement that a climate-specific vision isolated from social and economic development may prove very expensive and that it is likely to create a large mitigation and adaptation burden for developing countries that, which already struggling to respond to other human and environmental stressors (Shukla 2008). Following the Delhi Declaration made during the COP-8 meeting in 2002, there has been significant work in framework development for the realization of co-benefits between developmental objectives as well as climate change policies and measures. For example, some studies have developed a methodology for identifying synergies in climate change and other policy areas (Kok & De Coninck 2007: 593). Possible synergies and trade-offs between three policy areas (air pollution, energy and climate change) for South Africa are shown in Table 1.1. This table illustrates how energy planning, which remains one of the key focus areas for ensuring continued development, can be implemented in a “climate proofing” manner reduces the climate risk. For South Africa and possibly other developing countries too, aligning climate change with sustainable development is not only a question of saving mitigation and adaptation costs or alleviating the burden. It presents an opportunity to invoke a new paradigm shift in policy making, particularly in the areas of energy and environmental planning. For a very long time, adherents of both policy areas have consistently failed to understand the underlying challenges that face the other party. Fairly recently, in 2006, South Africa experienced an electricity crisis that threatened the economic growth of the country. At the same time, South Africa has been making advances in climate change by concluding the Long-Term Mitigation Scenarios (LTMS) process, which detailed the mitigation options with responsibilities for all the major government departments (Winkler 2007). Even though the LTMS demonstrated the economic benefits of undertaking most of these options, and even though it received a high level of consensus, some government departments have not really embraced the outcomes of this process fully.

Table 1.1: Linkages between potential measures in air pollution, energy and mitigation

Measure	Air Pollution	Security of energy supply	Climate Change Mitigation
Power generation:			
Plant efficiency improvement	(+ve)	(+ve)	(+ve)
Increased share of renewable energy sources	(+ve)	(+ve/-ve)	(+ve)
Construction of nuclear power stations	(+ve)	(+ve)	(+ve)
Construction of more coal power stations	(-ve)	(+ve)	(-ve)
Construction of more coal power stations with Carbon Capture and Storage (CCS)	(+ve/0)	(+ve)	(+ve)
Industry:			
Energy efficiency measures	(+ve)	(+ve)	(+ve)
End-of-pipe technologies (e.g. scrubbers) to absorb air pollutants	(+ve)	(0/-ve)	(-ve)[1]
Demand-side management (DSM)	(+ve)	(+ve)	(+ve)
Transport:			
Improved fuel efficiency	(+ve)	(+ve)	(+ve)
Coal to Liquids (CTL)	(-ve)	(+ve)	(-ve)
CTL with CCS	(+ve/0)	(+ve)	(+ve)
Gas to Liquids (GTL)	(+ve/-ve)[2]	(+ve)	(+ve)
Hydrogen Fuel Cell Vehicles (HFCV)	(+ve)	(+ve)	(+ve)

[1] End-of pipe solutions require energy for operation and therefore contribute to increased emissions of greenhouse gases

[2] A life cycle assessment of gas-to-liquids does show significant contribution to greenhouse gas emissions, particularly during fuel consumption by vehicles.

Measure	Air Pollution	Security of energy supply	Climate Change Mitigation
Residential:			
Liquefied Petroleum Gas (LPG) for space heating and cooking	(+ve)	(+ve)	(+ve)
Solar panels for water heating	(+ve)	(+ve)	(+ve)
DSM	(+ve)	(+ve)	(+ve)

As a result, key government departments such as the Department of Energy and the Department of Trade and Industry have commissioned their own mitigation analysis studies. Given this potentially contradictory situation, two policy areas are about to emerge: the first will set out to address climate change at all costs, given the limited time available to avoid the impacts of a 2^{o}C increase in global mean temperature, while the second places a greater emphasis on the real challenges facing development, such as energy security. This assessment is supported by the observation that government is continuing with plans to expand coal-fired power stations and Coal-To-Liquids (CTL) plants, while limiting implementation of the LTMS actions.

In the national energy system, demand drives supply and perhaps the solution to the above problem, particularly for energy, is to look seriously at the demand-side solutions. There are many of these. This means aligning mitigation options with the rest of the economy and society through demand-side institutions and climate policies that foster sustainable development.

1.1 Climate change impacts in South Africa

To date, there is substantial evidence that the release of CO_2 and other GHGs into the atmosphere is contributing to climate change. Over the years, both land and sea surface temperatures have increased exponentially in correlation with increased CO_2 emissions. More visible than this is the increase in anthropogenic CO_2 emissions, which has been largely associated with temperature rise (IPCC 2007). Impacts associated with climate change are likely to affect the developing world the most due to its lower adaptive capacity. Africa has seen, for example, increased desertification, reduction of agricultural land, floods in low-lying areas, particularly near coastal areas, high frequency of droughts, and reduction of biodiversity, just to mention a few. The global warming problem will also have a profound impact on humans and human health. Impacts on humans include forced migration of populations in search of fertile lands for food production. The fourth assessment report (AR4) produced by the IPCC predicts that there is going to be an increase in endemic mortality and morbidity due to diarrhoea attributed to frequent floods and droughts..

Research done in South Africa also reveals subtle changes in the climate as well as in biodiversity. For example, continued sea level monitoring along the Kwazulu-Natal coastline illustrates that sea levels have risen on average by over 0.1 meters between 1970 and 2003 (Mather 2007). Data from the Climate Systems Analysis Group (CSAG) show that Mean monthly minimum temperature measurements in the Western Cape have shown an increase of over $2^{o}C$ between 1970 and 2000 (SANBI 2009). Historical measurements of rainfall between 1945 and 2001 in the Western Cape (Jonkershoek) and KwaZulu-Natal (Cathedral Peak) have shown reductions of 20% and 14% respectively (SANBI 2009). Modelling work on biome shifts predicts significant reductions in all biomes with serious implications for fynbos and grassland biomes by 2050, if global mean temperatures increase by $2^{o}C$. Soil moisture days (the number of days when both soil moisture and temperature are suitable for plant growth) are expected to decrease to less than 20 days a year for regions such as the Northern Province and some parts of the Western Cape by 2050.

Based on this research and on the work of the IPCC, it is obvious that South Africa faces a serious risk of climate changes that it cannot afford to ignore. This means that the country must ensure that it strengthens its adaptive capacity to be able to withstand such climate changes.

1.2 Research objectives

The main objective of this research work is to examine how South Africa can change from its current 'business as usual' (BAU) development path into a

LCS developmental trajectory that takes into account behavioural change and sustainability over a 50-year period (2000-2050), using a goal-orientated approach as the point of departure for mitigation analysis. This will be addressed by means of the following sub-objectives:

- Building of two LCS scenarios and their respective storylines with contrasting developmental paths over a 50-year period. The first LCS scenario is that of a "technology driven" society. The second scenario follows a behavioural change sensitive society;
- Developing a set of twelve LCS mitigation actions, and populating two scenarios with variants and combination of these actions;
- Using base year energy consumption data and choosing the best LCS actions based on their potential to mitigate climate change, to determine appropriate goals for each LCS developmental path and forecasting in that regard;
- Assessing the obstacles to these and deriving related solutions (mitigation options) associated with implementing the identified actions in order to diminish greenhouse gas (GHG) emissions for the energy sectors identified;
- Analysing the scenarios by using a backcasting model (BCM) to assess the impact of the chosen actions with regard to reducing GHG emissions or simply meeting the mitigation goals;
- Comparing the results of fore- and back-casting

1.3 Thesis Outline

The outline of the thesis is as follows: Chapter 2 summarises existing approaches to LCS assessments by reviewing recent work in the areas of LCS policies and practices. It also demonstrates the alignment between climate change mitigation and sustainable development under the LCS approach. In this regard, Chapter 2 looks specifically at developing countries whose development characteristics resemble those of South Africa, as well as considering evidence of LCS implementation in countries such as India, Germany, Japan and the United Kingdom (UK).

Chapter 3 evaluates current tools and methods available for the assessment of low carbon societies. It assesses the energy snapshot (ESS) tool, which is both the foundation and the starting point for a LCS assessment. The ESS tool is populated with supply and demand-side energy data in the base year and integrated into the Backcasting Model (BCM), which is used to develop LCS scenarios, taking into account the obstacles outlined in Figure 1.1.

Chapter 4 assesses South Africa’s development path under different LCS developmental conditions. Two LCS scenarios (referred to as ZA50A and ZA50B respectively) are developed, and the ESS tool is used to assess LCS emission goals. LCS scenario ZA50A portrays a technology driven society with emphasis on individual needs, with convenience as a main priority. LCS scenario ZA50B, in contrast, portrays a society that is sensitive to behavioural change and that has a strong community orientation.

Chapter 5 develops the twelve proposed actions for each LCS scenario. Firstly, it analytically uses the ESS tool to determine the climate change mitigation goal for each developmental path. Thereafter, it uses the constraint analysis framework (CAF) to identify potential obstacles associated with the mitigation options, and it evaluates possible actions to avoid such obstacles. Actions are identified on both the supply-side and the demand-side. Then, using the BCM model, a quantitative analysis of emissions savings over the period of study (2000-2050) is performed for each LCS action.

Chapter 6 presents the results of the BCM scenario analysis as well as of the carbon emission decomposition analysis for all service demand energy sectors. Furthermore, it also provides an analysis of the energy supply mix and the penetration of LCS actions, showing the critical period of LCS action implementation for both scenarios.

Chapter 7 offers an in-depth synthesis of the results obtained in Chapters 4, 5 and 6, while assessing whether the mitigation results from backcasting analysis will meet the mitigation goals as determined in the forecasting analysis done in Chapter 5. Chapter 8 summarises the conclusions drawn from the outcomes of this study, and it recommends future improvements in LCS studies and the implementation of their findings.

In summary, this study seeks to assess whether South Africa, given its developmental challenges, can achieve a low carbon developmental path of any form by 2050. It is important to remember that South Africa is not facing this challenge alone. It can therefore learn from the experiences of other countries that have begun to move towards developing a low carbon society. As such, Chapter 2 below reviews what has been done in the area of LCS in other countries, specifically by looking at how LCS is implemented while taking into account the circumstances unique to each country, as well as obstacles and opportunities.

CHAPTER 2

2 Review of LCS approaches to mitigation assessment

The area of LCS research is relatively new. It arose mainly because countries around the world are realising the urgency of significantly reducing their GHG emissions (Mander et al. 2008, Shimada et al. 2007, Shukla et al. 2008, Skea & Nishioka 2008, Strachan et al. 2008). The need to associate GHG emission reductions with societal behaviour and lifestyles has never been fully explored in the past and certainly not in the South African context. In addition, there is a need to focus attention on demand-side technologies, as societies deal with them directly. Recently this has prompted the Intergovernmental Panel on Climate Change (IPCC) to discuss incorporating social and behavioural scientist in the working groups that deal with adaptation and mitigation (IPCC 2007). Over the past four years, Japan and the UK (Strachan et al. 2008) have established closer collaboration in this area, and both countries are already investigating future scenarios for achieving a low carbon society. Other countries, such as India, have followed suit (Shukla et al. 2008) and are starting to produce research based on the specific conditions prevalent in their own country conditions. Some of the most recent research work in this area is discussed in the following sections.

There are well-established approaches to GHG abatement that also ensure sustainable development, particularly for developing countries and in the least developed countries. An example of this is the so-called Sustainable Development-Policies and Measures (SD-PAMs) approach (Winkler et al. 2008). Its main objective is to align climate change and sustainable development objectives. It has limited influence in the developed world, which faces no or few challenges associated with Sustainable Development, unlike the developing world. Even though SD-PAMs are voluntary, they may not prompt developed countries to contribute seriously to GHG abatement.

Unlike SD-PAMS, however, the establishment of low carbon societies provides an opportunity even for the developed world to assess actions aimed at reducing GHG emissions that are not necessarily linked to developmental issues but that are nonetheless directly associated with service demand change by changing social behaviour, lifestyles and institutions. By following this approach, the standards of comfortable living in the developed world are maintained at low carbon intensities. For the developing world, similarly, it means that developmental growth is not compromised but can be achieved with low carbon intensities.

In essence, the LCS approach uses the concept of “backcasting” to set an emission reductions vision for the future. This is different from the conventional way of doing mitigation analysis, which has tended to be prospective in nature, or directed towards the future. Mitigation analysis studies that have followed a prospective approach include the ‘Long-Term Mitigation Scenarios’ (LTMS) for South Africa (Winkler 2007), and the Energy Futures study for South Africa (Taviv et al. 2008). Such studies develop scenarios that look forward towards possible futures, purely based on the extension of key drivers.

LCS based scenarios, in contrast, take the desired end point as their point of departure, before stepping back in time to explore how this end goal may be achieved (Mander et al. 2008: 3755). For example, in the case of Japan, the goal (or vision) is to achieve a 70% reduction in 2000 carbon emissions by 2050 (Skea & Nishioka 2008: 8). For the UK, the vision is to achieve a 60% reduction in 2000 by 2050 (Anderson et al. 2008: 3764). The backcasting model (BCM) for South Africa is discussed in detail in Chapter 3.

2.1 Hybrid modelling of long-term carbon reduction scenarios for the UK

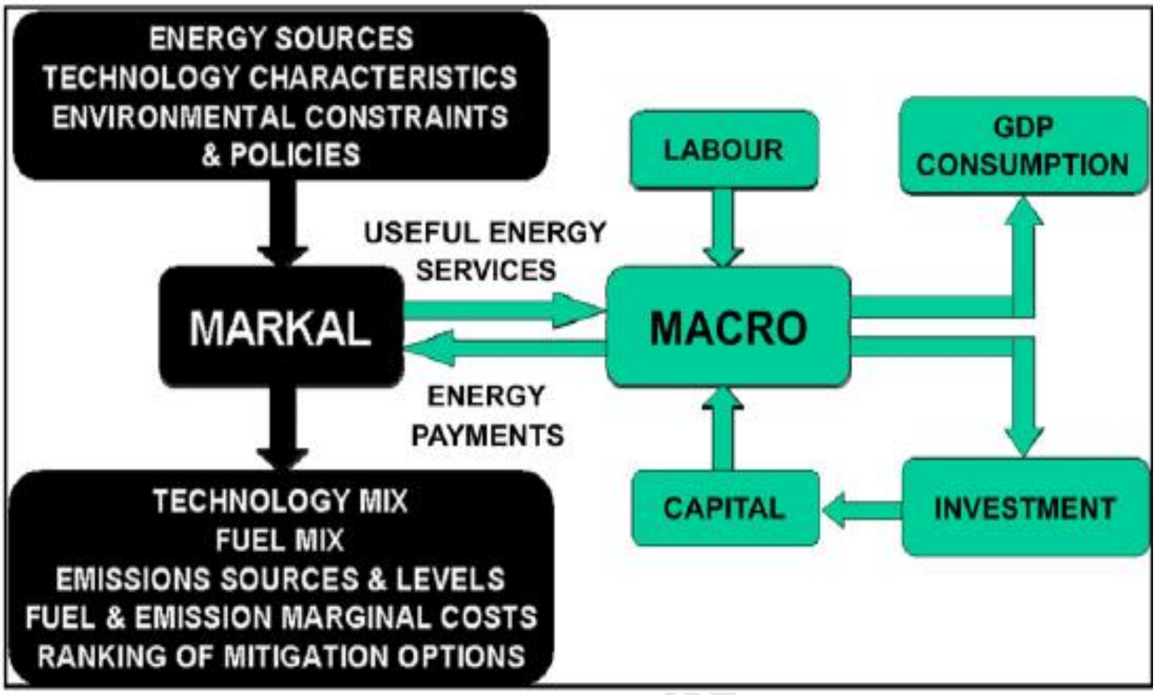
In an attempt to perform an analytical assessment according to the climate policy set by the Royal Commission on Environmental Pollution (RCEP 2000), Strachan and Kannan (2008) developed decarbonising energy scenarios for achieving a 60% reduction in carbon emissions by 2050, as set by RCEP. They thus used a hybrid MARKAL model termed MARKAL-Macro (M-M) whose characteristics are summarised in Figure 2.2. The results of hybrid modelling in this study show fundamental trade-offs between behavioural and technology changes. For instance, the study shows that, under CO_2 constrained scenarios, the M-M runs tend to favour carbon-neutral electricity generation, which implies an even further CO_2 reduction in the residential and commercial sectors with minimal behavioural changes.

However, expansion of carbon-neutral electricity in the UK is limited by the cost-effective storage of carbon. This means that the UK's CCS potential is very low. More importantly, in the context of LCS, and using a pathway leading to 60% CO_2 reduction in 1990 emission levels by 2050, the study showed that, once general conservation measures have been stretched to their upper limit, targeted behavioural changes in the service demand sectors are able to contribute between 10-15% towards emission reduction which is a sufficiently large amount.

In summary, this study confirms that significant long-term CO_2 emission reductions are possible and that the link between technological and behavioural change is fundamental in realizing emission reduction targets that are cost-effective and shared reasonably across sectors. Also, given future uncertainties in technological and behavioural changes, an iterative approach is needed within long-term energy and climate policy frameworks. It is important to note that emission reduction through behavioural changes, as proposed in this study, was not necessarily an objective function in the M-M model, but resulted through further scenario development. Hence, it is possible to reduce emissions even further by building more robust low carbon scenarios whose orientation is purely based on measures of behavioural change.

Figure 2.1: UK MARKAL-Macro (M-M) overview schematic

Source: (Strachan & Kannan 2008: 2950, fig.1)



In the case of South Africa, a technology-driven scenario can be weighed against a scenario that is sensitive to behavioural changes to assess the impacts of behaviour targeted mitigation interventions

2.2 A climate protection strategy for Germany

Erdmenger et al. (2009) investigated the possibility of reducing Germany's CO_2 emission by 40% by 2020, as compared to 1990 emissions, as shown in Figure 2.3. Even though the results of the study do present major savings on the supply side, mainly through electricity generation (savings of 40 Mt), the results also identify potential savings on the demand side through rehabilitation of buildings (savings of 31 Mt) and a shift to public passenger transport (15 Mt). Most importantly, and more relevant to the LCS approach, this study recognizes the obstacles associated with implementing the measures identified, which are listed as follows (Erdmenger et al. 2009: 159):

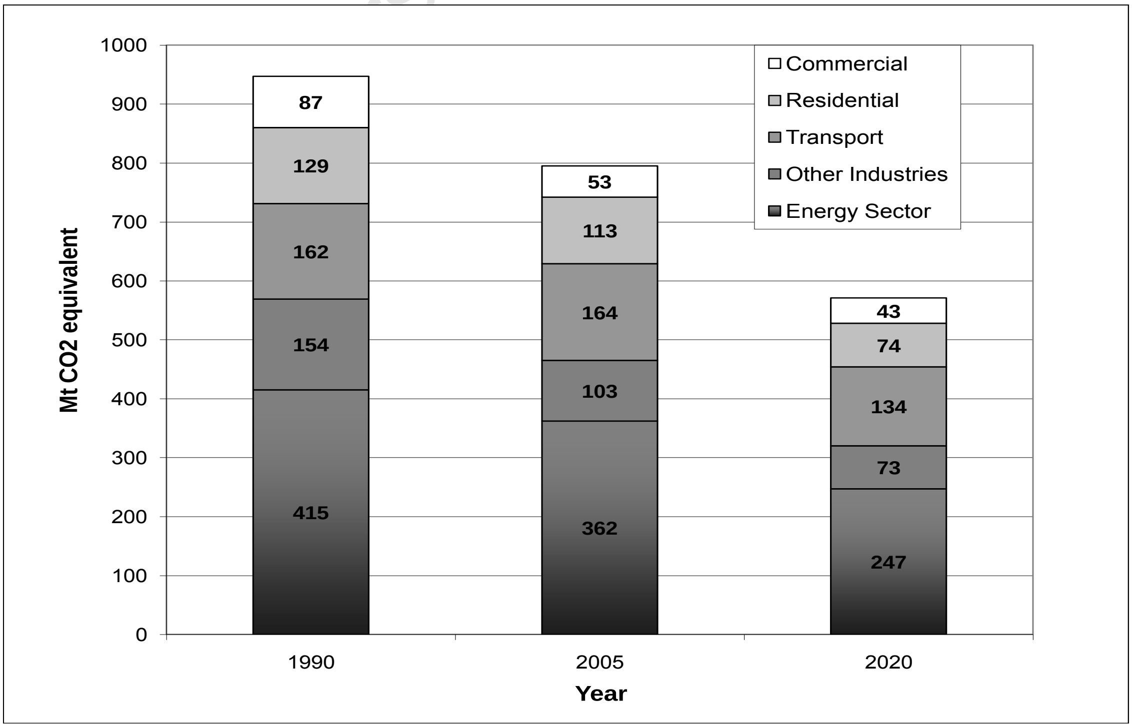
- Economic feasibility of the relevant measure in terms of the lowest abatement costs per reduced tonne of CO_2
- Ability to overcome administrative and legal obstacles to emission reduction

- Ability to identify and influence necessary behavioural changes

The obstacles identified by Erdmenger et al. (2009) are specifically addressed in the LCS approach, with a particular emphasis on behavioural changes. Even though their study has adequately addressed the first obstacle of economic feasibility (it identifies an average cost of 50 euro per tonne of carbon, its modelling framework has not properly addressed the last two obstacles (administrative and behavioural change). Hence, Erdmenger et al. (2009: 159) propose that the success of commercial and residential related actions depend on the eradication of obstacles such as information scarcity, especially with regard to energy-saving options, and that therefore the calculated emission reductions cannot be fully achieved. If their study had followed the LCS approach, I contend that it would have been possible to identify solutions to the problem. For example, the modelling framework of the LCS approach incorporates the influence of awareness campaigns in achieving planned emission reductions as well as establishing the time by which these are achieved.

Figure 2.2: Energy related CO_2 emission in German's economic sectors.

Source: (Erdmenger et al. 2009: 164, fig.1)



Leverage points for influencing behaviour in the South African case do exist. For example, interventions targeted at behavioural change, such as zero-carbon driven consumer spending, adoption of waste minimization principles and pedestrian friendly urban city design all have the potential to shift the country towards a low carbon society.

2.3 Policies and practices for a low carbon society

Skea and Nishioka (2008) reviewed the development of visions for a low carbon society in Japan. In their assessment, they evaluated two visions (or possible pathways) for Japan. The first vision (viz. of a technology driven society) recommends the implementation of a social development pathway that involves high economic growth with a reduction in population owing to high literacy rates. They argue that high literacy would lead to population reduction. The second vision (viz. of changing behaviour in that society) is a gentler pathway that involves reduced economic growth, even though the population is likely to decline. An assessment of both pathways revealed that GHG emissions could be reduced by 70% from their 1990 levels by 2050. In both scenarios, the key to achieving this target lies in the mixture of technologies applied. In the first scenario, for example, there is a heavy reliance on the use of nuclear and fossil fuel, coupled with carbon capture and storage (CCS). In the second scenario, however, there is significant reliance on the use of biomass to generate electricity, as well as the production of biofuel for use in hybrid vehicles.

Skea and Nishioka (2008) also concluded that significant interventions for achieving a LCS lie mainly in the built environment, transport and the power sector. Furthermore, they observed plausible synergies between sustainable development policies and those that prompt movement towards LCS. It is recognised that movement away from fossil fuels towards biofuels is likely to create job opportunities. In addition, government involvement is particularly relevant during the transition to a low carbon society for a number of reasons. Firstly, most interventions under LCS approaches are long-term and therefore fit perfectly with conventional long-term planning strategies of governments.

Secondly, alignment of sustainable development with a transition to a low carbon society requires the involvement of government to ensure that the basic needs of the society are met and maintained.

Skea and Nishioka (2008) furthermore emphasized that policies and strategies aimed at influencing change in human behaviour and lifestyles should be implemented. This can be achieved, for instance, by removing high carbon choices from markets and providing consumers with the opportunity to benefit from low carbon choices. Also, LCS studies are unique for each country. This offers an opportunity for South Africa to conduct an LCS study based on its unique local conditions.

The first step for South Africa will be to develop its own LCS scenarios and then identify potential emission reductions. Once LCS scenarios have been defined, LCS interventions to achieve such emission reductions targets can be explored. LCS allows for constant review of interventions, in order to identify obstacles as well as solutions to such obstacles (indirect interventions). In this way, it the effectiveness of interventions is constantly reviewed.

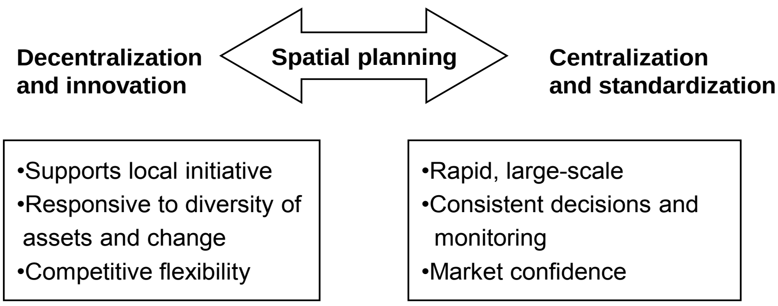
2.4 The role of spatial planning in a low carbon future with emphasis on the built environment: The UK experience

Crawford and French (2008) discuss the planning system required to support technological innovation for achieving a low carbon future in the built environment. They argue that such a planning system that is designed to deliver a low-carbon energy system should be characterized by significant levels of organizational and institutional capacity, as well as by quality knowledge systems that support the delivery of location-based objectives. Their work further reflects on some of the aspects of such a system, identifying the underlying challenges that must be addressed by spatial planning to establish a low-carbon energy system.

Crawford and French's (2008) assessment of spatial planning approaches has a bearing on the success of LCS implementation. Figure 2.4 presents two alternative spatial planning approaches, which are directly opposed to each other. Their assessment suggests that the D&I (decentralization and innovation) spatial planning approach seems to be consistent with the LCS approach. For example, they argue that the D&I approach allows for the appreciation of local resources and that it promotes local capacity development and community involvement. Furthermore, in a decentralized system, administration obstacles are avoided, which means that LCS actions are far easier to implement. Conversely, the C&S (centralization and standardization) approach involves a strongly centralised administration, which can be a major obstacle for LCS related actions. For example, a small wind farm that wants to connect to the national electricity grid may not only have to go through a rigorous process that involves significant red tape, but it may also have to incur a substantial connection fee. Moreover, the C&S approach effectively discourages innovation, as large scale installations do not easily accommodate idea driven changes that can prove to be expensive over the lifetime of the installation. This is further complicated by standardization, which makes it difficult to pilot new systems unless they are able to prescribe to all aspects of regulatory requirements, and unless they are able to either coordinate or compete with dominant infrastructures favoured by national government (Crawford & French 2008).

Figure 2.3: Approaches to Spatial Planning

Source: (Crawford & French 2008: 4576, fig.2).



The major advantage of having a D&I approach is that the role of local authorities is enhanced in response to the challenges associated with implementing LCS actions. This means that, as the local authorities develop frameworks that accommodate innovation and that set clear LCS objectives, informed decision making on LCS actions would be based on a greater understanding of local capacity. However, some LCS actions will require partnership between the public and the private sectors. As such, the role of the national government in facilitating such partnerships is crucial. The role of national government therefore would be to initiate such public-private partnerships as well as to set up funding structures and procedures and, most importantly, to raise awareness on such issues by using communication tools such as the internet. It is evident from Crawford and French's (2008) analysis that strong leadership is a crucial component for achieving a low carbon society. In addition, Crawford and French (2008: 4577) list key ingredients for shifting towards a low carbon society in the built environment, which should be consistent across other climate change mitigation sectors:

- Organizational and institutional capacity;
- The quality of knowledge basis and learning networks;
- Paying attention to innovation and constructive practice;
- Consideration of developmental issues and strategies focused on GHG reduction at source as opposed to end-of pipe solutions;
- Regulation that is sensitive to local conditions.

Even though these two distinct spatial planning approaches are applicable to all mitigation sectors, Crawford and French's (2008) study fails to allow for the possibility of a hybrid approach between C&S and D&I. Also, the link between the different approaches of spatial planning and a low-carbon society is not clearly stated. Under a D&I planning regime, it might be possible to exchange ideas, as individual local regions implement different low carbon actions. In a hybrid planning system, however, this exchange of ideas can be faster and more effective with continued monitoring by central government.

In conclusion, Crawford and French's (2008) study highlights the importance of public participation and the extensive use of communication tools to drive innovation when implementing LCS actions. This observation is further supported by the findings of the study done by Shimada et al. (2007), as discussed below. In the South African case, development of leadership in low-carbon society can act as a vehicle to drive the transition to a low carbon society and to encourage behavioural change.

2.5 Creating a low carbon economy: Application of LCS to the Shiga prefecture in Japan

Shimada et al. (2007) developed long-term scenarios to encourage the Shiga prefecture of Japan to create a low carbon society at local level. The result of their scenario analysis showed CO_2 emissions lowering by 30-50% from the 1990 level by 2030 without compromising the gross domestic product (GDP). In effect, the GDP results even showed an annual increase of 1.6%. They further argued that such emission reduction targets must be addressed through socio-economic structural changes as well as technological changes, whilst maintaining economic growth. In addition, emission reduction actions need to be driven by innovation at local level with strong leadership and capacity development from national government (Shimada et al. 2007; Crawford & French 2008).

In order to visualize a low carbon society for the Shiga prefecture, Shimada et al. (2007) developed a method of quantifying current and projected future CO_2 emission estimates from the prefecture's service demand sectors (transport, commercial, residential and industrial). In this way, it was possible to examine the society's future with an inherently low carbon economy (30-50% lower carbon emissions) and, using a backcasting approach, to identify measures that were necessary to achieve such reductions. This LCS approach was the first of its kind to be developed and applied in any area of the world. Table 2.1 shows the key drivers used by Shimada et al. (2007) to project energy both service demand and CO_2 emissions.

Table 2.1: Drivers for service demand and CO_2 emission projections

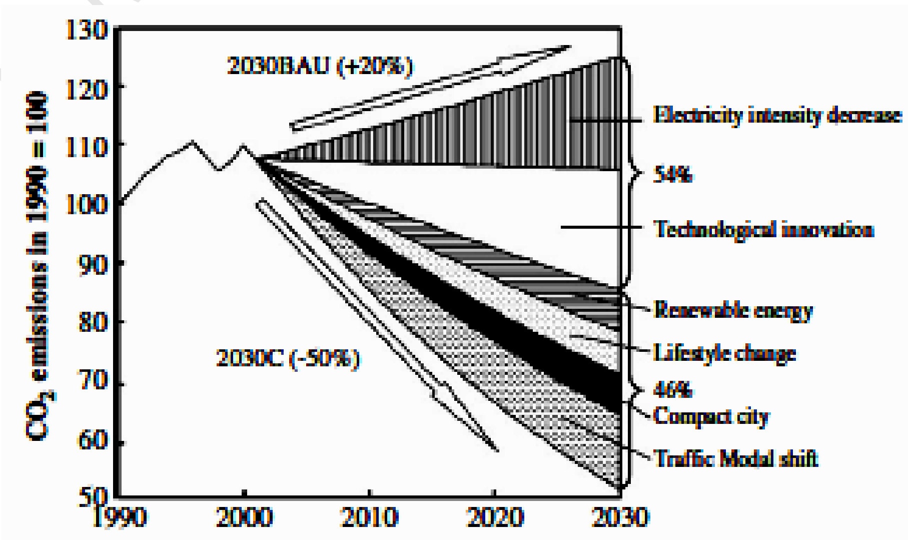
Source: (Shimada et al. 2007: 4692)

Sector	Activity level index by sector
Industrial	Production amount (Japanese yen) by industry
Residential	Number of households (households)
Commercial	Office floor areas (m^2)
Passenger transport	Transport volume by transport mode
Freight transport	Transport volume by transport mode (ton-km)

Furthermore, Shimada et al. (2007: 4696) developed a suite of measures across the energy service demand sectors to achieve the envisioned emission reductions. Results from the analytical assessment of these measures points to a 50% carbon emission reduction relative to the BAU scenario. A reduction in electricity intensity and technological innovation, when combined, contribute 54% in avoided CO_2 emissions (see Figure 2.5). A combined contribution of 46% is attributed to measures such as renewable energies, lifestyle change and traffic modal shift.

Figure 2.4: Emission reduction through LCS measures in the Shiga prefecture, Japan.

Source: (Shimada et al. 2007: 4700, fig.9)



Furthermore, Shimada et al. (2007) performed a sensitivity analysis to test the sensitivities of certain key drivers, such as the GDP growth rate, industrial structural change and traffic modal share. The results of the lowest GDP growth rate case (at 0.87%) show a 21% decrease whilst constant industrial sector structure will increase emissions by up to 30% by 2030. In their conclusion, Shimada et al. (2007) emphasise the importance of regulations and the development of efficiency standards, particularly for the commercial and residential sectors. As observed by Crawford and French (2008), this requires strong leadership and support from national government. Therefore, the role of local authorities would be to support innovation and the implementation of measures at local level. Another encouraging observation from the study by Shimada et al. (2007) revolves around the bold step taken by the local bank (Biwako Bank) situated within the Shiga prefecture: this bank had considered offering low-interest loans to promote R&D in the production of efficient appliances, mostly for the residential sectors but also to some extent in small office set-ups. Shimada et al. (2007: 4701) also noticed that such an initiative would not only contribute to emission reduction, but it would also contribute towards lowering the investment costs in alternative technologies for households. A lesson for South Africa in this regard is to place technology innovation and leadership at the forefront of behavioural change. This should also be supported by the introduction of public-private partnerships and a strong regulatory framework to accelerate implementation of mitigation options.

2.6 Developing pathways to low carbon land-based transport in Great Britain by 2050

A study by Bristow et al. (2008) examined the possibility of a 60-80% reduction in CO_2 emissions from 1990 levels in the transport service demand sector by 2050. Their study evaluates aspects, such as technological development, pricing and shift towards public transport. The following methodological approach was followed for this study:

- Set-up of specific targets for CO_2 reduction in the transport sector;
- Development of an Excel based model, largely founded on aggregated vehicle kilometres by mode to establish a baseline;
- Employment of the developed model to construct a BAU scenario projected for 2050;
- Further exploration of mitigation instruments such as traffic modal shift and engine efficiencies to determine their impacts on the overall reduction of emissions during the modelling period.

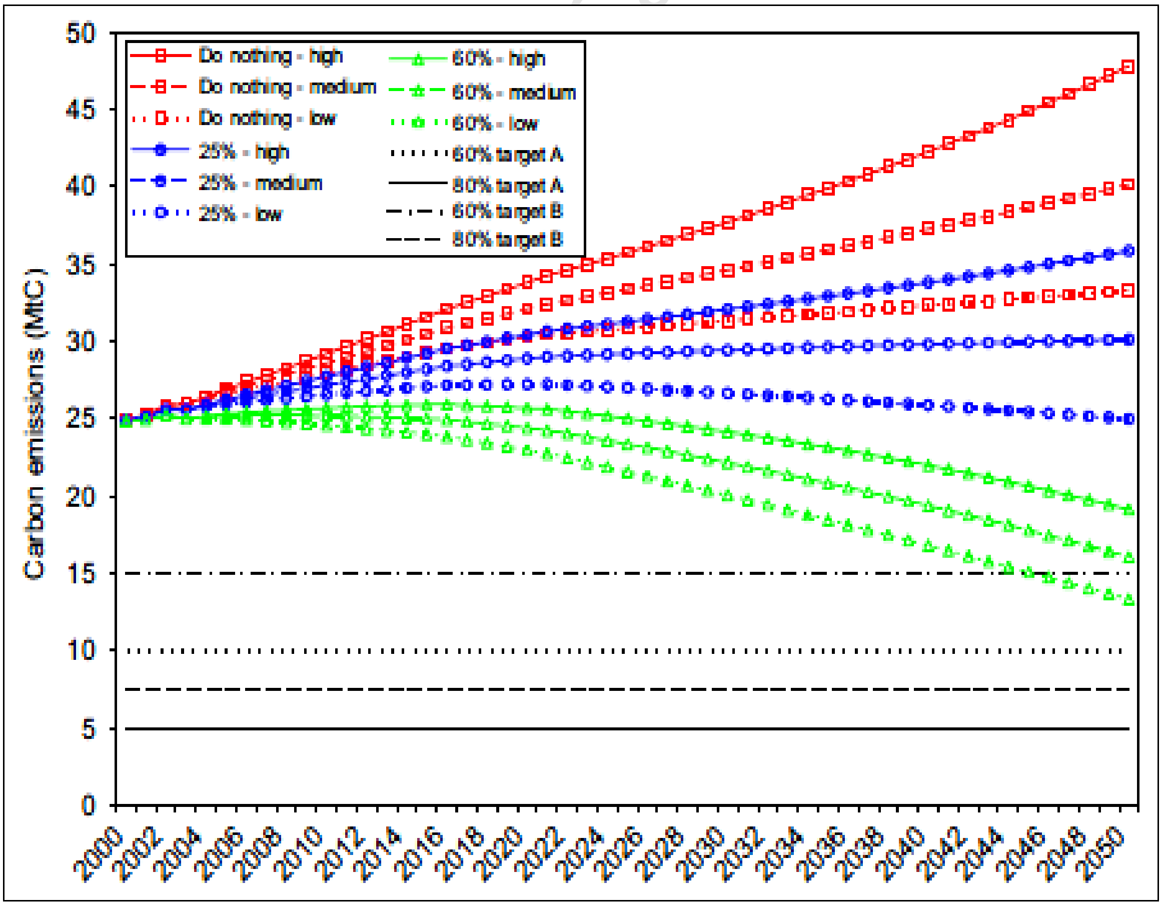
In the absence of sector specific targets, Bristow et al.'s (2008) study adopted the targets of up to 60% reduction in GHG emissions, set by national studies, such as those done by Strachan and Kannan (2008) and RCEP (2000). The study also assumed a maximum target of 80%, based on the new evidence to the effect that reductions that are even more stringent may be necessary to prevent dramatic climate changes in the future. At the same time, however, there is an appreciation that such targets may be difficult to attain, given significant evidence that GHG emissions from transport are likely to increase even in a carbon constrained world.

With regard to technological changes, the study argues that switching to newer cars without necessarily switching to smaller cars can nonetheless reduce CO_2 emissions from the 2006 figure of 167.2 g/km to 116.2 g/km; this amounts to a 30% reduction. It also implies using more hybrid cars, such as Toyota Prius and Honda Civic. However, according to Zachariadis (cited by Bristow et al. 2008: 3430), customers buy cars for the following reasons: safety, air conditioning, and increased power. All of these features contribute to increased fuel consumption due to extra weight and reduction in efficiency (related to air conditioning). It is therefore evident from this explanation that by influencing purchasing behaviour, significant emission reductions can be achieved. According to Bristow et al. (2008: 3430), such changes in purchasing behaviour could result in 25-30% reductions in CO_2 emissions without requiring any technological changes.

Bristow et al. (2008) also argues that it is possible to decarbonise the transport sector once carbon neutral hydrogen has been developed. However, it is not clear at this stage when such a feat will be achieved, given the uncertainty associated with penetration rates of hydrogen powered cars, competition with other sectors that will also require hydrogen to displace carbon emission, and, lastly, the need for substantial new electricity generating capacity. This study also reports that the use of hybrid buses will result in 25-34% reductions in CO_2 emissions. The highest savings are likely to be achieved in urban environments, where stop-start driving is prevalent (Anable & Bristow 2007). Figure 2.6 shows the results of a modest scenario (25% emission reduction) and an optimistic scenario (60% emission reduction).

Figure 2.5: GHG emissions: A BAU trajectory for 25% and 60% technology scenarios

Source: (Bristow et al. 2008: 3431, fig.2)

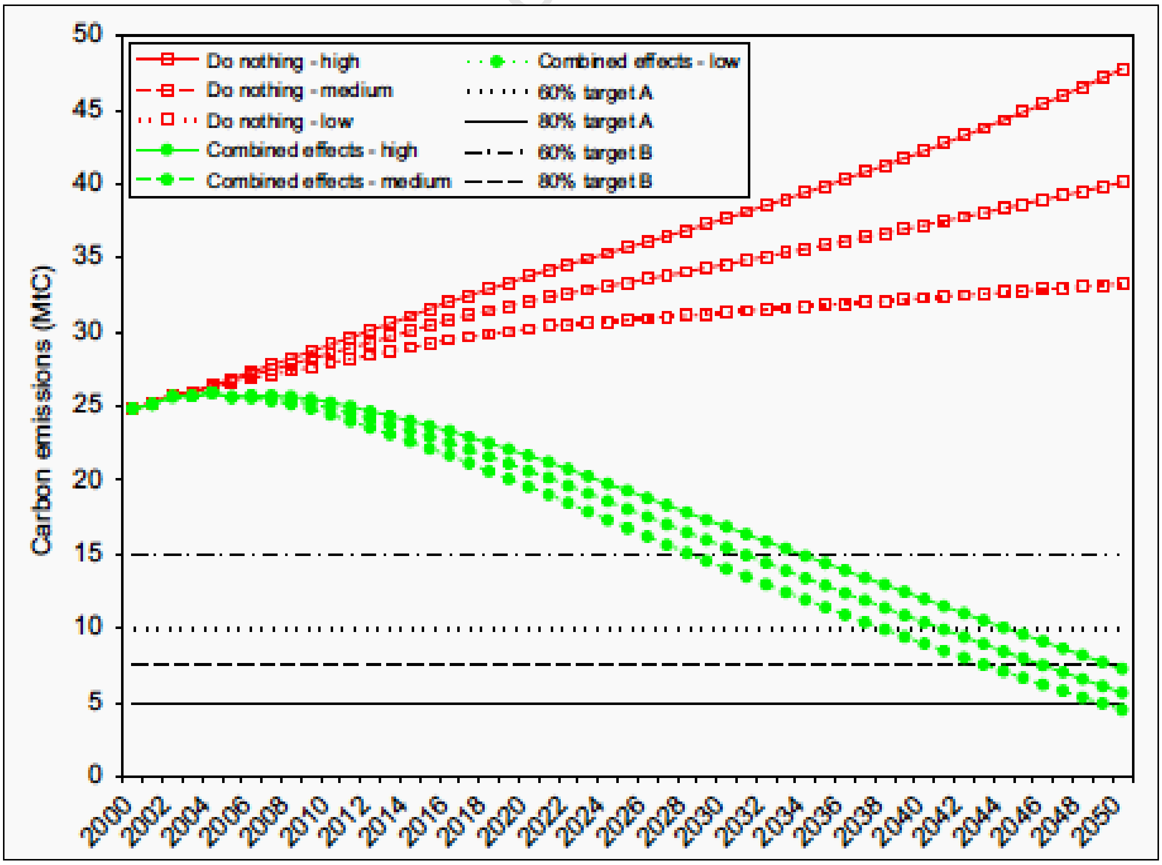


This assessment shows that the 25% technology scenario does not offset emissions related to traffic growth and that the 60% technology scenario only reaches the low target (60%) by 2044. This assessment has assumed no rebound effect. However, it is common knowledge that improvements in engine efficiencies, increased use of air conditioning, less efficient driving, and buying bigger cars due to increased income levels have actually had an opposite effect on emission reduction. For example, Small and Van Dender (2007) reported a rebound effect using price elasticity to mileage of -0.2 (dimensionless) to take into account such factors. To avoid rebound effects, it is important to have measures to derive the complete benefits of technological change.

Bristow et al. (2008) further investigated carbon pricing and soft measures (car sharing, workplace travel plans, teleconferencing and so on). The results of such combined measures are shown on Figure 2.7.

Figure 2.6: GHG emissions: Combined effects for the most optimistic scenario

Source: (Bristow et al. 2008: 3432, fig.3)



The combined measures as shown in Figure 2.7 achieve the 5MtC (80%) target by 2050 under the low growth scenario, and they reduce kilometres travelled by car by 35% from 2003 levels. Different pricing structures (both the high costs of fuel for private cars as well as the low fares on public transport) reduce emissions by 20-30%, whilst the soft measures result in a 25% reduction in traffic population. Similarly, Tight et al. (2007) examined the movement towards low carbon solutions households in the UK, and concluded that there is a limit value of 20% reduction in GHG emissions, beyond which it is extremely difficult to imagine further changes in behaviour (mainly involving lifestyle changes), as this would be connected to vehicle use. Also, it is evident from the study by Bristow et al. (2008) that such soft measures have a significant impact when combined with pricing instruments, such as taxation and lowering the costs of public transport (both for buses and rail). In addition, Bristow et al. (2008) conclude that a combination of technological changes and behavioural measures (pricing and soft measures) will potentially reduce GHG emissions significantly.

With regard to the transport sector, South Africa is generally a follower rather than a leader in the global arena, and as such some of technology improvements are imbedded in its BAU developmental pathway. However, recent work by Vanderschuren et al. (2008) shows that additional gains can be achieved. This work highlights soft measures such as improvement in road efficiency (10-15% emission reduction relative to current levels by 2030) and fuel efficiency measures (33% reduction relative to current levels by 2030). However, the implementation of these measures requires traffic officers to be trained and motorists to be made aware of the impact of inefficient driving on the environment

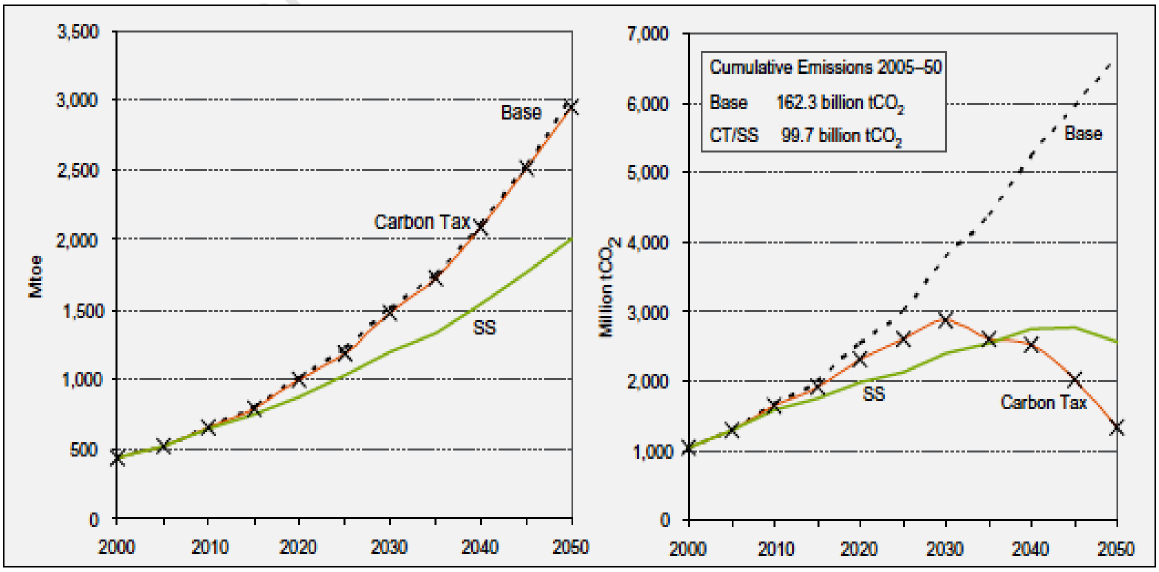
2.7 Low Carbon Society Scenarios for India

Shukla et al. (2008) embarked on a research project to investigate scenarios of low carbon society for India. They developed a modelling framework that encompasses two distinct development pathways. The first pathway makes use of a carbon tax (CT case) to ensure that India's GHG emissions contribute to an optimal 550 ppmv CO_2e stabilization level. The second pathway assesses the impact of 'sustainable scenario' (SS case) policies on GHG emissions. Measures considered under the SS scenario include transport modal shift, urban planning, reduced consumption, recycling, material substitutions, device efficiency, renewable energy, improved building design and electricity fuel switch for electricity generation. Using a backcasting approach, Shukla et al. (2008) developed an emission reduction target specific to India, and then constructed a method of achieving this target over a 50-year period (2000-2050).

A closer look at these two scenarios, both in terms of energy intensities as well as CO_2 emissions, reveals the following interesting results (see Figure 2.1). Firstly, energy demand in the SS scenario appears to be lower than in the CT scenario. The latter, however, realizes a greater carbon emission reduction by 2050. The measures taken under the SS scenario, which follows a sustainability paradigm, allows the Indian society to follow a low carbon path and thereby reduce their emissions more significantly by 2050 than in the CT scenario.

Figure 2.7: Energy and CO_2 emission for the two LCS scenarios

Source: (Shukla et al. 2008: 169, fig.11)



As most of the mitigation under the SS scenario occurs due to sustainability measures, Shukla et al. (2008: 169) argue that, if the sustainability is restricted to India (regional focus), there is likely to be more mitigation corresponding to the global carbon price, which can be further traded. They further argue that a mild tax is required if the sustainability paradigm is accepted globally. This essentially means that, if mitigation according to the CT scenario is equivalent to that of the SS scenario, then the carbon price becomes a shadow price. It is also interesting to note that, in the SS scenario, the mitigation options are more diverse and cover all energy demand sectors. Furthermore, the SS scenario places greater emphasis on investment in public infrastructure development (for example, infrastructure that ultimately leads to a shift towards public transport).

More importantly for a developing country such as India, the measures of the SS scenario seek to influence some indicators of sustainable development. This appears to be different from the Japanese LCS scenarios, which do not necessarily have a sustainable development objective function but instead emphasise maintaining the current quality of life whilst reducing GHG emissions (Shimada et al. 2007). Furthermore, Shukla et al. (2008) have demonstrated that, by using a carbon tax scenario for LCS, reduction of GHGs does not come at the expense of India's economic and social development. Instead, LCS policies encourage technology innovations, the set-up of institutional arrangements, investment flows and a long-term perspective to avoid lock-ins.

South Africa, which faces similar developmental challenges as India, can thus also transition towards a low carbon society whilst addressing developmental objectives, such as poverty alleviation and job creation. Energy efficiency measures and the adoption of waste minimization principles, as observed in Shukla et al.'s (2008) study can have a direct and immediate effect with regard to reducing emissions and changing behaviour.

2.8 Lessons for South Africa

It is evident from the studies reviewed in this chapter that technology and technological innovation are at the centre of a transition towards a low carbon society. This is well supported by the work of Skea and Nishioka (2008) in the case of Japan. However, evidence also shows that this transition can be further accelerated by means of embedded softer measures to address behavioural aspects. It also appears that leverage points for influencing behaviour do exist in the South African context. These include, but are not limited to, zero-carbon consumer spending, adoption of waste minimization principles, pedestrian friendly city design, and improvements in traffic efficiency. Furthermore, implementation of LCS measures will require a balance between D&I (decentralization and innovation) and C&S (Centralization and standardization). In this way, innovation and implementation of these measures can take place at local authority level whilst resource availability, monitoring and exchange of ideas can be facilitated by central government. However, this requires strong leadership (both at local and national level), institutional arrangements, financing through public-private partnerships and public awareness campaigns. South Africa can therefore explore possible LCS visions (pathways). One of these pathways could be based on fostering a technology driven society, while the second pathway could be centrered on the creation of a behaviourally sensitive society. Thereafter, using a LCS framework similar to that used by Shimada et al. (2007), the implication of each pathway on the overall reduction of emissions could be assessed. In this regard, Chapter 3 presents the methodology and tools used in this study to assess the implication of the LCS developmental pathways developed in the South Africa context.

CHAPTER 3

3 Study methodology and analysis tools

3.1 Study Methodology

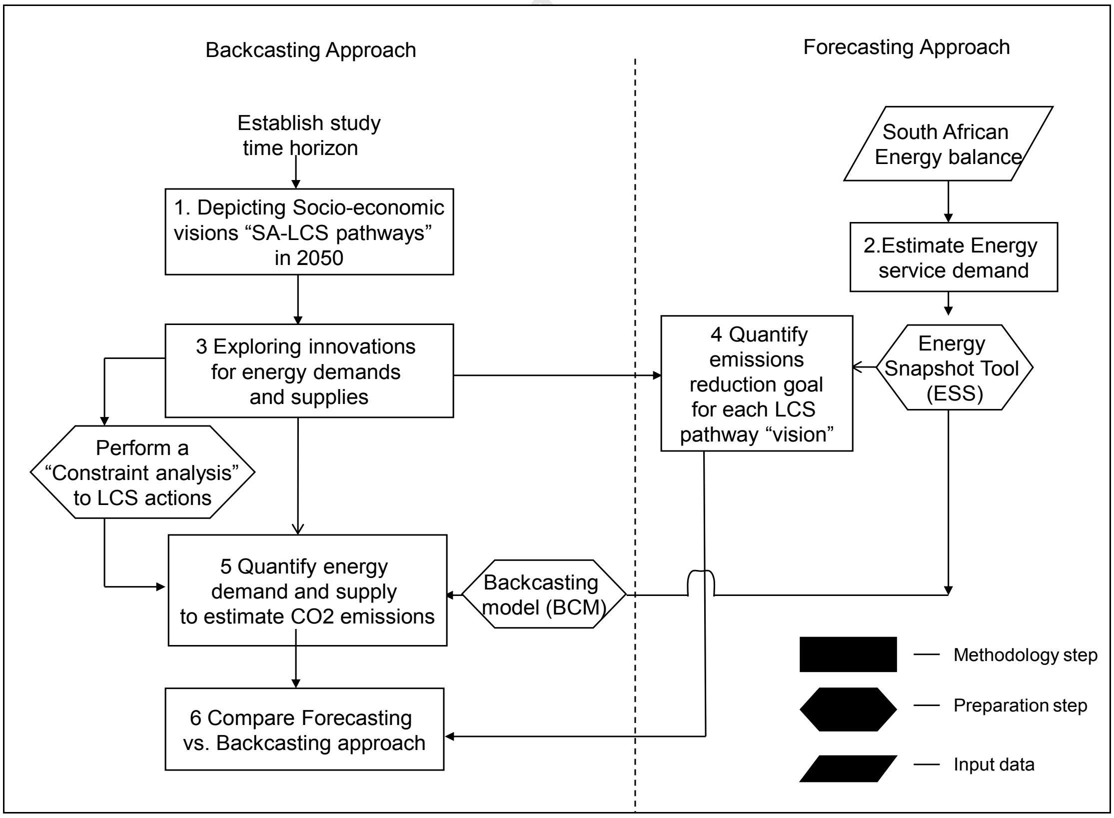
3.1.1 Study period

Studies of low carbon societies have generally adopted longer period for the assessment of mitigation options (Anderson et al. 2008; Bristow et al. 2008; Fujino et al. 2005; Kawase et al. 2006). The reason for this is that most of the options require some level of commitment from governments in terms of public-private partnerships and capacity building. This also links well with government planning, which is mostly long-term in nature. Furthermore, climate change impacts are subtle and long-term and therefore more than 50 years is normal in assessing such impacts (CGER 2007). Also, climate change mitigation requires long-term efforts, especially if it involves fundamental changes in economic and social systems. Therefore, this study is based on a 50-year period, with 2000 as the base year.

3.1.2 Relevant data and information

Data requirements fall into six broad categories of steps (see Figure 3.1), which underpin the overall methodology followed in this research work. The first step is to depict socio-economic visions for 2050. The second step is to determine energy service demands in the base year. The third step involves the exploration of innovations in respect of both energy demands and energy supplies. The fourth step deals with the quantification of emission reduction goals for each vision, as set out in step 1. In the fifth step, an estimate of energy demand and supply to estimate CO_2 emissions is required. The BCM used in step five also takes into account the influence obstacles to implementing LCS actions. Furthermore, both step four and five require emission factors to convert energy activity into emissions for the 50-year period. In step six, the successful reduction of GHG emissions obtained in step five using a BCM is compared with the emission reduction goals determined in step four using a prognostic model (ESS tool) to determine whether the backcasting analysis meets the LCS visions for 2050. The limitation of this study is that it has only focused on energy related emissions. This is because of the modelling tools employed. The modelling framework for both the ESS and the BCM analysis tools does not accommodate non-energy emissions. The second limitation is that both the ESS and BCM account for CO_2 as the only GHG. However, the latest available GHG inventory for South Africa shows that energy related emissions in South Africa have contributed about 86% to the total national GHG emissions, when emissions from land use, land use change and forestry (LULUCF) are considered (DEAT 2009). Furthermore, a comparison of total emissions by gas shows that CO_2 related emissions accounted for 79%; the remaining 21% were made up of Methane 'CH_4' (17%) and Nitrous Oxide 'N_2O' (5%). This analysis demonstrates the need to focus on energy related emission in order to address the climate change mitigation challenge that South Africa is facing.

Figure 3.1: Steps involved in the assessment of Low Carbon Society



3.1.3 Depicting socio-economic visions in 2050

This step involves the determination of future development scenarios under a low-carbon society, and thus the narration of possible storylines for each of these scenarios. These storylines furthermore need to be interpreted by identifying indicators or drivers. Some of the key drivers necessary in this context are the GDP of the country, its population and its household sizes. This therefore requires an understanding of how such drivers are likely to grow with time. Hence, research work on GDP growth projections as well as population and household size projections are critical for depicting socio-economic visions for the future. Once growth rates of key drivers have been determined, it is possible to determine the level of CO_2 emission reduction achievable over the period of concern (in this case, 2000 – 2050).

3.1.4 Estimating energy service demand

Forecasting from the present into the future and backcasting from the future to the present depends on the correct specification of energy service demand in the base year (2000). Therefore, a sector-by-sector analysis of energy demand in the South African context has been constructed here using the energy snapshot (ESS) tool that will be described in Section 3.3.1 below. Five energy sectors are assessed, namely, the industrial, residential, commercial, transport and energy sectors.

3.1.5 Exploring innovations for energy demands and supplies

Reductions in energy service demand equates to reductions in CO_2 emissions. This however, requires that we identify smart interventions to realize the emission reductions that are needed. Even more important is, firstly, that the interventions identified are linked with changes in social behaviour and, secondly, that they are also linked with sustainable development objectives. In addition, the obstacles associated with realizing such interventions need to be identified to avoid unforeseen costs and even environmental implications. This identification of interventions, and of the obstacles associated with them, is described in detail in Chapter 5. Ultimately, it is possible to develop a basket of interventions, presenting twelve actions ‘dozen of actions’ which can result in emission reductions equivalent to 65% in 2050 relative to 2000 emission levels. This dozen of actions must be undertaken without delay in order to create a low carbon society in South Africa. This study has therefore followed these twelve LCS actions, using the constraint analysis to identify the obstacles associated with realizing the necessary actions.

3.1.6 Quantifying emission reduction goals for each vision

In this step, a forecasting approach assesses the impact of the chosen LCS actions on emission reduction goals by 2050. This is done by using an ESS tool populated with base year (2000) energy supply and demand data. Other relevant data inputs include quantified reductions in energy service demand for each LCS action over the period of study. Essentially, the ESS tool combines energy service demand data in the base year with quantified reductions in service demand over the 50-year period. Using emission factors, quantified changes in energy demand are translated into carbon emission reductions. In turn, forecasted carbon emission reductions are used as goals for each vision or LCS developmental pathway.

3.1.7 Quantifying energy demand and supplies to estimate CO_2 emissions

This step is similar to the previous step in that innovations related to supply and demand-side energy sectors are used to quantify reductions in energy required. However, instead of following a forecasting approach, a backcasting approach is used to estimate the resulting reduction in energy required. The backcasting approach thus starts by visualizing the future requirements (reductions in energy required) and then backcasting to the present to establish whether it is possible to achieve the desired future goal. A critical component of this step is the constraint analysis, which identifies obstacles associated with the chosen LCS actions for each LCS developmental pathway. The solutions to these obstacles are factored into the BCM, which automatically calculates the resulting reductions in the energy required and converts that into carbon emission reductions.

For each of the actions identified in the list of twelve actions or ‘dozen of actions’ it is important to realize how much energy savings can be achieved in the case of demand-side energy sectors (e.g. residential) and how much fossil fuel displacement can be achieved in the case of supply-side energy sectors (e.g. power generation). The energy savings or displacement can be achieved in a number of ways, namely, changing demand, improving energy efficiency, shifting to other fuels, shifting to other transport modes, and so on. Potentials for energy supply are considered too by assessing future energy mix scenarios on the supply side.

3.1.8 Comparison between backcasting and forecasting approach

In this step, the carbon emission reductions from the backcasting approach using the BCM model are compared against the carbon emission reduction goals determined using the ESS tool. For consistency, the BCM model also requires base year estimates of energy service demand. Therefore, base year energy service demand data in the BCM model are fed by the ESS tool. This comparison analysis determines whether the combined carbon emission reductions determined by the twelve LCS actions for each individual LCS pathway meet the specified goals of carbon emission reduction, as determined by the forecasting approach using the ESS tool.

3.2 Data Requirements and Collection

3.2.1 Data for depicting socio-economic visions in 2050

Data on the GDP growth rates are sourced from institutions such as the National Treasury, the South African Reserve Bank, and Statistics South Africa (AsgiSA 2006; National Treasury 2005; Vessia 2006). Data on the population is sourced from organizations such as Statistics South Africa, the Medical Research Council and Actuarial Science bodies (Dorrington et al.

2006; SSA 2003a; SSA 2003b). Much work has been done by some academic research institutions and individuals on the growth rates of population and household sizes (Haw and Hughes 2007a; Winkler et al. 2006). Such information is also used in the development of scenarios.

This study has assumed that the pattern of household and population growth in the past will continue. However, lower growth rates have been assumed due to the impact of AIDS. While this is strongly debated, some highly respected studies show a substantial levelling off in population during our study period 2000-2030. Studies by Professor Dorrington of the University of Cape Town Commerce Faculty for the Actuarial Society of South Africa are well respected academically (ASSA 2002).

The Development Bank of Southerm Africa (DBSA) also projects trends in population, differentiating between low and high impacts of HIV/AIDS (Calitz 2000a, 2000b). The first Integrated Energy Plan included projections of population growth (ERI 2001), which are shown together with other estimates in table 3.1.

Table 3.1: Population projections from various sources (in millions)

Source: (Witi et al. 2009: 5)

	DBSA low Aids impact	***DBSA high Aids impact***	***ASSA 2002 (base run)***	***(DME) IEP assump-tions***	***UN world population projection***	***Witi et al***
2001			45	44	43	44.8*
2006			46			46.4
2011	56	49	48	50		47.6
2016	61	50	48		45	48.5
2025	70	49	50	57	44	49.7
2030			50			50.0

* The 2001 Census reported 44 819 778 people in South Africa (SSA 2003a) and this study has used this number instead of ASSA's projection.

The Actuarial Society of South Africa (ASSA) projections seemed to be most reasonable, indicating a growth of 12% over the period, with annual growth rates between 0.1% and 1.0%. An important difference between this study and others relates to population projections in the reference case. The population projections used in the Integrated Energy Plan (IEP) were for 50 million in 2011 (here: 47.6 million) and 57 million in 2025 (49.7 million). While the IEP projections are lower than previous estimates, they are still higher than those of demographic experts. Another source of difference relates to confidential data which was used for previous studies and was not available for this study. Section 4.4 discusses the key drivers in more detail.

3.2.2 Data for estimating energy service demand

Data on sectoral energy demand comes mainly from surveys and from research studies carried out for the purposes of modelling energy demand. However, some municipalities have already started to compile so-called State of Energy reports (CCT 2003; EMM 2004; Tshwane 2006). Such information has been used quite extensively in many energy demand forecasting studies in the past, and it is used in this study as well. In addition, the Department of Minerals and Energy (DME) has from time to time produced Energy Outlook reports (DME 2002; DME 2005) as well as national energy balances (DME 2000; IEA 2001a). Such information is also useful here, even though its accuracy may be questionable. Other useful sources of data include the public utility Eskom, the South African National Energy Research Institute (SANERI), the Energy Research Centre (ERC) and the National Energy Regulator of South Africa (NERSA). In this case, EBT data sourced from the International Energy Agency (IEA) was used (IEA 2001a). National energy balance data from the IEA was preferred over the data from the Department of Minerals and Energy (DME) due to observed inconsistencies in the DME data, particularly around liquid and solid fuels (DEA 2009). Table 3.2 shows the results of populating the ESS tool with the year 2000 EBT data, as provided by the IEA (IEA 2001a). Table 3.3 summarizes the emission factors used in this study

Table 3.2: South Africa's Energy Balance Table (EBT) for the year 2000 (base year).

Source: (IEA 2001a)

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total
Energy Balances (Mtoe)											
Power Gnr.	48	0	0	0	3	0	0			-14	37
CCS											0
Heat											0
Coal/Oil/Gas		7									7
Hydrogen											0
Industrial	46	99	10	7			0	0	0	28	190
Residential	1	0	0	0			0	0	0	2	4
Commercial	0	15	9	0			1	0	0	22	46
Trans. Prv.	0	8	0	0			0	0	0	0	8
Trans. Frg.	0	13	0	0			0	0	0	0	13
End use	47	135	19	8			1	0	0	53	261
Total	95	141	19	8	3	0	1	0	0	39	305
Feedstock in total		31									
Emission Factor[3] (MtC/Mtoe)	1.05	0.80	0.55	0.00	0.00	0.00	0.00	-	-	-	
CO_2 Gnr. (MtC)	99	88	10	0	0	0	0	-	-	-	198
CO_2 CCS (MtC)								-	-	-	
CO_2 Ems. (MtC)	99	88.3	10	0	0	0	0	-	-	-	198

Table 2.3: Carbon emission factors used in this study.

Source: (IPCC1997:1.6)

Carbon Emission Factors	
Fuel	**Carbon Emission factor (t C/TJ)**
LIQUID FOSSIL	
Crude oil	20
Natural Gas Liquids	17.2
SOLID FOSSIL	
Coking Coal	25.8
Other Bituminous Coal	25.8
Sub-bituminous Coal	26.2
GASEOUS FOSSIL	
Natural Gas (Dry)	15.3
BIOMASS	
Solid Biomass	29.9

[3] Emissions factors adapted from Table 1-2 of the “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories”

3.2.3 Data for exploring innovations for Energy Demands and Supplies

Data and information employed in this step is mainly sourced from energy research studies. Current and future directed energy initiatives planned by the government, the public utilities and industry are taken into account too. The functioning of a low carbon society relies on government accepting a major role in realising the necessary innovations. The reason for this is that most of the innovations needed to realize a low carbon society are long-term. This aligns well with the government's way of planning, as it normally plans its activities on a long-term basis. Appendix D shows the data and information used in this study

3.2.4 Data for quantifying emission reduction goals, energy demand and supply to estimate CO_2 emissions

As Climate Change gains more attention in the world media, and with the realization of the energy crisis in South Africa, many studies have been done to identify potential solutions to problems in energy demand and supply by assessing various options, either to reduce energy demand or to propose radical changes in the current energy mix, which is heavily fossil-fuel dependent (Winkler et al. 2006). Such studies are viewed as starting points for the quantification of energy savings. Appendix E summarizes key data used in this study based on the studies mentioned in chapter 5

3.3 Study Analysis Tools

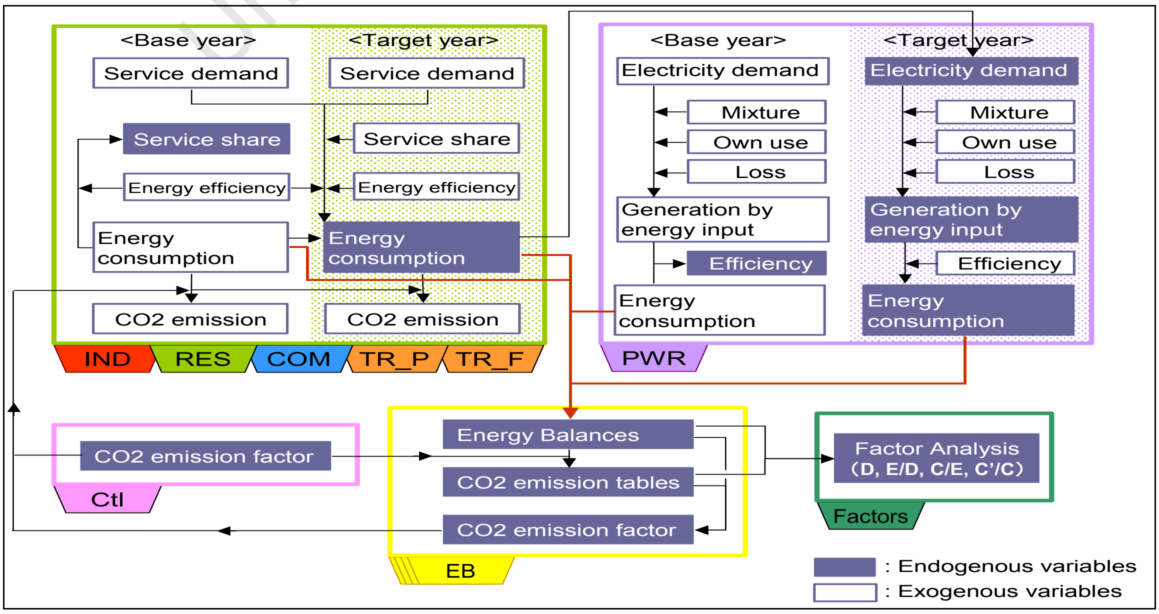
3.3.1 Energy Snapshot Tool (ESS)

The ESS is used here to estimate energy service demand in end-use sectors as well as to estimate the energy requirements needed to meet such energy service demands. ESS is a Microsoft Excel based spreadsheet tool that integrates all emission-producing end-use sectors (Industry, Commerce, Residential and Transportation) as well as the Power sector. The main outputs comprise CO_2 reductions, which are broken down by sector and fuel-type in the target year for different constructed scenarios. The key drivers of emissions in the ESS are population, number of households and GDP.

Essentially, the ESS is an energy supply and demand accounting tool that utilizes the Energy Balance Table (EBT) to calculate projected changes in energy supply and demand in the target year, as well as CO_2 emission reduction. Even though the ESS tool calculates CO_2 emission reduction using IPCC default factors (IPCC 1997), it does not provide for concrete mitigation options. Therefore, the ESS tool is integrated into the Backcasting Model (BCM) to allow for assessment of actions and mitigation options to obstacles associated with implementing related mitigation actions. Given that this study has chosen a 50-year period with the year 2000 as a base year, the EBT for the year 2000 was used to populate the ESS tool. The outputs of the ESS tool are energy service demand, share of energy and energy improvement by classification of service and CO_2 emission, both in the base year and the target year. It therefore uses the energy balances to show fuel consumption and primary fuel transformation, as well as the service demand structure (see Figure 3.2). The energy supply and demand values in the ESS tool are presented in million tons of oil equivalent units.

Figure 3.2: Structure of the Energy Snapshot tool

Source: (CGER 2007: 70)



The first step in populating the ESS tool is to obtain EBT data from national statistics. The second step involves setting energy use efficiency and energy consumption by sector. For the target year, there is no need to specify energy service demand, as this is calculated endogenously in the BCM model integrated with the ESS tool. In terms of the third step, emission factors need to be specified by fuel type across all supply and demand sectors. For this study, the emission factors are sourced from the IPCC guidelines (IPCC 1997). Once all these variables have been specified, it is possible to perform a carbon emission decomposition analysis, which is often referred to as the factor analysis. It is also referred to as the Kaya identity, as calculated by means of Equation 3.1, which has been developed by Morita and Robinson (cited by Kawase et al. 2006: 2113-2115). In principle, the Kaya identity measures the rate of CO_2 emission change as a function of rate of change in the following indexes: economic activity, energy intensity, carbon intensity, carbon capture and storage (Kawase et al. 2006). In turn, this allows for the characteristics of a country's carbon reduction policy to be analysed by determining the rate of change of these indexes, and then assessing how this influences the rate of change of carbon emissions.

$$C = D \times \frac{E}{D} \times \frac{C'}{E} \times \frac{C}{C'} \tag{3.1}$$

Furthermore, Equation 3.1 can be further expanded and expressed in differential changes to take into account future visions for LCS scenarios relative to the base year, as calculated by means of the following equation (Kawase et al. 2006: 2114)):

$$\frac{\Delta C}{C} = \frac{\Delta D}{D} + \frac{\Delta(E/D)}{(E/D)} + \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta(C/C')}{(C/C')} + \text{Residual term} \tag{3.2}$$

Where:

D: Driving forces (service demand)

E: Energy Consumption

C': CO_2 emission without measures in transformation sector

C: CO_2 emission with measures in transformation sector

E/D: Energy Intensity

C'/E: CO_2 intensity in end-use sector (without measures in transformation sector)

C/C': Change of CO_2 intensity by measures in the transformation sector.

Therefore, Equation 3.2 calculates the changes in CO_2 emission due to changes in energy consumption, energy intensity, fuel switching, fuel mix carbon capture and storage, as well as improvement in energy efficiency. To make the terms additive, the differential of each term is divided by its base term. The results of the above factor analysis for this study are presented in Chapter 6.

It is evident from the above discussion that the ESS tool can firstly assist us in creating narrative scenarios to achieve a low carbon society by 2050 and to determine the amount of CO_2 reduction that is possible. However, the ESS tool does not indicate the specific actions that South Africa would need to implement in order to achieve the vision of a low carbon society by 2050. This means that we must develop actions independently of ESS. Secondly, ESS is integrated into the BCM model to study the impacts of LCS actions for South Africa in a quantitative manner. The next section discusses the framework for assessing LCS related actions.

3.3.2 A 'Dozen of Actions' Approach exploring innovations for energy demands and supplies

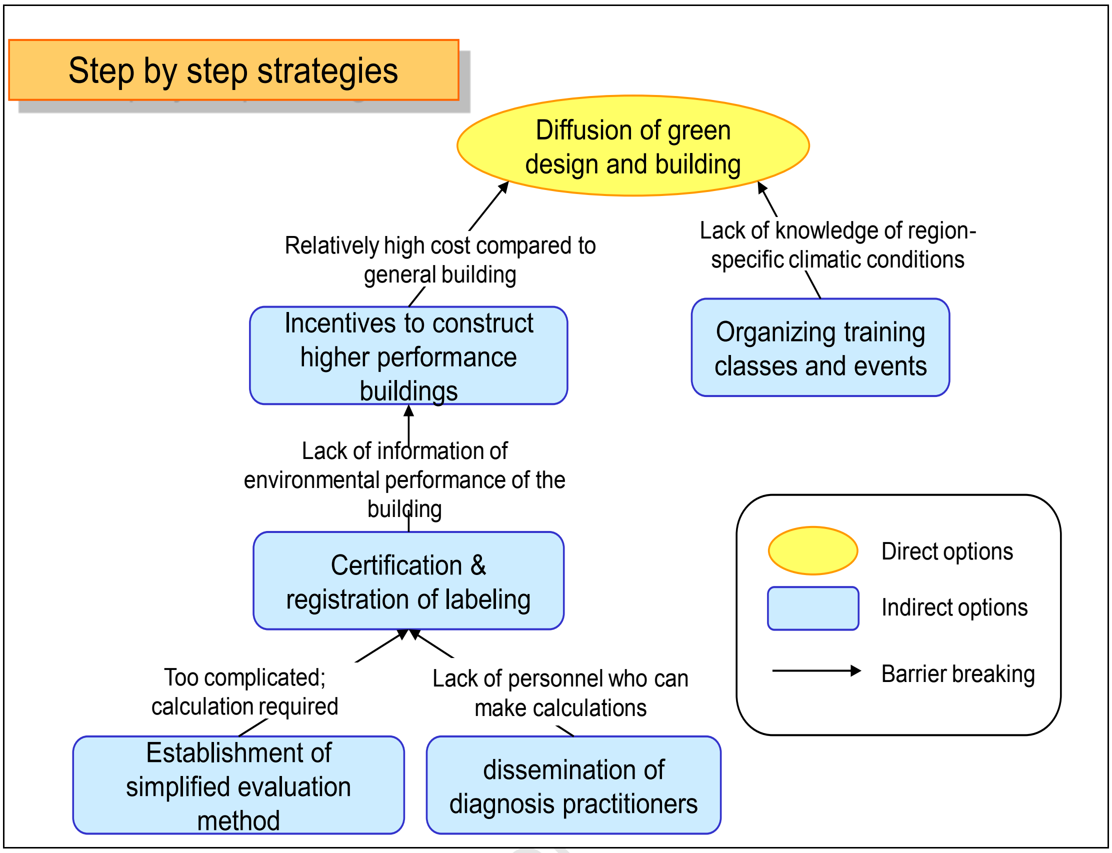
Actions are seen as a package of **options** (interventions) that, when executed in a timely and logical manner, can realize the objectives of the LCS. However, the question arises as to whose mandate it is to implement these actions. The answer is that government is responsible for implementing such actions. The reason for that is that these actions require long-term implementation and that society cannot rely on the private sector alone to deliver on such actions. The solution, therefore, is to establish public-private partnership to facilitate implementation of LCS actions.

Options can be divided into two types, namely, *direct options* and *indirect options*. Direct options are those that directly reduce CO_2 emissions. However, implementation of such options quite often requires certain obstacles to be are removed so that changes can be implemented more smoothly. Indirect options, in contrast, are necessary to overcome the obstacles to ensure that the direct options are implemented with minimum or no obstacles. Direct options and indirect options for a particular problem present an action.

An example here is the introduction of nuclear power generation. In this case, nuclear is observed to be the *direct* option. However, we also want to identify the obstacles associated with introducing and implementing the direct option. It appears that we may have to deal with issues, such as (a) overcoming a lack of capacity to operate and run nuclear plants, (b) ensuring a regular supply of enriched uranium as a source of fuel for power generation, (c) accessing sufficient capital to build such nuclear plants, (d) dealing with the negative perception of the public about nuclear energy and (e) finding creative, safe and effective solutions of dealing with the waste generated by nuclear power stations. The solutions to such obstacles are what we call *indirect* options. It means that obstacles are overcome by implementing indirect options before executing the direct option. An example of an indirect option in this case would be to create a public-private partnership to address obstacle (c), while also developing local uranium enrichment capacity to address obstacle (b) and so on. A more practical example is shown in Figure 3.3 in respect of the diffusion of green design and building.

Figure 3.3: Identification of necessary options

Source: (Ehara 2008:16)

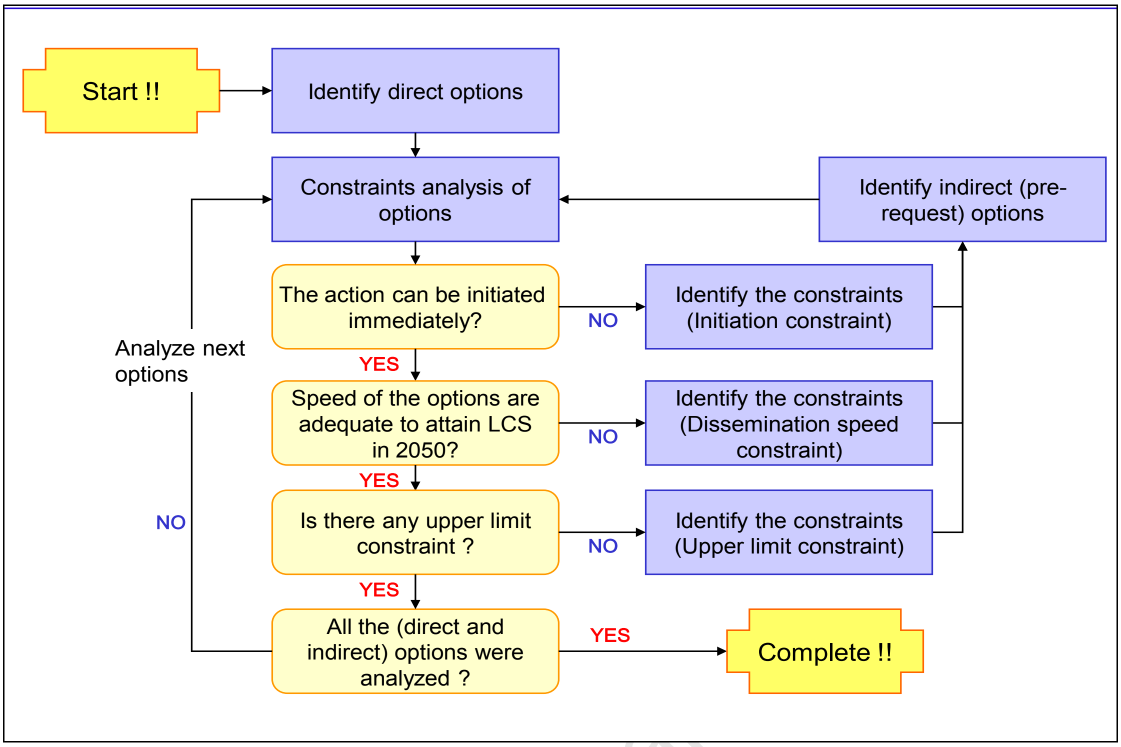


The constraint analysis framework (CAF) is used to determine the direct and indirect mitigation options that can be used to overcome the obstacles to achieving the visions as set out in the future objectives (LCS scenarios). Hence, the CAF (see Figure 3.4) is employed here to assess three broad types of constraints as described below:

- Option initiation constraints (Infrastructure, institutional arrangements, capacity)
- Dissemination speed constraints (cost, amenity, efficiency)
- Dissemination limit constraints (physical, social, and technological)

Figure 3.4: Constraint Analysis

Source: (Ehara. 2008: 15)



Also, it is important to summarize the future objectives of each action and to use the CAF to check whether there might be obstacles to achieving such objectives. In doing so, four factors are considered (see Table 3.4).

With the 'dozen of actions' we get a *sense* of what actions are required to realize LCS, but we still do not know the quantitative information associated with such action (e.g. required term for implementing actions). The BCM model provides information about the actions that must be introduced, and when they are to be introduced. The following section discusses the BCM model in detail.

Table 3.4: Factors to consider when setting future LCS objectives

Factors	Contents
Technologies	What technologies will be mainstream in South Africa by 2050? Where and how will those technologies be applied?
Infrastructure	What kind of infrastructure should be developed in order to realize a low carbon society?
Social systems/	What kinds of innovations in social systems are needed in 2050?

Factors	Contents
Governance	Who (which stakeholders) would have a central role in the innovations?
Environmental awareness/mindsets	To what extent should the environmental awareness of citizens or private companies be enhanced?

Table 3.5 below summarises the data and information for the LCS mitigation action titled “Energy efficient lighting”. A more detailed table of all LCS mitigation actions for both ZA50A and ZA50B scenarios is provided in Appendix D.

Table 3.5: Summary data and information for the LCS action titled “Energy efficient lighting”

No	LCS Action	Explanation	Mitigation options	Technology Change	Start	End
AB 10	**Energy efficient lighting**	This action involves a switch from incandescent lights to compact fluorescent light bulbs (CFLs).	Energy Efficient Lighting	100% of households use CFLs by 2050. Energy consumption is reduced by 75% for every inefficient light replaced. Similarly, for the commercial sector, 100% penetration is achieved by 2050.	2005	2050
			Promoted use of CFL lighting	period shorten = 2 years	2007	2016
			Country-wide roll-out of CFL light bulbs	period shorten = 3 years	2008	2015
			Public awareness on safety of use and safe disposal of CFL light bulbs	period shorten = 2 years	2006	2020
			Markets to phase-out inefficient Incandescent light bulbs	period shorten = 5 years	2020	2050

3.3.3 Backcasting Model (BCM)

The BCM is an analytical tool to examine which actions and policies of reducing emissions must be combined and implemented to achieve a certain

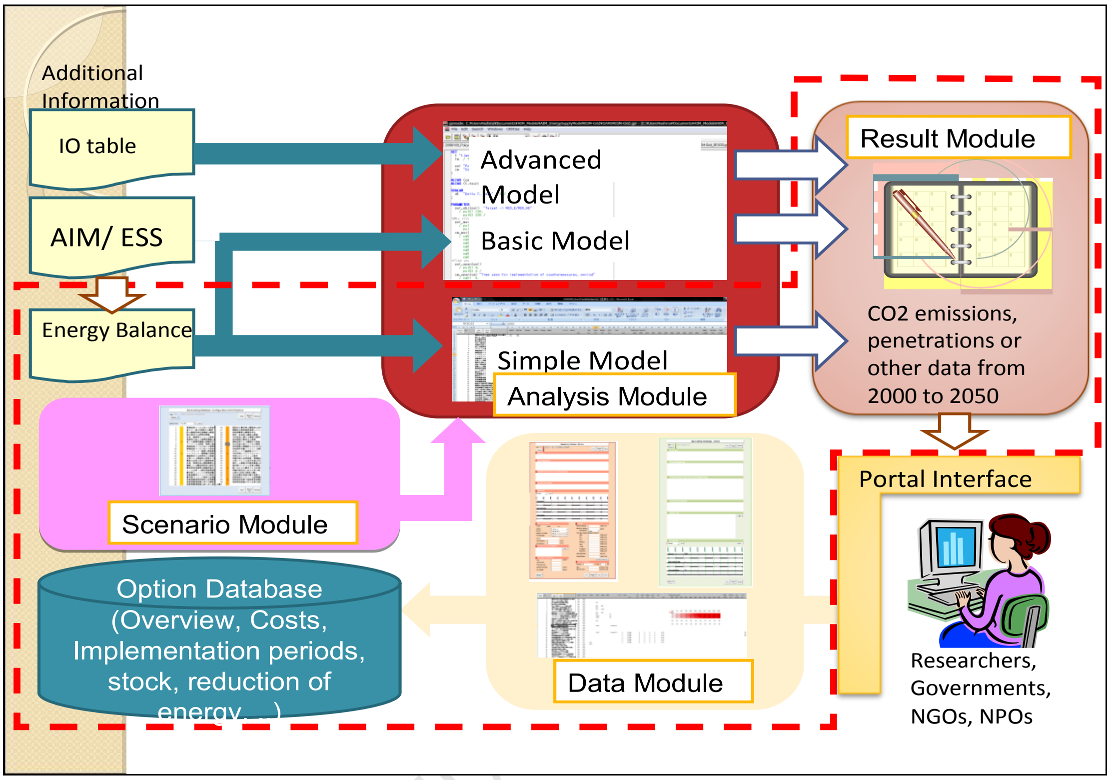
GHG reduction goal. Using a linear programming approach, the BCM model can also set a deadline for technological development, and a deadline for the widespread use of new technologies and implemented actions/policies. It can also calculate the expected costs of realising such options or policies. One of the strengths of this model is that it allows analysis not only on the target year but also on the path to reach the GHG reduction goal.

Figure 3.5 shows the structure of the BCM model. In the data module, both quantitative and qualitative data of options are sent to the options database in the Backcasting System. Quantitative data involve cost, stock, reduction of energy or CO_2 emissions, and implementation terms and options. Qualitative data include an overview of the action, future objectives, obstacles, and steps for overcoming such obstacles. The scenario module configures a set of feasible options in the chosen scenario. Scenarios describe both narrative scenarios and assumptions for the ESS tool in a consistent way. Based on these option data and scenarios, the models in the analysis module simulate future penetration rates, CO_2 emissions and costs. The results module shows the results. The BCM model runs in MS Excel, together with a modified version of the ESS tool described above. The BCM is therefore a powerful tool to assess the viability and the potential of mitigation options to achieve the required emission reductions in terms of visions for a low carbon society.

Specifically for this study, the ESS tool is embedded in the BCM tool so that the energy supply and demand structure, as provided by the energy balance tables for South Africa, can be included in the BCM model. For each of the dozen of actions identified (see Chapter 5), a QI (Quantity and Impact) measure is calculated based on local energy studies and climate change mitigation studies. The BCM model handles QI measures, such as energy efficiency, fuel switching, period shortening (e.g. relaxation of regulation) and direct CO_2 reductions (e.g. from Carbon Capture and Storage). Appendix A describes how the BCM model handles these QI measures by using actual data employed in this study. Appendix B contains a detailed description of how the BCM model works. Appendix D contains a table with actual data and information on the QI measures mentioned above for all LCS actions developed in this study. The penetration rates and other assumptions made with regard to fuel switching are discussed in detail in Chapter 5.

Figure 3.5: Overall structure of the BCM model

Source: (CGER 2007: 70)



This chapter has described all the tools used in this study in detail. Furthermore, the analysis framework presented in Figure 3.1 has clearly set out the methodology steps taken. Chapter 4 below is concerned with depicting socio-economic visions for South Africa by following a LCS approach. More specifically, two LCS visions and their respective storylines or narratives are developed below. One vision is that of a Technology driven society, whereas the second vision is that of a society sensitive to behavioural change and willing to implement it.

CHAPTER 4

4 LCS scenarios development

4.1 Overview on mitigation assessment scenarios

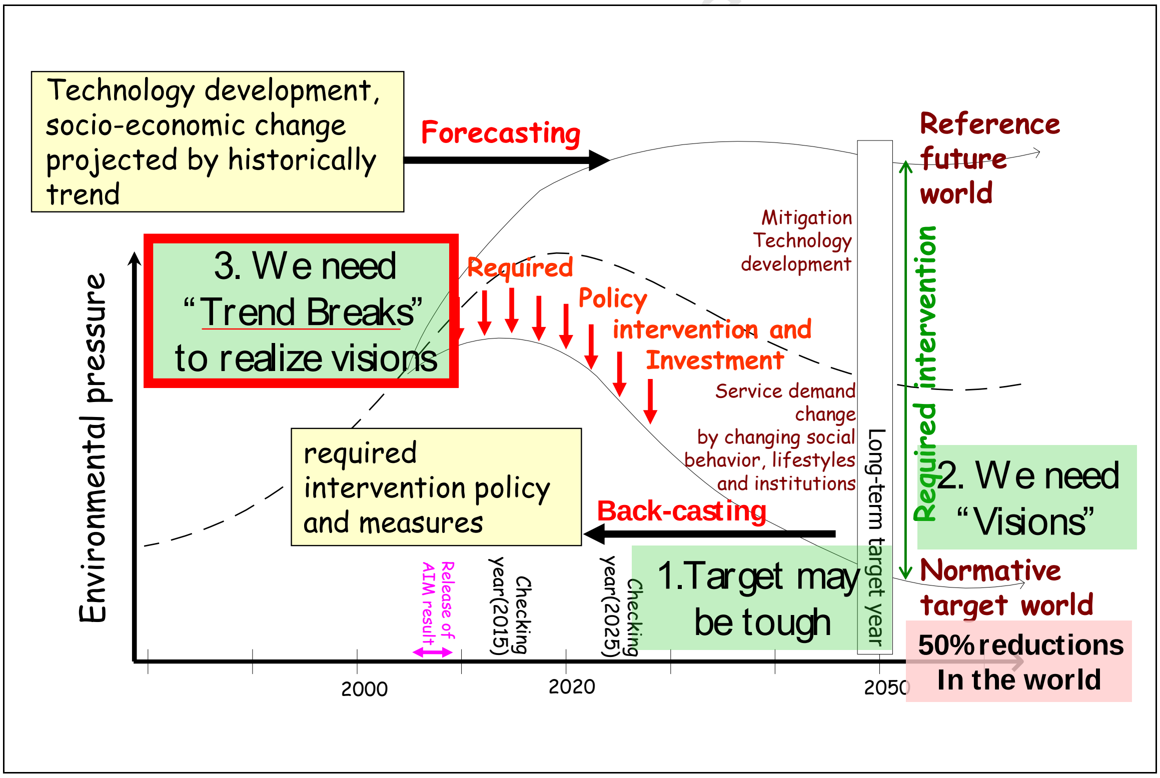
As discussed in the previous chapter, it is necessary to take a long-term view of the multiplicity of possibilities to consider the ultimate risks of not responding to climate change on time. This is even more important in the context of LCS, because this requires drastic changes in social and economic systems. Therefore, scenarios play an important role in this regard by providing a structured approach of depicting future possibilities (Bennet et al. 2005). Also, scenarios can be used to facilitate decision making or planning or even for narrowing the gap between the scientific and policy-making communities. In this way, scenarios can be used in a more informative and educational way (e.g. Winkler 2007).

In addition, there are many definitions of scenarios in the literature. Definitions tend to differ, depending on the intent of the scenarios and on the way in which they are developed. However, there does seem to be consistency in the manner in which they are characterized as either 'exploratory' or 'normative' (CGER 2007). Exploratory scenarios begin in the present and explore trends by using key drivers going into the future. Examples include the Long-Term Mitigation Scenarios (LTMS) for South Africa (Winkler 2007) as well as the IPCC Special Report on Emissions Scenarios (IPCC 2000). In contrast, normative scenarios start by depicting a vision for the future and then working backwards in time to visualize how that future could emerge (Alcamo 2001). These visions can be optimistic, neutral or even pessimistic in nature. Figure 4.1 illustrates the difference between an exploratory and a normative scenario. As can be observed from this figure, forecasting, a form of an exploratory scenario approach, is driven mainly by current technologies as well as past trends. In contrast, backcasting, which is a form of normative scenario approach, starts with a vision and works backwards.

In the field of climate change mitigation, the application of normative scenarios has only recently been explored with evidence from the UK (Anderson et al. 2008) and Japan (Shimada et al. 2007). From the developing world's point of view, the key difference between explorative and normative scenarios is that it must balance technological considerations and developmental imperatives, such as poverty alleviation. The exploratory scenario approach can be used to see what mitigation potential can be realized with current technologies. In contrast, the normative scenario approach can be used to provide insights on what kinds of technologies should be developed and installed by a specific period.

Figure 4.1: Difference between Forecasting and Backcasting

Source: (CGER 2007: 18, fig.2.2.3)



Scenarios developed herein qualitatively express the vision for achieving a LCS 2050 and therefore follow a normative approach. Once the visions have been expressed in a narrative way, LCS related actions are developed in Chapter 5 for each scenario and the ESS tool is used to express the visions in quantitative terms. The implementation of the LCS related actions across the period of study is modelled in Chapter 5 using the BCM model. After the modelling exercise has been performed, the overall mitigation potential of the actions across the period (2000-2050) is compared against the vision, which is expressed by the scenarios developed here. This chapter thus discusses the development of LCS scenarios for South Africa and evaluates the visions for LCS by 2050 by considering differing development paths.

4.2 Consideration for scenario development

According to Skea and Nishioka (2008: 4), it is important to pay attention to changes in the major social factors. They indicate that one obvious and drastic change is population structure. Hence, this chapter also discusses South African population dynamics in the period of study (2000-2050) as well as economic growth as key drivers for the modelling framework. Also, uncertainty exists in long-term scenarios. Although infinite pictures can be drawn about the future (e.g. LCS scenarios), it is still impossible to assess them all perfectly. Representing the far-reaching reductions in carbon emissions is more meaningful. Consequently, in the South African context, two scenarios are developed by focusing on cause and effect relationships among the factors. The scenarios are named Scenario “ZA50A” and Scenario “ZA50B”.

The first scenario is based on a society that is techno-economic driven with emphasis on individual needs. The second scenario focuses on a society that is driven by sustainability and characterized by low-energy economic activities, and whose societal lifestyle and values are linked to LCS practices. A summary of these two scenarios is given in Table 4.1.

Table 4.1: Possible future South African LCS trends toward 2050

Scenario: ZA50A (Thriving)	Scenario: ZA50B (sustainable)
Technology-driven	Conservation-orientated
Centralized Urban/ Individual Focus	Community friendly developmental focus
Competency gains in technological capacity	Autonomy, locally centered production and

Scenario: ZA50A (Thriving)	Scenario: ZA50B (sustainable)
	consumption
Convenience is a key priority	LCS forms part of social and cultural values
GDP growth of 2% per year	GDP growth of 1% per year
	

4.3 Narrative scenarios for a LCS in South Africa

This section provides a qualitative assessment of South Africa's LCS scenarios.

4.3.1 Scenario ZA50A development

This scenario assumes that technological advances are achieved by 2050 through technology transfer, which follows the third stream proposed by Ockwell et al. (2008). This means South Africa, through low carbon technology transfer would have accumulated sufficient technological capacity to acquire knowledge, expertise and experience in generating and managing technical change. Under this scenario, the benefits of technology capacity are significantly realized in the power generation and industrial sectors due to R&D, which is jointly and financially supported by the government and the business sectors. Economic activities are prosperous, ensuring that the average GDP per capita is kept at 2 per cent. Also, the domestic consumption of goods and services increases over this period in both the commercial and residential sectors largely due to improved affluence. This further contributes to the assumed high economic growth.

Under this scenario, employment dynamics change considerably from employment practices in 2000. By 2050, equal opportunities have become a reality, as employees are employed based on their abilities regardless of their nationality, gender, age or even race. This result in high morale on the part of the workers, and productivity levels are high. Furthermore, because of greater affluence, individual purchasing power improves significantly and new technologies are thus constantly embraced by society. This also results in rapid changes in technologies, as innovation results in continuous technology improvements.

In addition, since the emphasis is on individual needs, the household size under this scenario has been significantly reduced by 2050. Therefore, the number of single-occupant households increases, and complex-type dwellings are preferred over stand-alone households. The complex-type dwellings are also favoured because they give a greater sense of security and because the maintenance responsibility is shifted to the landlord of the complex. Also, urban lifestyle and culture is favoured over the sluggish rural lifestyle.

4.3.2 Scenario ZA50B development

Under this scenario, there is greater emphasis on developing local energy resources and low carbon technologies. The GDP per capita is assumed to be constant across the period of study at an average of 1 per cent annually. This scenario emphasis sustainability compared to rapid economic growth. Instead of investing in large scale infrastructure to deliver services, the government focuses on funding R&D aimed at improving service delivery to the most remote areas. Also, there is a strong emphasis on production and consumption of goods and services at local level, which improves economic growth at regional level. This also improves the Gini coefficient at local level. Across the period of study, volunteer work and community based mutual aid activities are the main service providers. Both these factors results in improved medical and educational services across the country, such that there is constant migration of the semi-urban population from urban environments towards rural areas.

Unlike in the ZA50A scenario, the number of families living in detached houses increases. This is particularly prevalent in rural areas. This implies increases in floor area and in the size of the household. The average household size also increases from that of 2000. Unlike in 2000, both partners in a household contribute income to share the responsibilities equally. Also, families strive to spend more quality time together, and the time spent on agricultural, sport, cultural and volunteer activities increases by 2050 too.

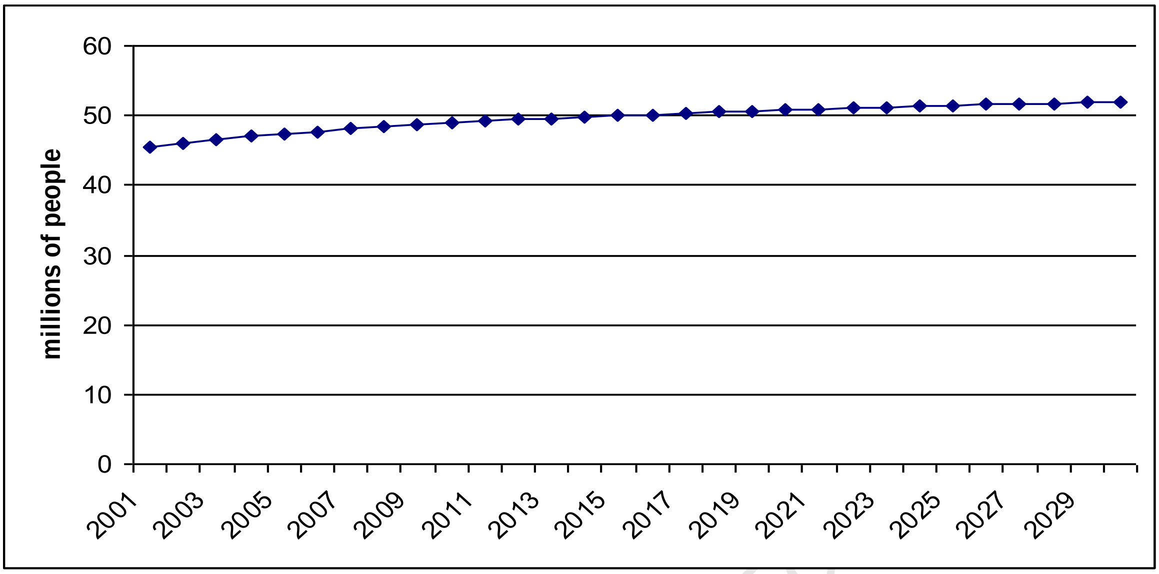
4.4 Key drivers of scenarios

4.4.1 Population size

It is widely accepted that HIV/AIDS complicates the projections of population growth in South Africa. This is further compounded by a lack of accurate information on the uptake of antiretroviral drugs and their impact, given the inconsistencies in their use and their availability in some parts of the country. According to Dorrington et al. (2006), population growth is expected to be about 0.7% by 2006, falling to about 0.2% by 2025. Population analysis done by Statistics South Africa has shown a similar trend to that of Dorrington et al. (2006) with a decline in population between 2001 and 2008. The estimated overall growth rate decreased from approximately 1.5% between 2001 and 2002 to 0.8% for 2007 and 2008 (SSA 2008). The South African population, taking into account the influence of HIV/AIDS for the year 2001, was approximately 47,486,216 (Dorington et al. 2006). Figure 4.2 shows population projections for South Africa for a 50-year period (2000-2050).

Figure 4.2: Population projections.

Source: based on ASSA (2003), cited in Winkler (2007)



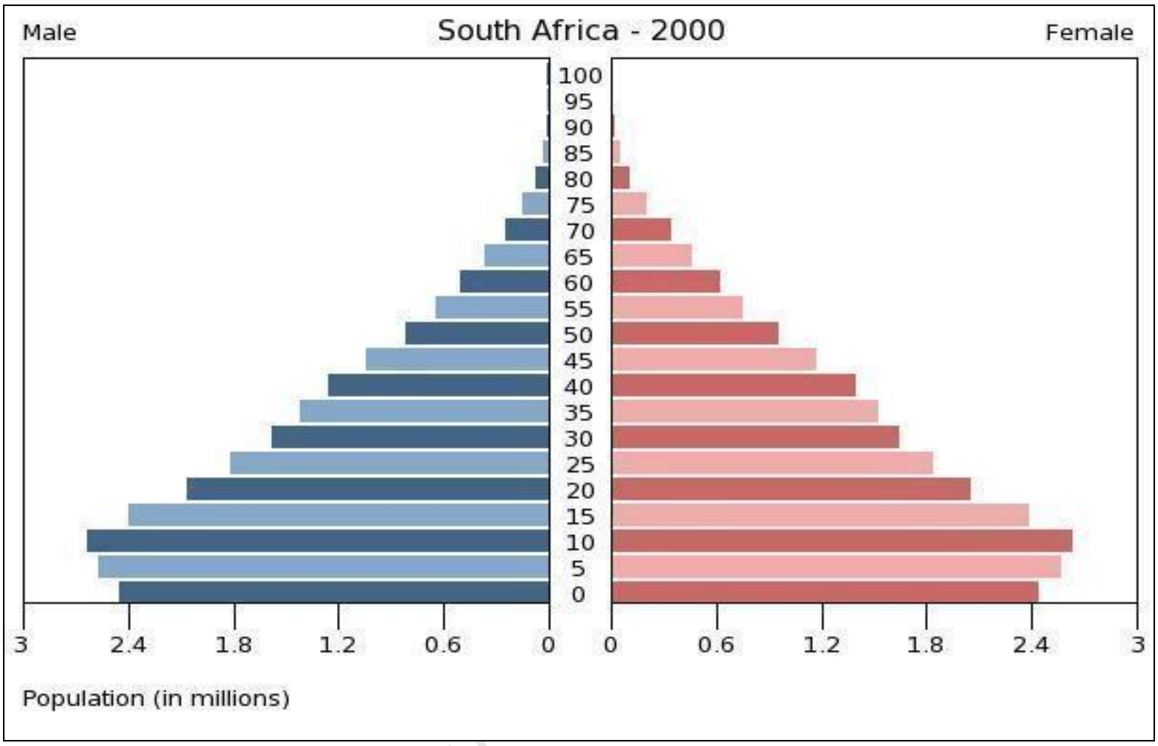
4.4.2 Population pyramid

Figure 4.3 shows a population pyramid for South Africa for the year 2000. It shows that the majority of the population is young, with a tapering old population. The existence of large numbers of adolescents and teenagers is also linked to teenage pregnancies]. The working population group is observed to be small too. This implies that a small working population is supporting a large population of children. This is also supported by the finding that the average South African household consists of 4.0 persons per household, as reported by SSA (2003b, cited by Winkler 2006). In most cases, only one person in the household is working. However, the size of the working population is likely to decrease over the years due to poor lifestyles and exposure to health risk factors, such as alcohol abuse, smoking, indoor and outdoor air pollution and most significantly HIV/AIDS, which has lowered the population growth rate. These factors contribute to a reduction in life expectancy as observed for South Africa (48 years for males and 52 years for females). High illiteracy rates are also contributing to unemployment and low income. Consequently, only 10% of the population contributes as much as

90% towards social services through income deductions. This leads to highly skilled persons leaving the country and seeking employment elsewhere.

Figure 4.3: Population pyramid for South Africa for the year 2000

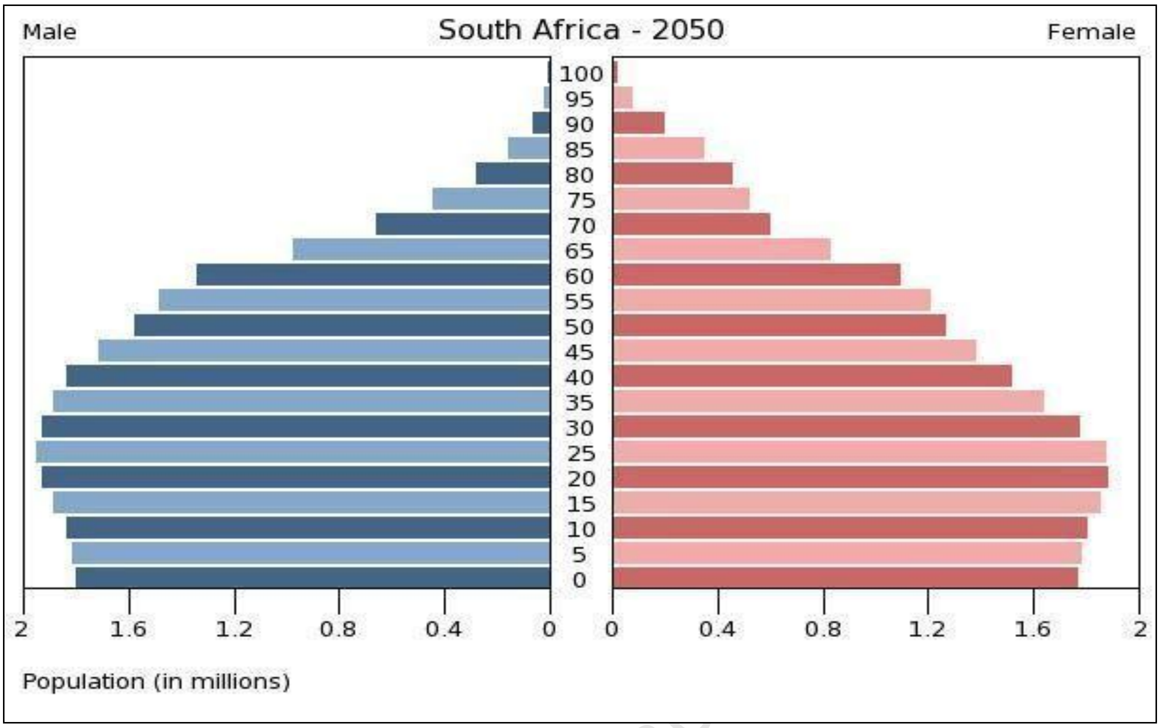
Source: U.S. Census Bureau (2009), International Database



A projection of the population pyramid into the future, as shown in Figure 4.4, shows a more encouraging situation: by 2050, the working population group is estimated to represent a large portion of the total population. It also shows larger numbers of older persons, which hints at improved lifestyles and improved health conditions. By this time, it is safe to assume that the household size would have reduced quite drastically, decreasing to between 2.0 and 2.5 persons per household. Generally, as observed elsewhere, the more educated the population, the smaller the household size tends to be.

Figure 4.4: Projected Population Pyramid for South Africa for the year 2050

Source: U.S. Census Bureau (2009), International Database



4.4.3 Household Size

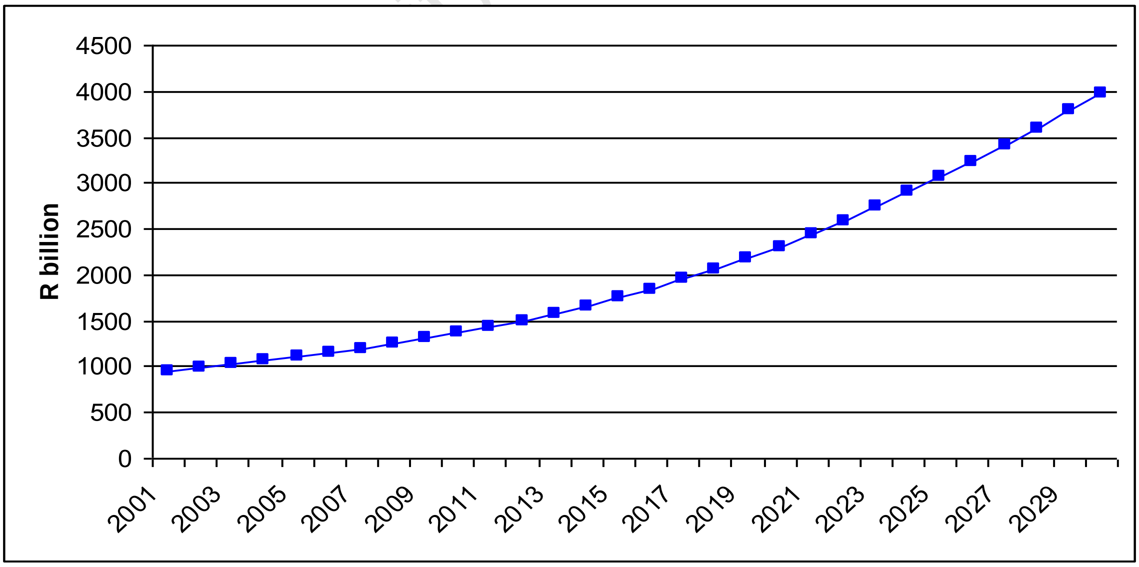
There is a link between the urban/rural population ratio and the number of households. Fairly recently the urban/rural population ratio has been increasing due to the movement of people from rural areas to urban areas in pursuit of job opportunities. Similarly, the increase in income locally and elsewhere shows a negative correlation with population growth and the number of households (UNPD 2000). This is clearly demonstrated by the drop in household size from 4.5 to almost 4.0 between the 1996 census and the 2001 census (SSA 2003b). Given rapid local urbanization and economic growth, it is fair to assume that the household size is likely to decline over the study period. A household size base year value of 3.985 is computed from the growth rate provided by Winkler et al. (2006). When Winkler (2006) considered household growth rates for South Africa, he assumed a figure of 3.8 dwellers per household by 2030.

4.4.4 Economic growth

Over the past 12 years, GDP growth in South Africa has fluctuated between 0.5% and 5%, but it has shown a positive trend. Targets for GDP growth rates of 3 to 6% have been set as part of the Accelerated and Shared Growth Initiative for South Africa (AsgiSA 2006; National Treasury 2005). The literature on GDP growth rates has been assessed *inter alia* by the IPCC (IPCC 2000). The world has witnessed high periodic economic growth in many countries. A per capita GDP growth rate of 3.5% per annum was achieved, for instance, in Western Europe between 1950 and 1980. Similarly, high per capita GDP growth rates were achieved in the developing economies of Asia. Per capita GDP growth rates of individual countries have been even higher – 8% per annum in Japan over the period 1950-1973, 7% in Korea between 1965 and 1992, and 6.5% per year in China since 1980 (IPCC 2000). Based on such analysis, it is suggested that South Africa might be considered to be in an acceleration phase (stage 5). This would be consistent with the AsgiSA targets of economic growth increasing from recently relatively low values to around 2.5%. In the long term, GDP growth rates might settle around 3%, consistent with the IPCC's recommendation for discount rates of 3% to be applied for long-term, inter-generational studies (IPCC 2001a: 467).

Figure 4.5: GDP projections

Source: (based on Vessia 2006), cited in Winkler 2008 et al: 25, fig.3)



The projections used here and following earlier work (Vessia 2006), assume that the current growth trend extends to 2015 and 2016, in which the peak growth at 5.24% is reached, after which growth decreases to a more stable lower level of approximately 2% annual growth.

The next chapter (Chapter 5) discusses LCS actions for each scenario as well as implementation parameters and mitigation options for the obstacles associated with each option. Appendix C discusses the keywords that characterize the two LCS scenarios. Once actions have been developed for each LCS pathway, two methodology processes unfold simultaneously. Firstly, the BCM approach will unfold, taking into account mitigation options. Secondly, the ESS tool is employed, using energy balance data as well as actions developed to determine the emission reduction goals. The results of both approaches will thereafter be compared in Chapter 6.

CHAPTER 5

5 Development of actions for a low-carbon society

5.1 National context for development of LCS actions [4]

While the energy sector in South Africa could be used to provide a clear example of the synergies between development and sustainable development, policies and measures in other sectors, if adopted with sustainable development considerations, can also have significant potential for reducing GHG emissions. Conducting a complete analysis across all sectors in South Africa would require an inter-disciplinary team, significant time and data. The following table, adapted from a study by the Energy Research Centre (ERC), shows some emission reduction estimates in response to different policies and measures in several development sectors.

Table 5.1: South African SD-PAMs, sustainable development benefits, energy and GHG implications

Source: (Winkler et al. 2008, 4-6)

Policy – name	*Policy – short description*	*Local SD benefits*	*Energy implications*	*GHG implications, from existing studies*
Industrial energy efficiency	Through various measures, the energy efficiency in industry is improved. Measures include improving boiler efficiency, decreasing coal dependency, improving motor efficiency and introducing variable speed drives.	Lowers the demand for extra generating capacity, improves industrial competitiveness, improves industrial efficiency.	15% savings against baseline projection, improvement by 2015. Extended up to 2030.	Emission reduction of 45Mt CO_2 in 2030. Cumulative emission reductions of 486Mt CO_2 for 2001-2030 from non-electricity energy carriers (Haw and Hughes 2007b).
Renew-able energy generation	The use of renewable energy (RE) is strongly advocated and targets are set for renewable energy.	Decreases CO_2 per capita, increases investment in renewable options and strengthens energy security, less local pollution, lower fuel costs.	RE to contribute 27% by 2030. 10000GWh (36PJ) from RE by 2013.	180Mt CO_2-eq over 25 years 2001-2025 (Winkler et al. 2006)

[4] This section draws on Winkler (2009) *Cleaner Energy Cooler Climate*.

Policy – name	Policy – short description	Local SD benefits	Energy implications	GHG implications, from existing studies
Improve light vehicle efficiency	Standards and targets are set for light vehicle fuel economy.	Improves local air pollution, slows growth in demand for petrol, reduces fuel imports, increases fuel exports.	An improvement of 1.2% is made per year on light vehicle economy, as opposed to a 0.4% increase in the base case.	33Mt CO_2 can be saved in 2030.
Transport mode shift	Shift passenger transport away from personal vehicles to public transport.	Improves local air pollution, slows growth in demand for diesel and petrol, reduces fuel imports, increases exports, significant improvements in traffic.	Public transports share of passenger km's increases from 50% in 2001. Increase by 0.5% per year to 65% in 2030.	35Mt CO_2 saved in 2030.
Hybrid Vehicles	The share of hybrid vehicles on the roads is gradually increased.	Reduces local air pollution, slows growth in demand for diesel and petrol, lowers fuel imports.	Hybrid vehicles will account for 7% of private passenger kilometres by 2015 and 40% of private passenger km's by 2030. Ratio of public to private kilometres = 50% for whole scenario.	13Mt CO_2-eq reduction in 2030.
Commer-cial energy efficiency	Energy efficiency measures are implemented in commercial and public buildings and public awareness is promoted. The main areas for improvement are lighting, thermal design and heating, ventilation and air conditioning (HVAC) systems.	Reduces pollution, slows growth in energy demand, reduces urgency for increased capacity, raises public awareness, and promotes job creation.	A final energy demand decrease of 15% by 2015 compared to the baseline is targeted for commercial energy. Final energy demand decreases by 30% in 2030 compared to the baseline.	1.5Mt CO_2 reduction made in 2030, cumulative reduction of 19Mt CO_2 reduction (2001-2030). These emissions are from non-electricity energy carriers.
Residen-tial energy efficiency	Various measures are implemented to improve residential energy efficiency. The main areas are lighting, water heating by means of solar water heaters (SWH) and cooking.	Energy poverty alleviation, decreases localized air pollution (total suspended particulate solids) through reduced use of coal, improves health.	Final energy demand decrease of 10% by 2015 for residential energy. 32PJ by 2030 (Haw and Hughes 2007b). 20%-60% of rich households have SWH by 2030, 10-50% of poor households have SWH.	Final energy demand decrease of 10% for residential energy. 8.13PJ by 2025 (Winkler et al. 2006) and 32PJ by 2030 (Haw and Hughes 2007b).
Imported hydro	The amount of imported hydro-electricity is significantly increased over the base case.	Reduces local air pollution and lowers the need for more domestic power generating capacity, improves energy mix.	Increases share of imported hydro from 9.2TWh per year in the base year to 17TWh in the policy case.	167Mt CO_2 avoided. Possible increase in methane emissions.
Biodiesel / biofuels	Biodiesel is used to supply more of the transport needs.	Job creation, and increase in fuel specific agriculture, small reduction in local pollutants, less imported crude oil, promotes job creation and economic growth.	8% petrol, from bioethanol, 8% of diesel is from biodiesel.	5Mt CO_2-eq/annum emission reduction by 2025, cumulative savings are 31Mt CO_2 for the period.

Policy – name	Policy – short description	Local SD benefits	Energy implications	GHG implications, from existing studies
Imported gas & increased CCGT	In this policy scenario, a stronger emphasis is put on imported gas and gas generation. Three combined cycle gas turbines (CCGT) of 1950MW each are built.	Lowers demand for coal generating capacity, and lowers air pollution.	By 2015 build 1, 2020, build another, 2025 build another.	199Mt CO_2e saved,
Electric vehicles	More uptake of pure electric vehicles. It is a requirement for renewable electricity to contribute towards this increase in demand, off-setting the potential increase of fossil-fuel requirements.	Significantly reduces local air pollution, decreases import of crude oil, increases petrol exports as diesel makes up bigger share.	Increased renewable electricity generating capacity is required. By 2030 - 60% of private passenger km's.	90 Mt CO_2 is saved in 2030 with an increased share of renewable energy sources of 27% by 2030.

5.2 Focus areas and potential

In an attempt to assess the mitigation potential of LCS actions while taking into account behavioural aspects, the next section considers the respective actions for the two LCS scenarios (scenarios ZA50A and ZA50B) developed in Chapter 4. The actions chosen are consistent with South Africa’s national priorities and status as a developing country, and they all address behavioural aspects that often hinder the potential of mitigation actions. Some actions are unique to each individual scenario, whereas others are common to both scenarios. Scenario ZA50A actions are technology driven with no direct influence on people’s behaviour. Instead, these actions focus on redesigning systems (e.g. improved transport logistics) including a shift towards greener fuels. In contrast, scenario ZA50B actions seek to change behaviour including higher rates of renewables in low-carbon electricity generation in ZA50B than in clean electricity generation in ZA50A. For example, actions such as designing a pedestrian friendly urban city encourage a move away from cars and towards the use of bicycles. Also, the adoption of waste minimization principles and leadership in a low carbon society has direct influences behavioural change. Since power generation remains the major source of GHG emissions (DEAT 2009), this scenario also has to take this into account. Actions that are common to both scenarios are discussed in Section 5.5. The majority of the options are focused on the demand-side with a few supply-side actions targeting mainly electricity generation. Table 5.2 summarizes the actions considered in this study.

Table 5.2: Actions for the two South African LCS scenarios (ZA50A and ZA50B)

Scenario	LCS Action	Sector
ZA50A	Clean electricity generation	Power generation
	Improved transport logistics	Freight transport
	Clean synfuels production	Energy sector
	Climate sensitive private transport	Private transport
	Cleaner cooking	Residential
	Clean vehicle fuels	Energy sector
	Transport modal shift	Private transport
ZA50B	Low-carbon electricity generation	Power generation
	Pedestrian friendly urban city design	Passenger transport
	Adoption of waste minimization principles	Power generation
	Minimum carbon-driven consumer spending	Residential
	Leadership in low carbon society	All
	Cleaner process heating	Industry
	Second generation fuels	Energy
Scenario	**LCS Action**	**Sector**
Common to both scenarios	Carbon-neutral water heating	Residential
	Greener settlements	Residential
	Energy efficient lighting	Residential
	Climate sensitive commercial sector	Commercial
	Climate conscious manufacturing	Industry

5.3 LCS actions for ZA50A scenario

5.3.1 Action A1: Cleaner electricity generation

South Africa has vast resources of renewable energy, mainly in the form of wind and solar. It experiences amongst the highest solar radiation levels in the world, with daily solar radiation levels in the range of 5.5 to 8.5 kWh/m^2/day (CCT 2003). Similarly, there is a huge potential to harness wind energy, mainly in coastal areas, with a total expected contribution of 3000 MW by 2020 (CCT 2003 and SEA 2003). Currently, however, renewable sources account for less than 1% of total installed capacity. In realising the potential of renewable energies, the government has set targets for these, and it has committed itself to actions to ensure greater penetration of renewable forms of energy. In this regard, in a study conducted by the Energy Research Centre (Winkler 2007), results of modelling have shown that it is possible to achieve a 27% share of renewable energy sources (mostly solar) by 2030 and to remain at that level until 2050. This study has therefore assumed that renewable energy sources will contribute a share of 30% towards electricity generation, with nuclear energy contributing 50% and the remainder being cleaner coal with CCS. This based on the assumption that In the short-to-mid term, renewables are seen to easy to implement. However, in the long term, nuclear which is a well established technology, is seen as a feasible and stable electricity generation option to implement. Also, clean coal technologies improve the thermal efficiency of conventional coal-fired power stations by 8% (Haw and Hughes 2007b).

These options are seen as part of a technology driven LCS pathway, as they require local R&D as well as capacity building in the production and operation of such technologies. However, a number of obstacles still exist that need to be resolved. Firstly, in the local context, renewable energy sources have to compete with cheap yet dirty fuel in the form of coal for electricity generation. This problem is further compounded by the absence of a competitive electricity generation market in South Africa (Steyn 2003: 53). This situation makes it impossible for independent power producers (IPPs) to consider electricity generation from renewable energy sources. Secondly, the need to import utility-scale renewable technologies in their entirety makes them unattractive economically. Hence, local production of these technologies is likely to accelerate their uptake, as capital and logistical costs are guaranteed to decline significantly. Thirdly, research work on renewable energy availability requires a comprehensive review and consolidation. Not only is the literature in this area outdated, but it is also inconsistent from one study to the other. The solution to this problem is to commission an in-depth study applying the latest technologies such as Geographical Information Systems. Fourthly, more changes in legislation are needed to encourage the participation of independent power producers (IPPs) in electricity generation, particularly from the renewable energy point of view. This situation will result in competitive pricing, and the ability to consider small grid-connected renewable energy systems, particularly in wind and solar power generation. This is one opportunity of encouraging less dependence on dirty coal-fired power generation. Also, government needs to set renewable energy targets by sources, so that it is clear to which renewable energy sources government is committing. This will stimulate public-private partnerships on the development of such renewable technologies. Lastly, pilot studies, which focus not only on technical feasibility but on economic feasibility of solar technologies, are limited in the local context. Consequently, investors find it difficult to consider renewable technologies because they are uncertain of the economic performance of such technologies in the local context. Therefore, more pilot studies with concrete results are needed to inform investment in renewable energies. Government has a big role to play in realising some of these interventions, as government involvement means that information on interventions such as research work and the results of pilot work become available to the public.

Moreover, institutional arrangements are inadequate and sometimes too saturated to deal with energy issues. What is needed is sound coordination and better definition of roles and responsibilities as well as financial backing to ensure adequate implementation of renewable energy policies. This has huge implications for the allocation and use of resources aimed at realising the implementation of renewable technologies in South Africa. The solutions (indirect options) to these obstacles are indicated in Figure 5.1.

Figure 5.1: Obstacles and mitigation options for "clean electricity generation"

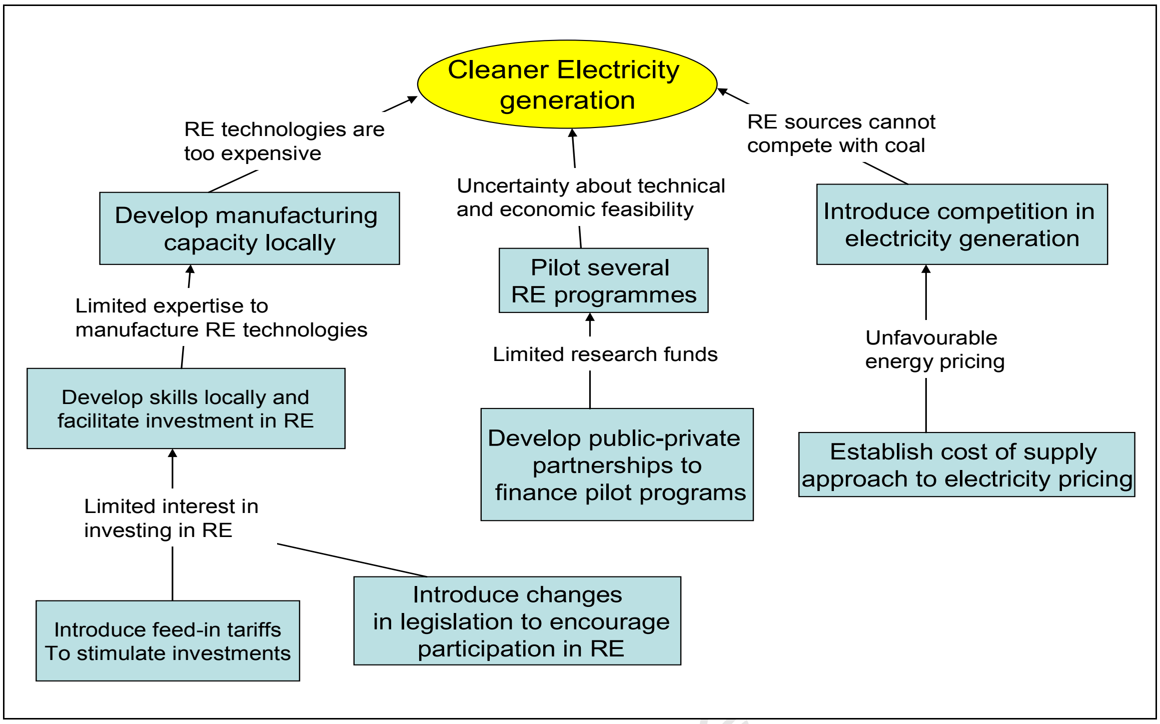


Figure 5.2: Implementation plan for the ZA50A LCS scenario action "clean electricity generation"

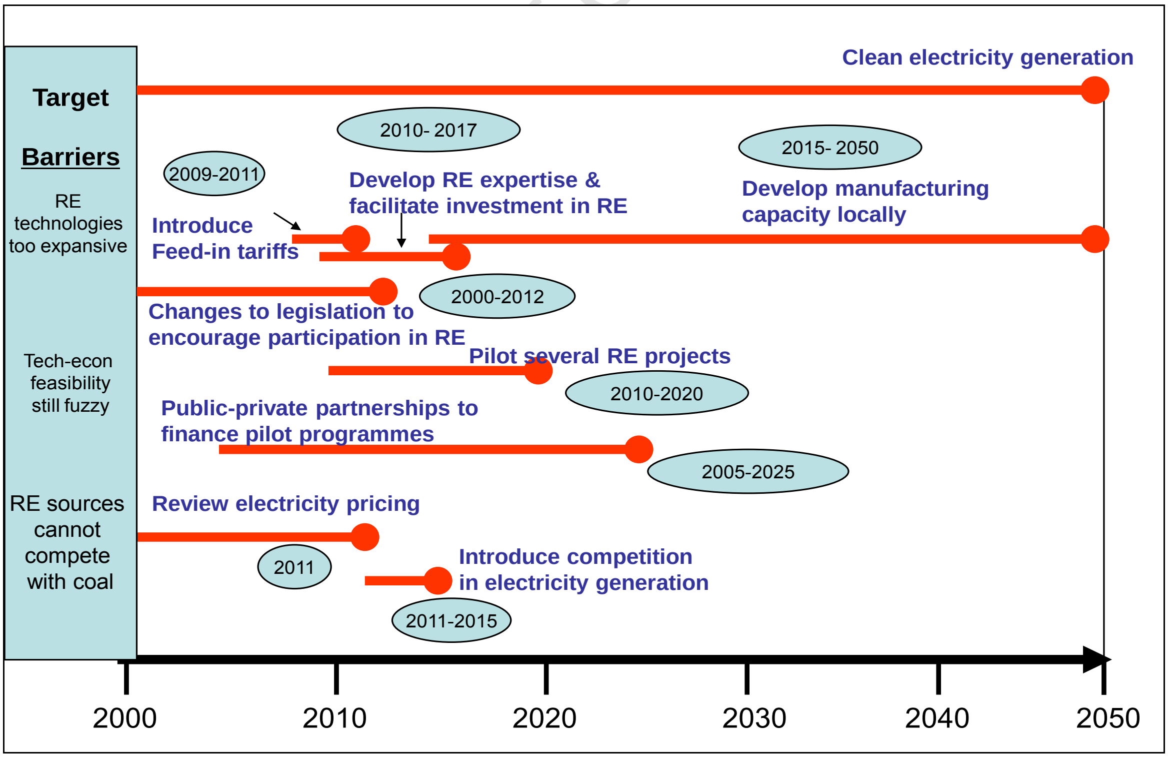


Figure 5.2 shows timelines for the implementation of the options in an effort to realize a 30% share of renewable energy contribution to electricity generation

by 2050. The implementation plan for renewable energy technologies (RETs) takes into account the Renewable Energy Feed-in Tariffs (REFIT) published by the National Energy Regulator of South Africa (NERSA 2009) shown in Table 5.3, which is aimed at stimulating investment in this sector.

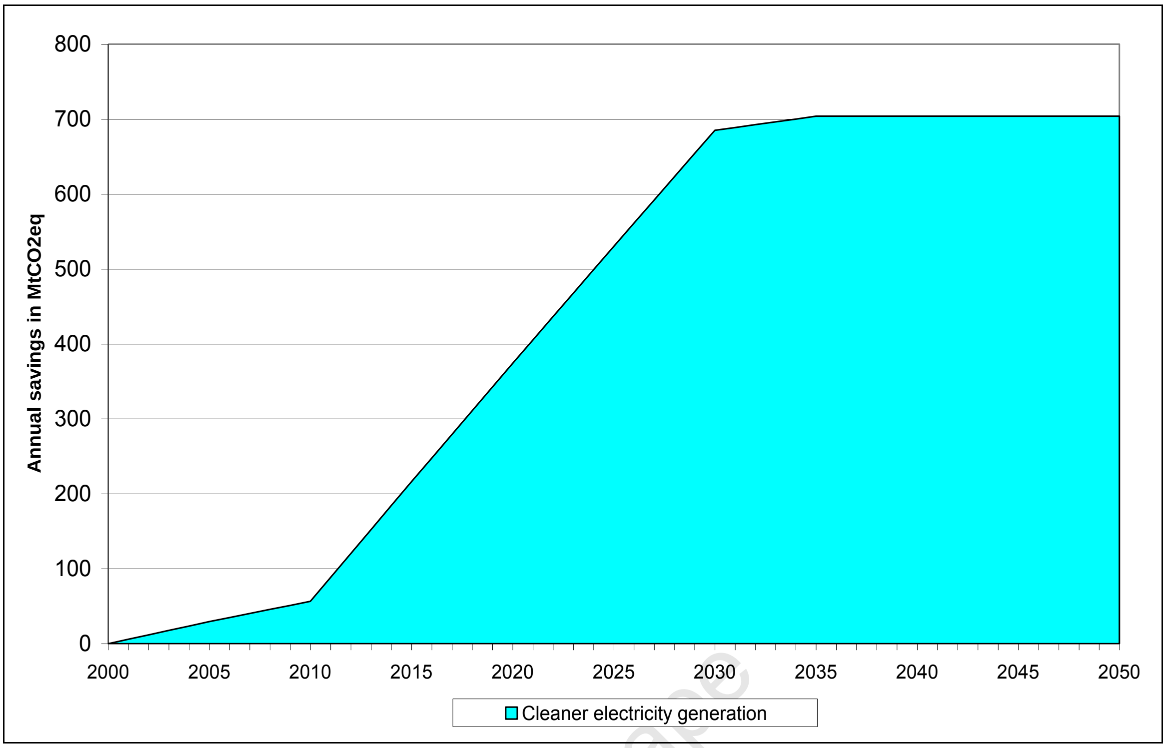
Table 5.3: Renewable energy tariffs under the REFIT guidelines

Source: (NERSA 2009: 36)

RE Technology	Unit	REFIT
Wind	R/kWh	1.25
Small hydro	R/kWh	0.94
Landfill gas	R/kWh	0.90
Concentrated solar	R/kWh	2.10

The development of these feed-in tariffs should be finalised by 2011 in terms of the implementation plan. Concurrent to the introduction of renewable feed-in tariffs, local manufacturing capacity for RETs should be established. However, this requires South Africa to develop manufacturing expertise locally. Thus, government must engage in a programme to develop RE expertise locally as early as 2010, and such a programme should reach maturity by 2017. Full scale production of RETs should be in operation by 2015. Also, changes in legislation should be effected to promote further participation in RE. As such, public-private partnerships in piloting RE projects should kick-start by 2010 and reach maturity by 2020. Review of electricity pricing is also critical to ensure investment in RETs as well as to introduce competition. However, these require critical examination to establish a competitive energy sector by 2015.

Figure 5.3: Emission savings in $MtCO_2$-eq associated with implementation of "cleaner electricity generation"



By 2035, emissions savings from cleaner energy generation will have reached a peak of 703.8 $MtCO_2$-eq, remaining at that level of savings until 2050. Renewable energy feed-in tariffs, clean energy levies on carbon based electricity generation and public-private partnership on nuclear implementation are fundamental to achieving this goal. For example, the introduction of renewable energy tariffs coupled with the introduction of IPPs as well as facilitation of investment in renewable energies contributes to the observed abrupt increase in emission savings between 2010 and 2015. Uptake of nuclear energy ensures that emissions savings continue to accrue until 2035, when implementation of alternative power generation technologies has reached maturity.

5.3.2 Action A2: Improved transport logistics

There remains a significant opportunity to improve freight transport in South Africa so that it is more energy efficient. The current railway network can be extended. The pipeline transport network also needs to be extended, particularly the links to coastal and inland routes. Road freight transport can also benefit from interventions such as improved supply chain management enhanced with information and communication technologies (ICT) systems such as vehicle fleet tracking systems. This will ensure the smooth and optimized flow of goods from the supply source to the area of demand. According to a study by Vanderschuren et al. (2008), improved supply chain management can reduce oil dependence by 15% in 2030. With continued improvements in transport logistics and the availability of low carbon technologies in the future, this study has assumed that this figure increases to 25% by 2050. Furthermore, with the expansion of the railway network and a shift towards electrified railway systems, an assumption has been made that the share of electricity for railway freight transport saturates to 100% by 2050. In addition, expansion of the railway network reduces the demand for road freight transportation across long distances. Therefore, this study assumes that 30% of road freight transportation will be shifted to rail freight by 2050. In a technology driven LCS pathway with sufficient electricity generation capacity, a 30% penetration is regarded as a conservative estimate. Local road freight transport consumes more energy than long distance freight transportation. As such, the study has assumed that 50% of energy demand for freight transport is met by electric and hybrid mini vans.

As observed from Figure 5.4, there remain a number of obstacles to improving transport logistics. For example, the pricing structure for transport via rail and pipelines tends to favour long distance transportation of goods because of low transportation fees. In addition, public-private partnerships are needed to expand the railway network. Research into cost-effective fleet management systems for medium to small enterprises is needed to encourage them to use such technologies. Implementation of the proposed mitigation options is presented in Figure 5.5.

Figure 5.4: Obstacles and mitigation options for "improved transport logistics"

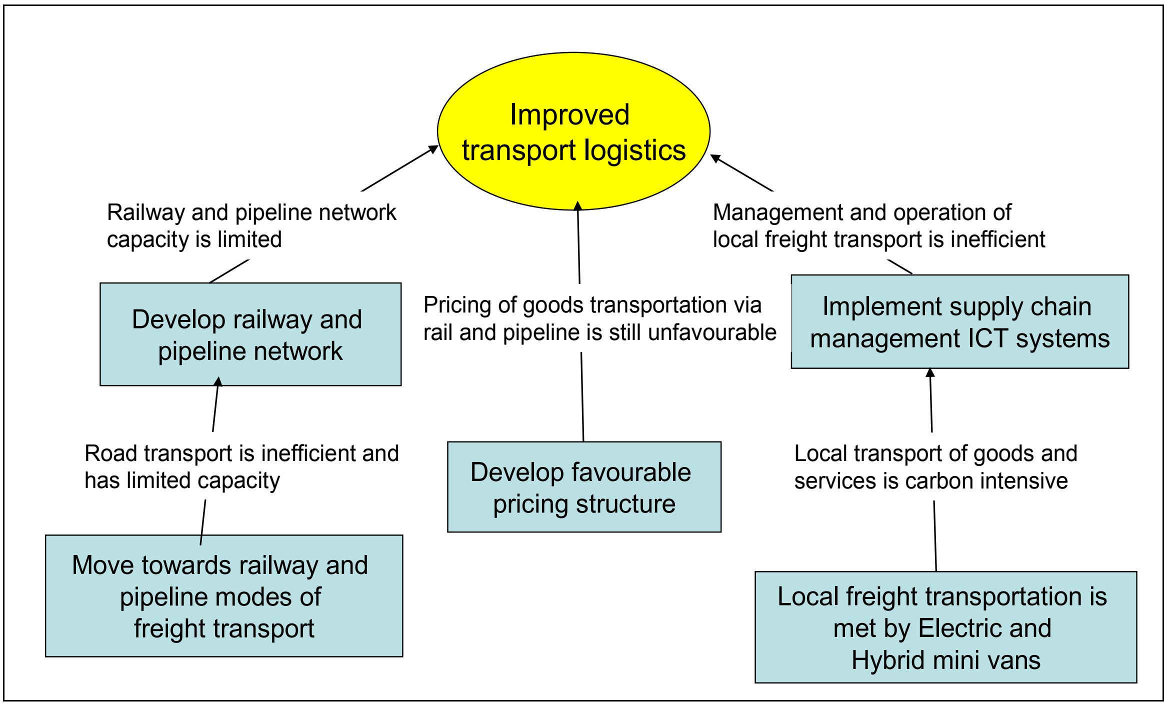


Figure 5.5: Implementation plan for the ZA50A LCS scenario action "improved transport logistics"

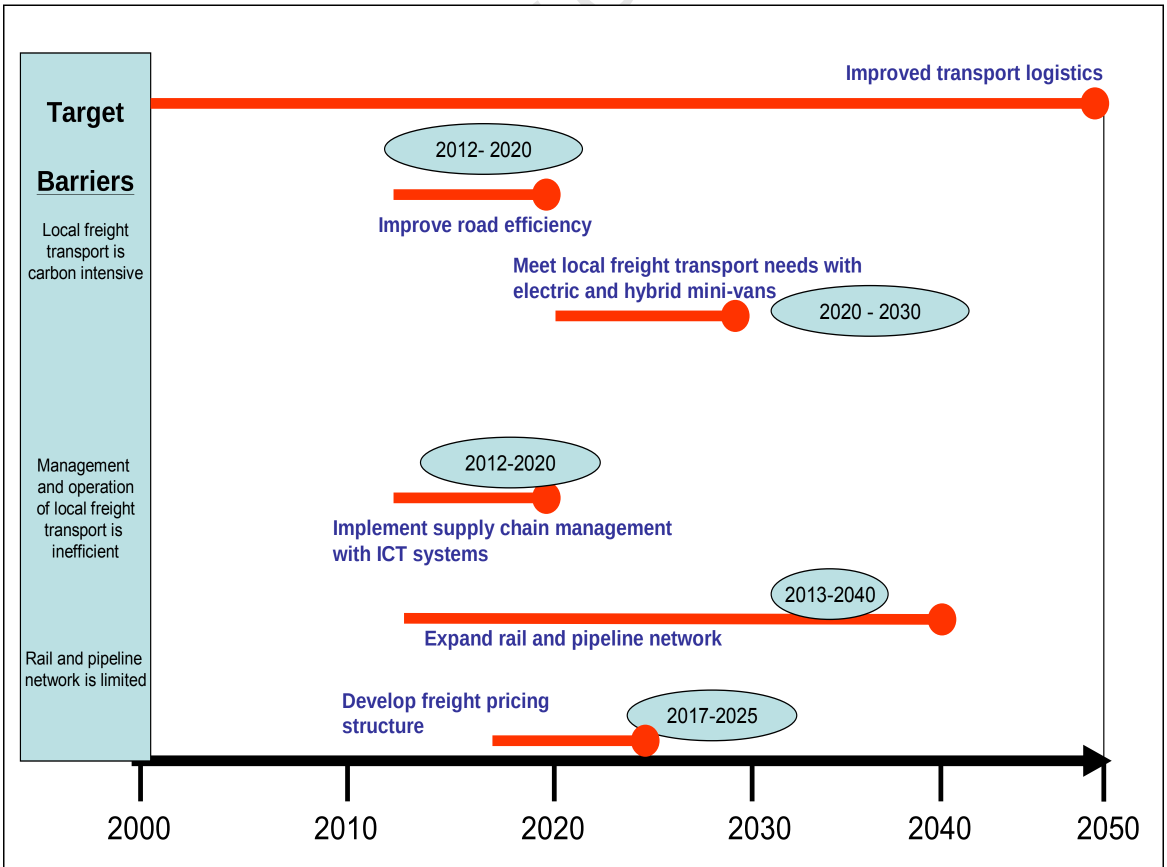
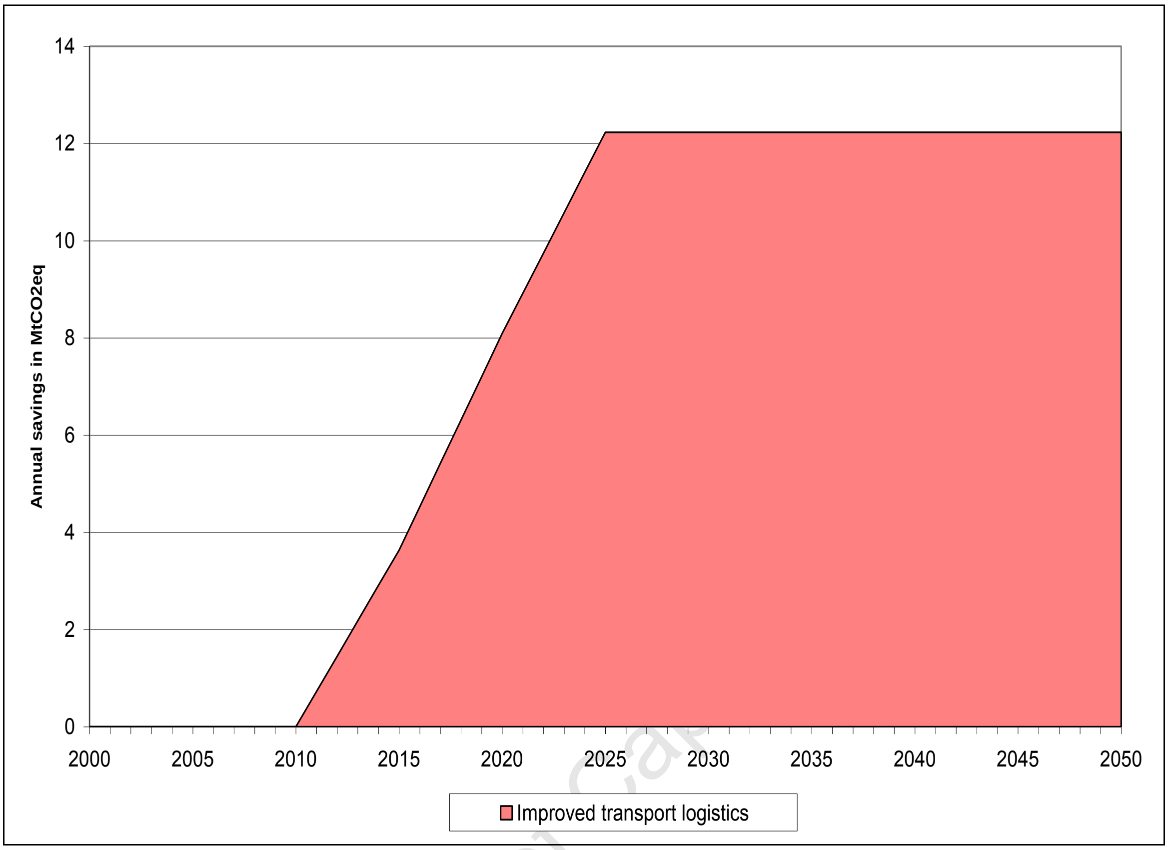


Figure 5.6: Emissions savings related to the ZA50A LCS scenario action "improved transport logistics"



Improved transport logistics result in peak savings equalling 12.2 $MtCO_2$-eq by 2025 and remaining at that level until 2050 (Figure 5.6). Total savings amount to 401 $MtCO_2$-eq. Long-term improvements in the current railway and pipeline infrastructure and improved supply chain management integrated with current ICT are responsible for the observed peak in 2025.

5.3.3 Action A3: Cleaner synfuels production (CCS for Coal-to-Liquids)

The Department of Environmental Affairs and Tourism (DEAT) has announced that no new coal powered fire station is to be build without carbon capture and storage. In our local context (South Africa), for example, the best locations for carbon storage are found on the western side of the country, i.e. far away from the carbon intensive power stations and CTL plants (Hallowes and Munnick 2007). This means that long-distance pipelines would need to be constructed to pump CO_2 to suitable locations. Transporting CO_2 over long pipelines may prove expensive and possible leaks in such pipelines are inevitable. Furthermore, carbon capture and storage (CCS) is not a proven technology and therefore piloting locally would be a first step to test its applicability in the South African context. A private-public partnership may have to be initiated to absorb the high capital costs of CCS. Figures 5.7 and 5.8 summarize the direct and indirect options to deal with CCS as well as realistic implementation timelines.

Figure 5.7: Obstacles and mitigation options associated with implementation of cleaner synfuels production

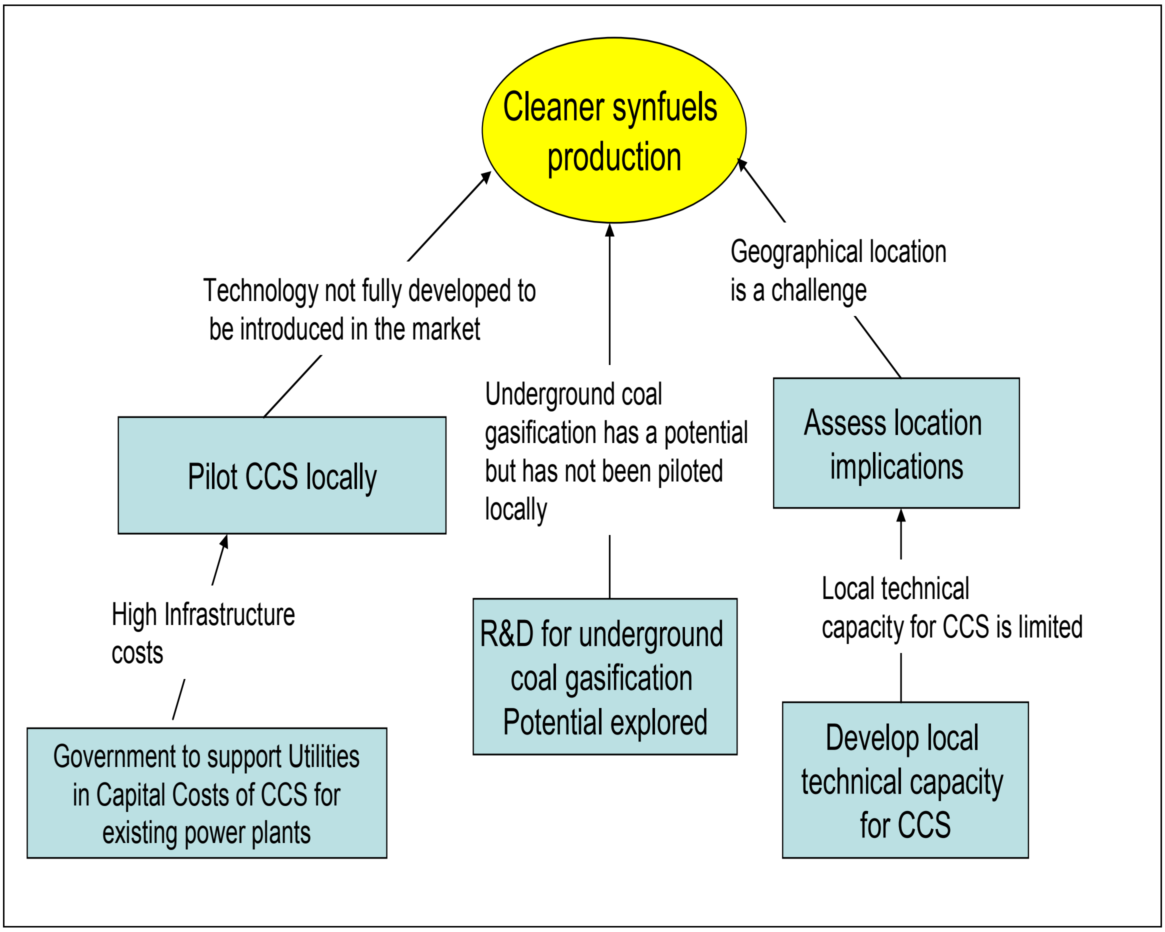
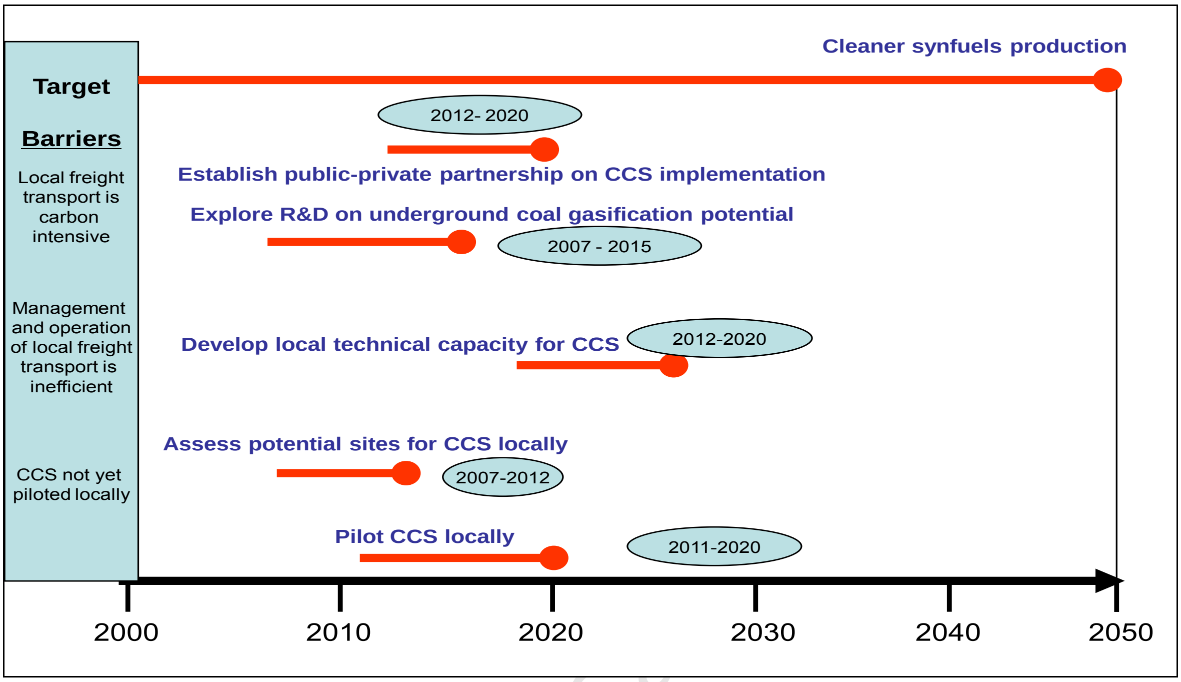
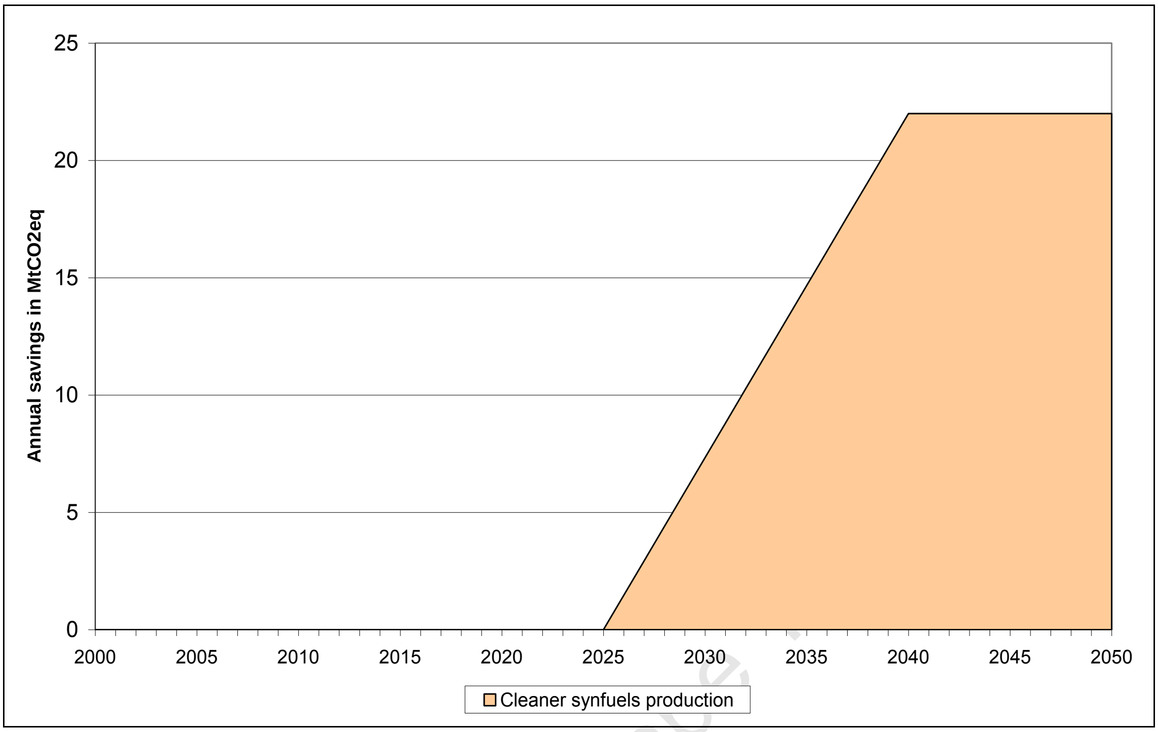


Figure 5.8: Implementation plan for cleaner synfuels production in South Africa, showing the implementation of indirect and direct options in relation to specific timeframes



The production of cleaner synfuels is calculated to save a total amount of 396 $MtCO_2$-eq over the study period. Peak savings are achieved as early as 2040 (Figure 5.9). Implementation of carbon capture and storage (CCS) starts as early as 2026 and the full savings potential is achieved in 2040 and maintained at that level until 2050. Early joint partnerships on CCS to cover pilot studies and infrastructure costs and to develop local technical capacity on CCS, are seen as key in obtaining these emission savings. The peak in emissions savings achieved in 2040 is attributed to limitations in coal-fired power generation and a shift towards renewable energies.

Figure 5.9: Emissions savings in $MtCO_2$-eq for the LCS action "cleaner synfuels production"



5.3.4 Action A4: Climate sensitive private transport

Private transportation remains one of the key contributors to poor air quality and climate change. In major cities such as Cape Town, transport related emissions are estimated to account for approximately 45% of total air pollution emissions. Despite this, a suite of interventions does exist to reduce transport emissions significantly, if they are implemented. These interventions range from near-term (e.g. improvements in road efficiency), to mid-term (e.g. import levies on heavy vehicles) to long-term (e.g. electric cars). Hybrid vehicles already exist in the market. According to Vanderschuren et al. (2008), increased use of hybrid cars could reduce oil dependence by 16.8% by 2030. This study has assumed that this figure will increase to a modest 20% by 2050. In addition, electric cars, once implemented, can reduce oil dependency by 10% in 2030, increasing to 20% by 2050.

It is common knowledge that smaller engines are more efficient than bigger engines. As such, a move towards smaller engines can reduce oil dependency by 3.8% in 2030 (Vanderschuren et al. 2008). This figure is allowed to increase to 10% by 2050. This increase is encouraged by high levy charges on heavy vehicle imports and high fuel prices. Diesel engines are generally more efficient than petrol cars. Therefore, a move towards diesel engine cars could reduce petrol consumption by 17%, which translates into a 6% reduction in oil dependency by 2030, increasing to 10.5% by 2050.

Obstacles associated with implementing this action include the absence of levies of taxes on heavy vehicles, the absence of funding for research on electric cars, the lack of subsidies to stimulate green car sales and the lack of capacity to produce green cars locally (Figure 5.10). Figure 5.11 shows an implementation plan for mitigation options aimed at addressing identified obstacles.

Figure 5.10: Obstacles and mitigation options for the action "climate sensitive transport"

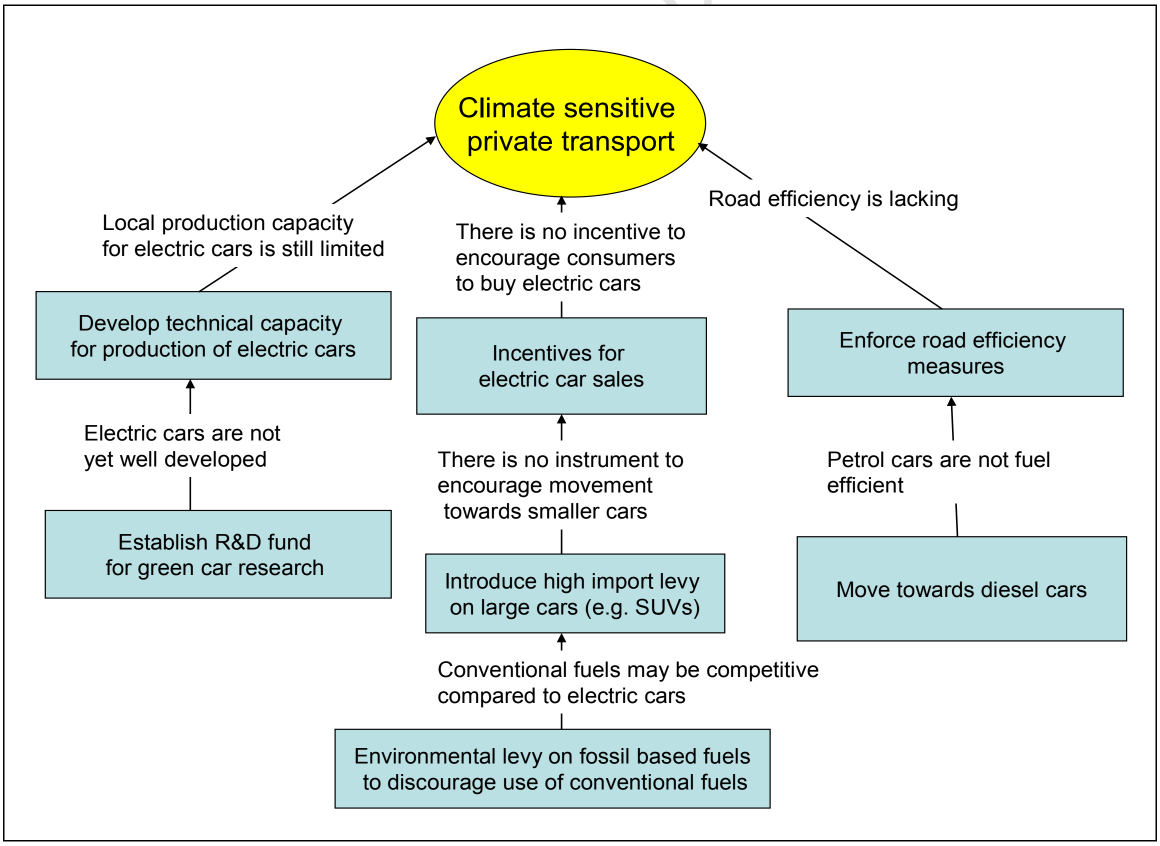


Figure 5.11: Implementation plan for the ZA50A LCS scenario action "climate sensitive transport"

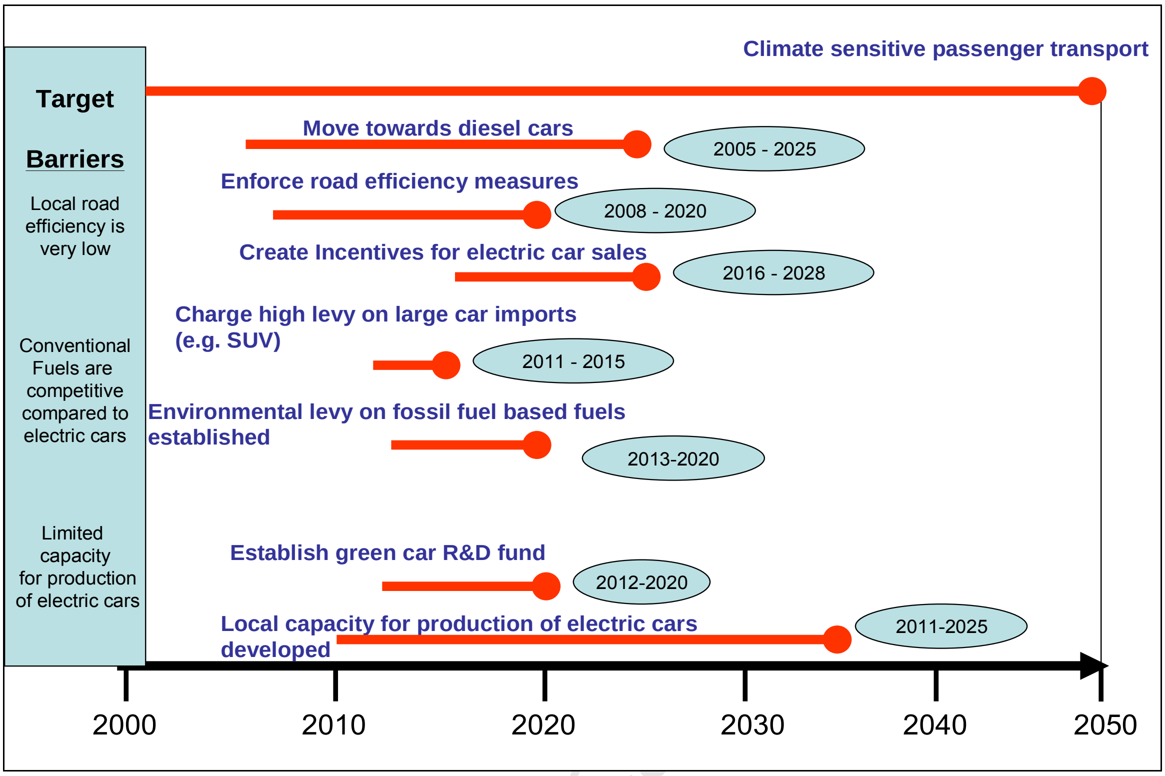
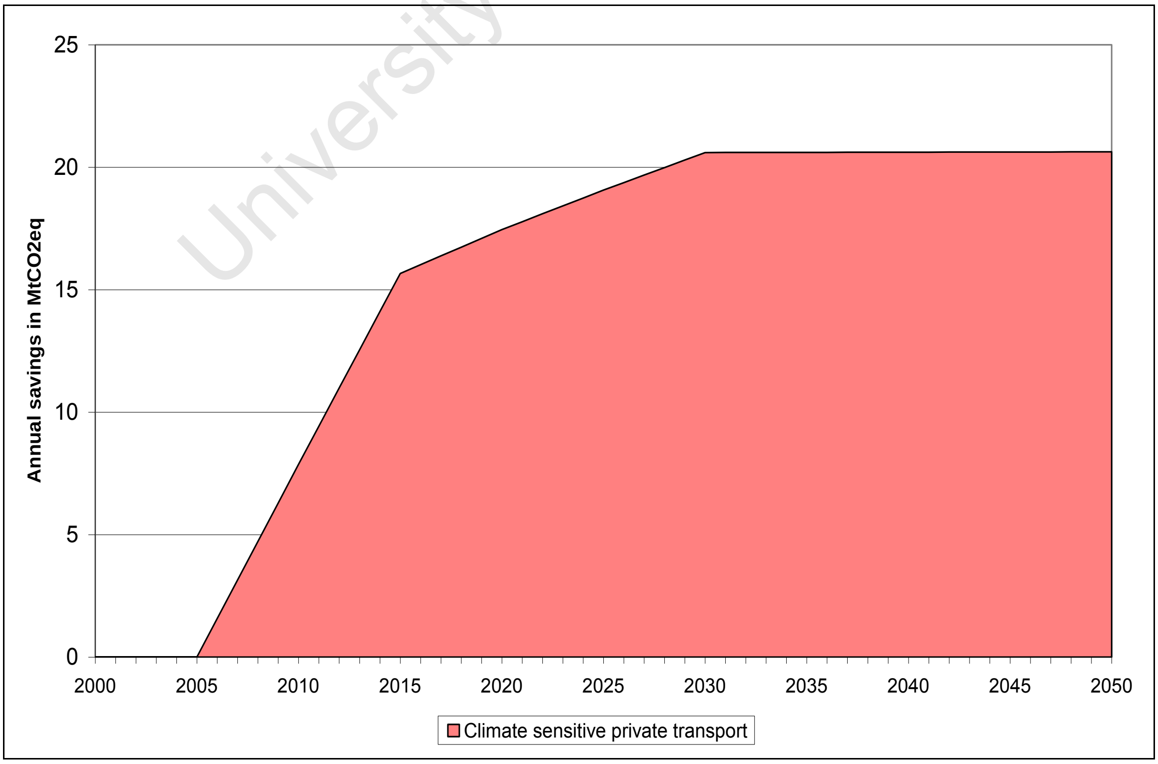


Figure 5.12: Emissions savings in $MtCO_2$-eq for the ZA50A scenario action "climate sensitive private transport"



The realization of climate sensitive transport results in 20.6 $MtCO_2$-eq savings by 2050 (Figure 5.12). A total emissions savings totalling 774 $MtCO_2$-eq can be achieved in the study period. A combination of factors, such as moving towards diesel cars (10.5% oil dependence reduction), implementing greater road efficiency (15% oil dependency reduction) and enforcing measures such as high import tax on heavy vehicles (e.g. sport utility vehicles or SUVs) all contribute significantly towards these savings.

5.3.5 Action A5: Cleaner cooking

As part of this action, 50% of energy service demand for cooking using electricity is replaced by the use of Liquefied Petroleum Gas (LPG). As highlighted on Figure 5.13, however, the cost of LPG is high and income levels in some household categories are very low which means that it is not easy to persuade people to use it. For example, in rural electrified households, LPG competes with other energy carriers such as biomass, which are readily available free of charge. One of the key challenges associated with LPG gas is that its prices are not regulated, and hence they are subject to manipulation (Ward 2008: 58). Government can intervene in this regard by regulating the price and thus protecting consumers as well as small businesses that wish to become distributors of LPG. Furthermore, government in partnership with the private sector can help to fund small LPG distributors to expand their distribution network to remote and rural areas. Also, use of LPG gas presents a safety risk, which must be managed properly (Ward 2008). This can be achieved by means of public awareness campaigns on the safe handling and operation of LPG cylinders. A detailed implementation plan for all mitigation options identified for this action is presented in Figure 5.14.

Figure 5.13: Cleaner cooking (obstacles and mitigation options)

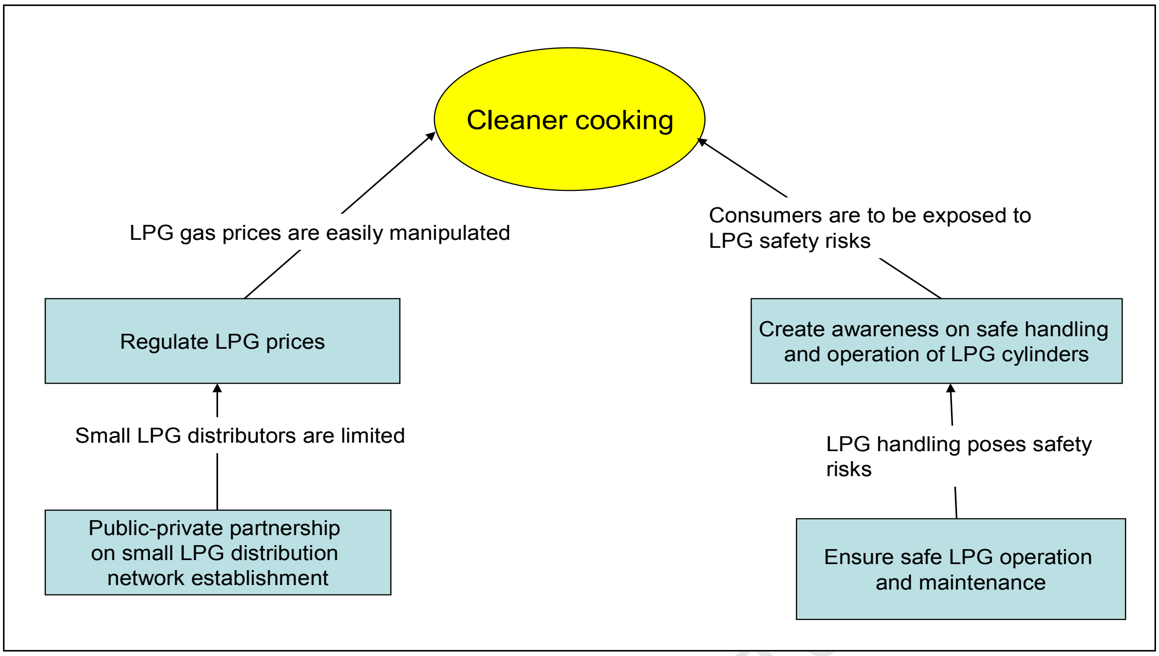
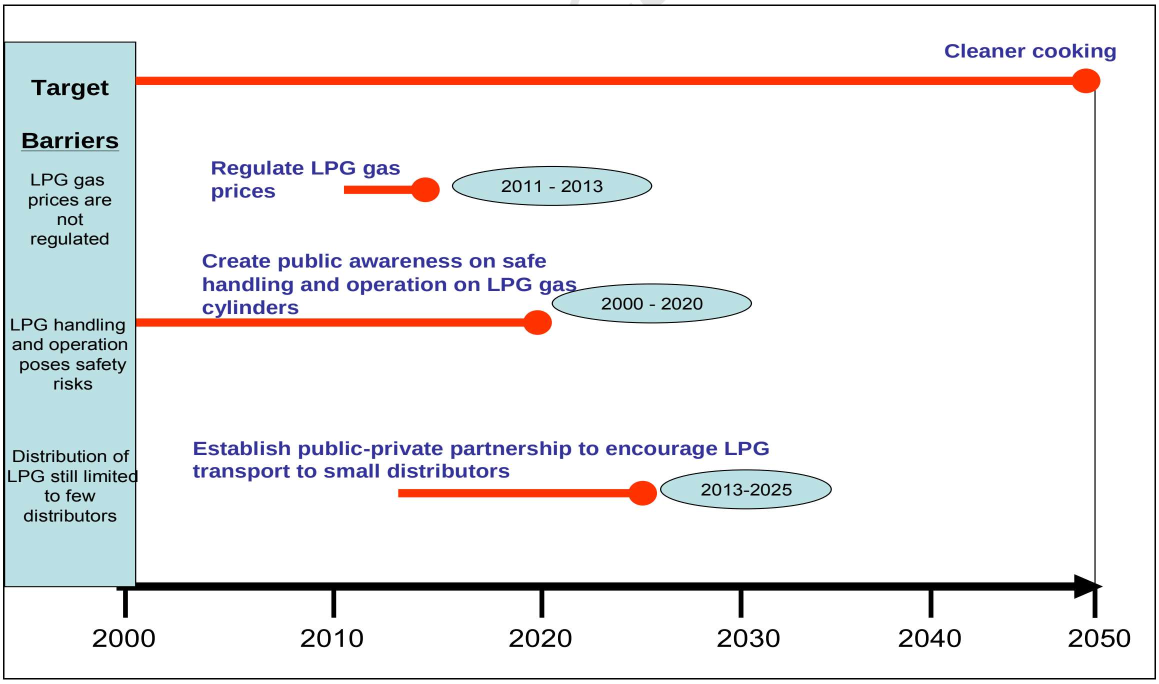
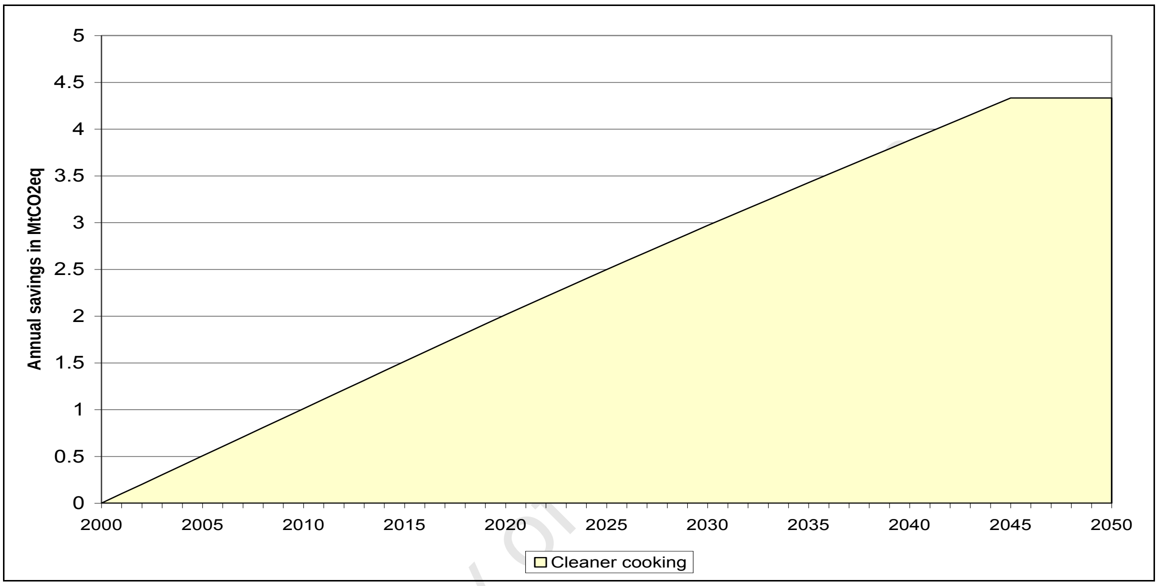


Figure 5.14: Implementation plan for the ZA50A LCS scenario action "cleaner cooking"



Clean cooking methods can realise peak savings equivalent to 4.33 $MtCO_2$-eq by 2045, remaining at that level until 2050 (Figure 5.15) because of maturity in the LPG penetration rate. Total savings over the 50-year period reach a total amount of 124 $MtCO_2$-eq. Ease of access to LPG gas because of the expansion of small distribution networks and well regulated LPG gas prices contributes to these modest savings. Furthermore, increased confidence levels on the use of LPG through safety awareness programmes results in high penetration rates for LPG gas for cooking (50% of the energy service demand for cooking can be met by LPG gas).

Figure 5.15: Emissions savings for the ZA50A LCS scenario action "cleaner cooking"



5.3.6 Action A6: Clean vehicle fuels

This action implies switching from oil to natural gas for petrochemical fuel production. The study assumes that the share of gas in petrochemicals increases from 8% in 2000 (SAPIA 2008) to 30% by 2050, with the remaining percentage being petroleum products from crude oil refining and coal-to-liquids (CTL). South Africa already has a fully developed gas-to-liquids plant in operation. However, if petroleum production is to achieve a 30% share, more funding is needed to build new plants. At most, this can be addressed through public-private partnerships. Local capacity for operation of such plants is also crucial. Ensuring a reliable gas supply is another critical element that needs to be considered. A summary of the obstacles to implement countermeasures is presented on Figure 5.16 and Figure 5.17.

Figure 5.16: Clean vehicle fuels (obstacles and mitigation options)

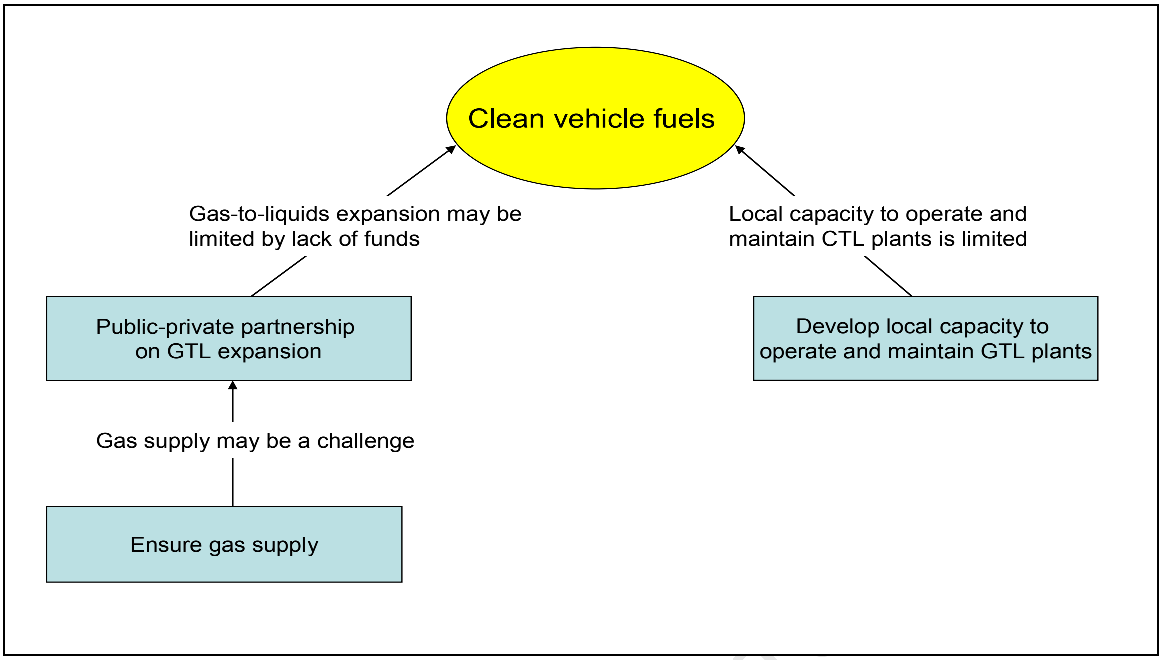
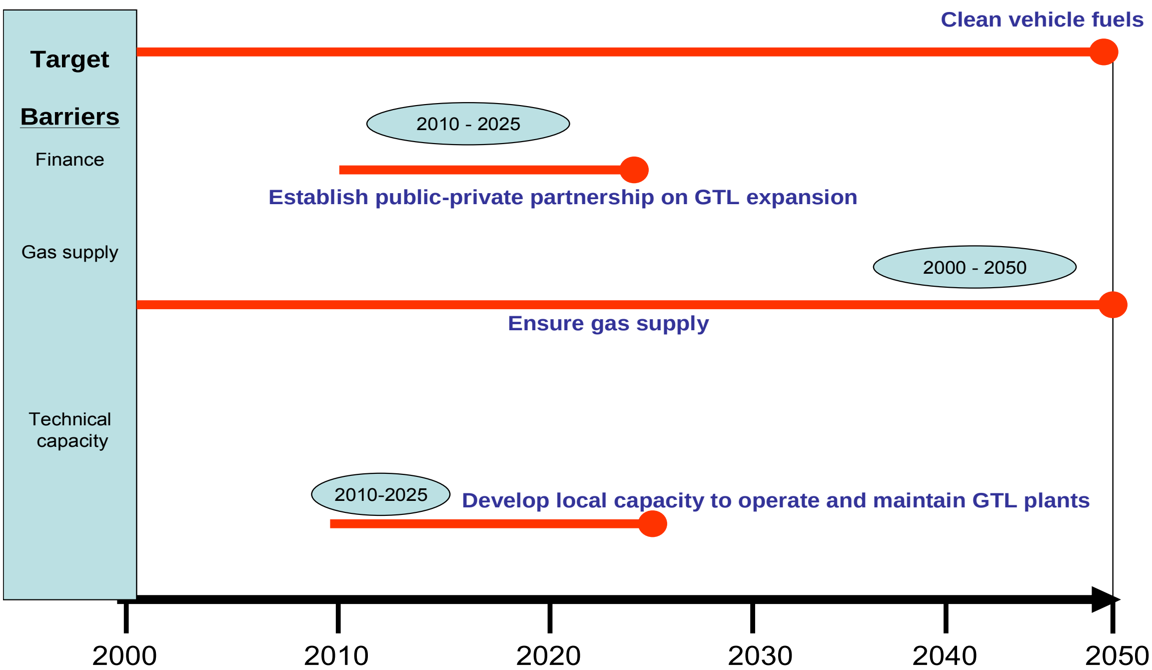
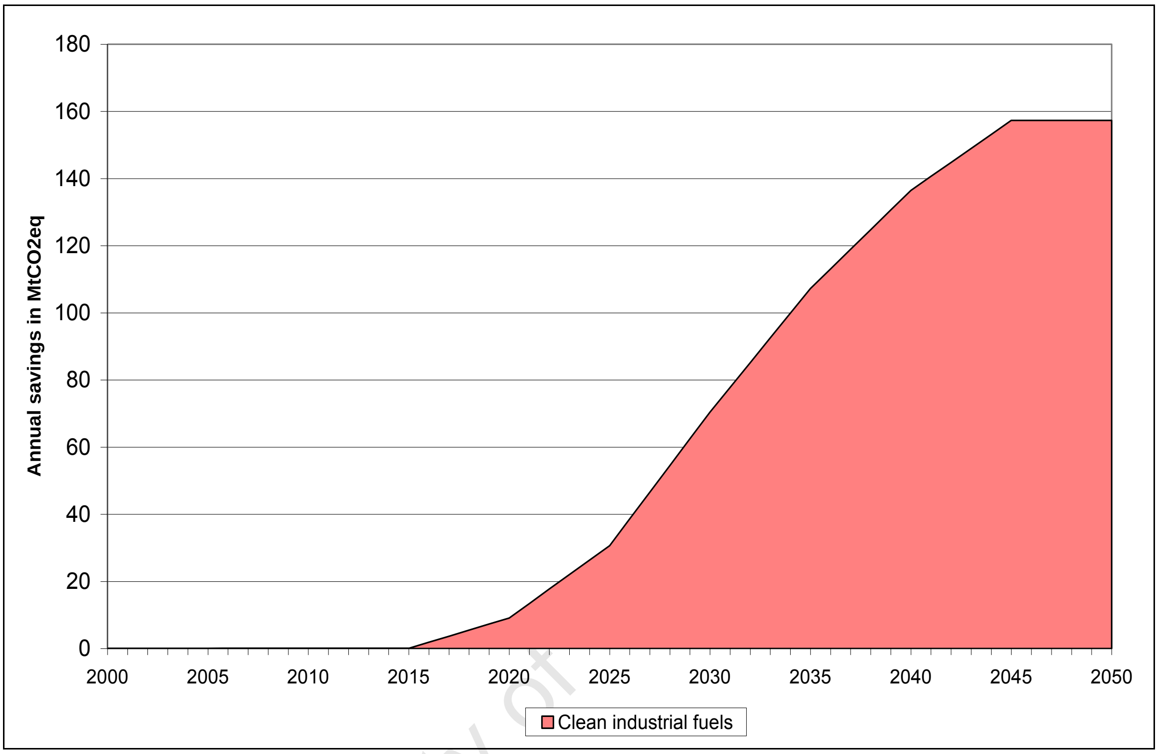


Figure 5.17: Cleaner vehicle fuels implementation plan



This action results in peak savings of 157 $MtCO_2$-eq by 2045, remaining at that level until 2050 (Figure 5.18). This is largely related to the implementation of gas-to-liquids (GTL) plants such that by 2050, 30% of liquid fuels originate from natural gas. With the capacity to operate and maintain GTL plants fully established by 2025, acceleration of emission reduction is possible through increased CTL capacity. Also, the peak observed in 2045 is a result of competition between this action and the implementation of greener cars and road efficiency measures.

Figure 5.18: Savings in MtCO2-eq for the LCS action "clean vehicle fuels"



5.3.7 Action A7: Transport modal shift

An improved public transport infrastructure coupled with convenience and a favourable public transport fee structure and security can push up this modal shift to high levels. According to Vanderschuren et al. (2008) and Winkler et al. (2008), a modal shift of 30% is possible to achieve by 2030, thus reaching an overall figure of 65%. With ambitious public transport infrastructure expansion programmes, this figure is assumed to increase up to 85% by 2050.

Also, it is assumed that bus units are to be retrofitted with gas units so that, by 2050, 10% of energy service demand for the bus fleet is met by LPG gas. Vanderschuren et al. (2008) estimate that it is possible to achieve a figure of 5% by 2030. This intervention will target mostly buses in major cities. However, because of low standards related to convenience and safety in existing public transport systems, private car owners are not keen to move towards public transport. This is further compounded by the lack of safety on public transport in South Africa (Figure 5.19). Therefore, an upmarket public transport system is needed to attract car owners. Also, improvements in the public transport infrastructure and in efforts to attract private car owners should be accompanied by a favourable fee structure that benefits the consumer. For convenience, dedicated lanes for public transport are also needed. The introduction of a high speed train railway network for intercity travel can significantly reduce the need for air travel, provided there is price compatibility and convenience. In the absence of penetration rates in the literature, this study assumes that a conservative 30% of air travellers will shift to using a rapid intercity railway service by 2050. An implementation plan for the identified measures is presented in Figure 5.20.

Figure 5.19: Transport modal shift (obstacles and mitigation options)

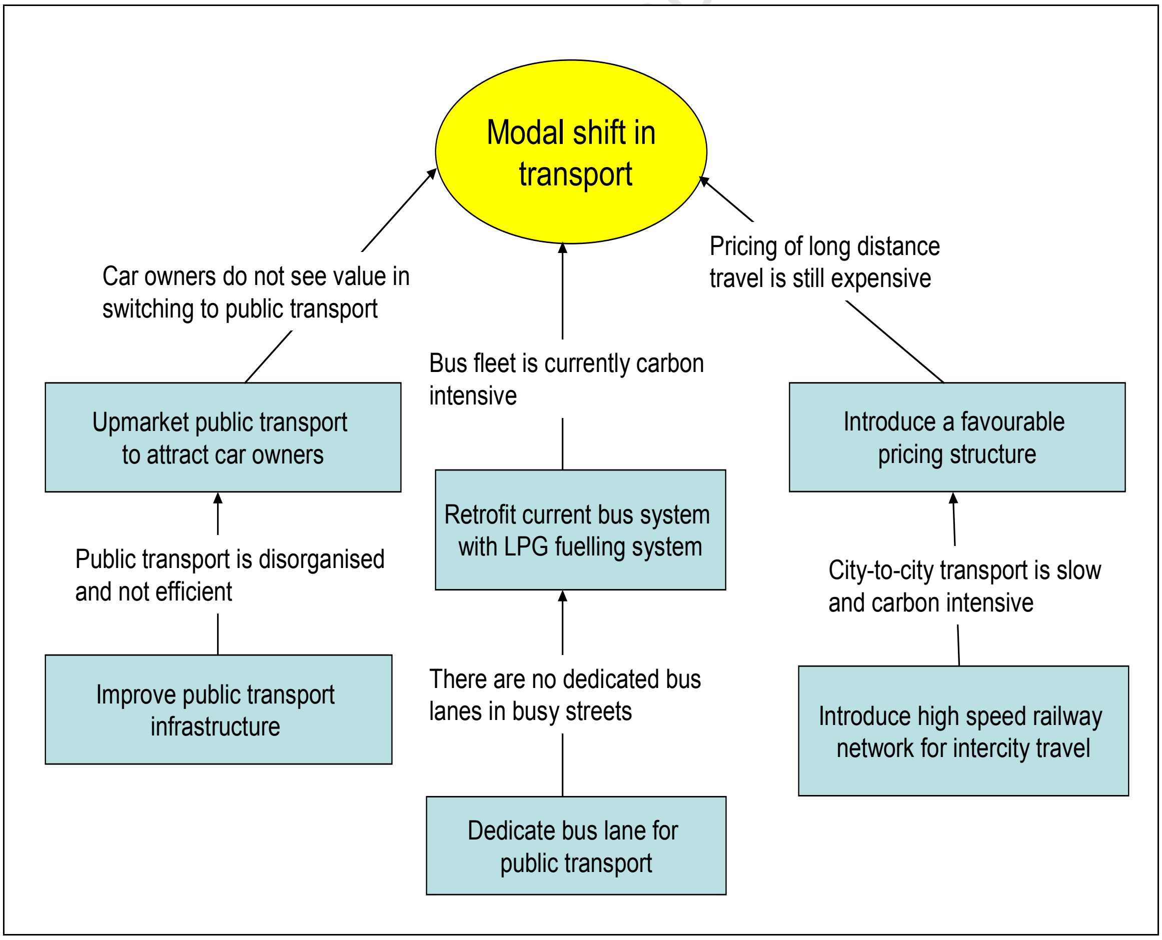
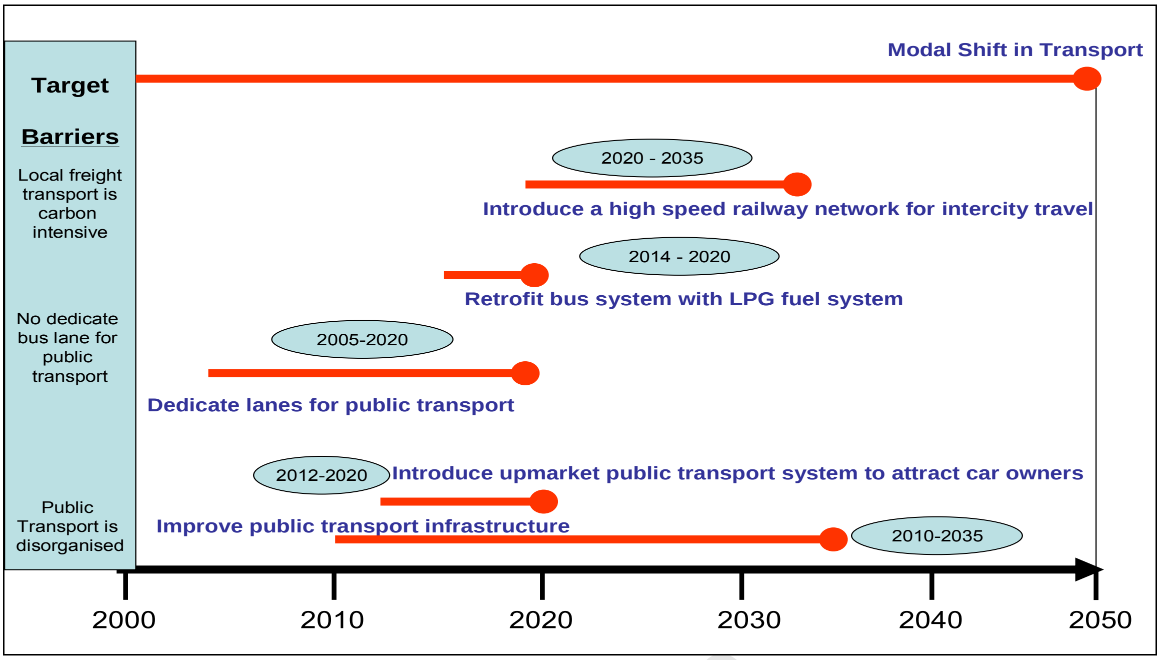
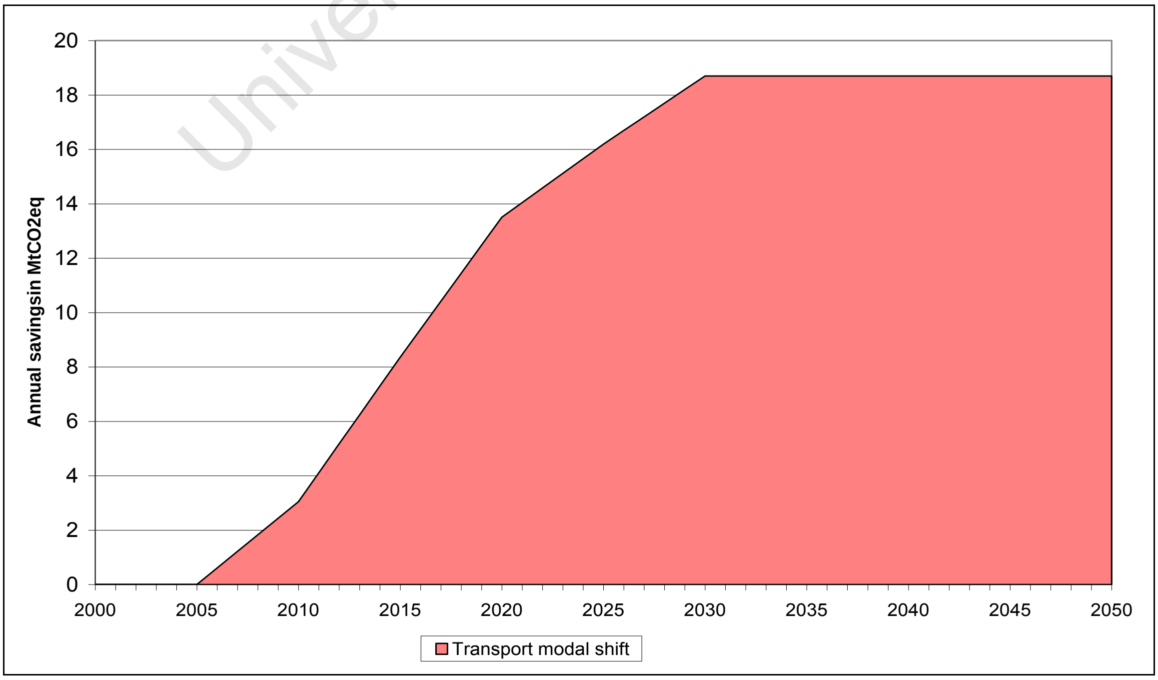


Figure 5.20: Implementation plan for the ZA50A LCS scenario action "transport model shift"



Transport modal shift results indicate an early peak savings of 18.7 $MtCO_2$-eq by 2030 (Figure 21). This can be largely attributed to the implementation of a high speed railway network for intercity travel and to improvements in the public transport infrastructure.

Figure 5.21: Savings in $MtCO_2$-eq for the LCS action "transport modal shift"



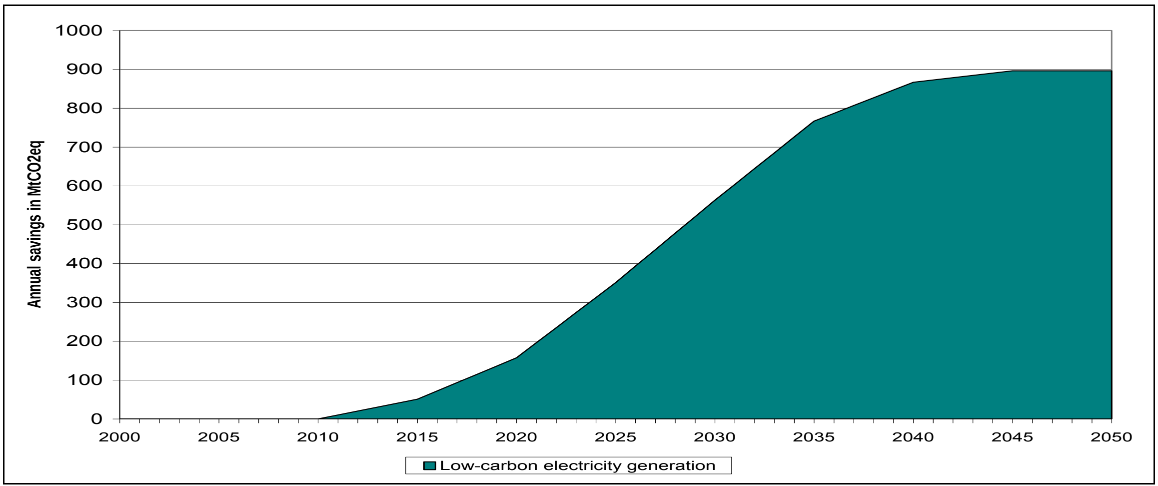
5.4 LCS actions for ZA50B scenario

5.4.1 Action B1: Low-carbon electricity generation

This action is a transmutation of Action A1 (Cleaner electricity generation) under LCS scenario ZA50B. Here, the contribution of renewable energy sources towards electricity generation is scaled up from 30% to 40%. The percentage contributed by coal is kept at 20% with CCS. Under the ZA50B scenario, there is an effort to move away from coal based electricity generation. Therefore, the percentage contributed by nuclear energy is downscaled from 50% to 30%. The remaining 10% is shared alike between hydro (5%) and biomass (5%). Biomass used for electricity generation forms part of the ZA50B LCS scenario action termed "Adoption of waste minimization principles". Therefore, the results shown in Figure 5.22 also include the results of the latter LCS action.

The low-carbon electricity generation results show a peak savings of 896 $MtCO_2$-eq by 2045, remaining at that level until 2050. From 2020 to 2040, the savings increase by 515 $MtCO_2$-eq. These significant savings are attributed to key factors such as locally developed technical capacity to develop renewable technologies, locally developed nuclear technology and clear regulations that encourage participation in the renewable energy market. Also, technologies such as CCS are assumed to be in operation by 2025.

Figure 5.22: Emission savings in ($MtCO_2$-eq) for the action "Low-carbon electricity generation"



5.4.2 Action B2: Pedestrian friendly city design

Generally, South African cities are designed in a manner that is unfriendly to both pedestrians and cyclists. This is supported by the absence of dedicated bicycle lanes and traffic control lights that do not allow for easy and safe pedestrian crossing (Figure 5.23). As such, current city design only favours short trips by pedestrians and cyclists. In response to this, a couple of things can be done. Firstly, walkways and bicycle lanes need to be created. Secondly, rules and standards for bicycle lanes need to be developed and people need to be made aware of such procedures (IEA 2001b). Thirdly, local cost-effective production facilities for bicycles need to be developed. This requires a public-private partnership to be in place to guarantee the sustainability of such a production facility. This option needs to be supplemented by legislation that limits the use of private cars in cities. Such legislation should be enforced by introducing permits for driving in cities. The permit conditions can stipulate that only hybrid or electric cars be allowed to drive in specific areas of the city where vehicular traffic is prevalent. Such areas can be easily identified by traffic departments doing vehicle count surveys as well as by comprehensive transport emission models (IEA 2001b). This will also allow disabled people in wheelchairs and blind persons to travel safely and comfortably within cities.

Furthermore, frequently visited areas in cities that are located in the central city are often referred to as central business districts (CBDs). Therefore, another indirect option to reduce private transport is to have public transport that links these frequently visited areas from one region or city to those of another region or city. In addition, through improved road efficiency, fossil fuel consumption can be reduced. For example, Vanderschuren et al. (2008) assumes that fuel consumption gains that could be achieved in most South African cities lies between 10% and 20%, and that improved traffic and speed management could reduce fossil fuel reliance by 15% by 2030. Van der Voort (cited by Vanderschuren et al. 2008:13) believes that sustained awareness campaigns could reduce fuel consumption by 15%. This study has assumed that, through improved city planning, energy service demand from passenger cars can be reduced by 30% by 2050. Figure 5.24 presents an implementation plan for the identified mitigation options.

Figure 5.23: Pedestrian friendly urban city design (obstacles and mitigation options)

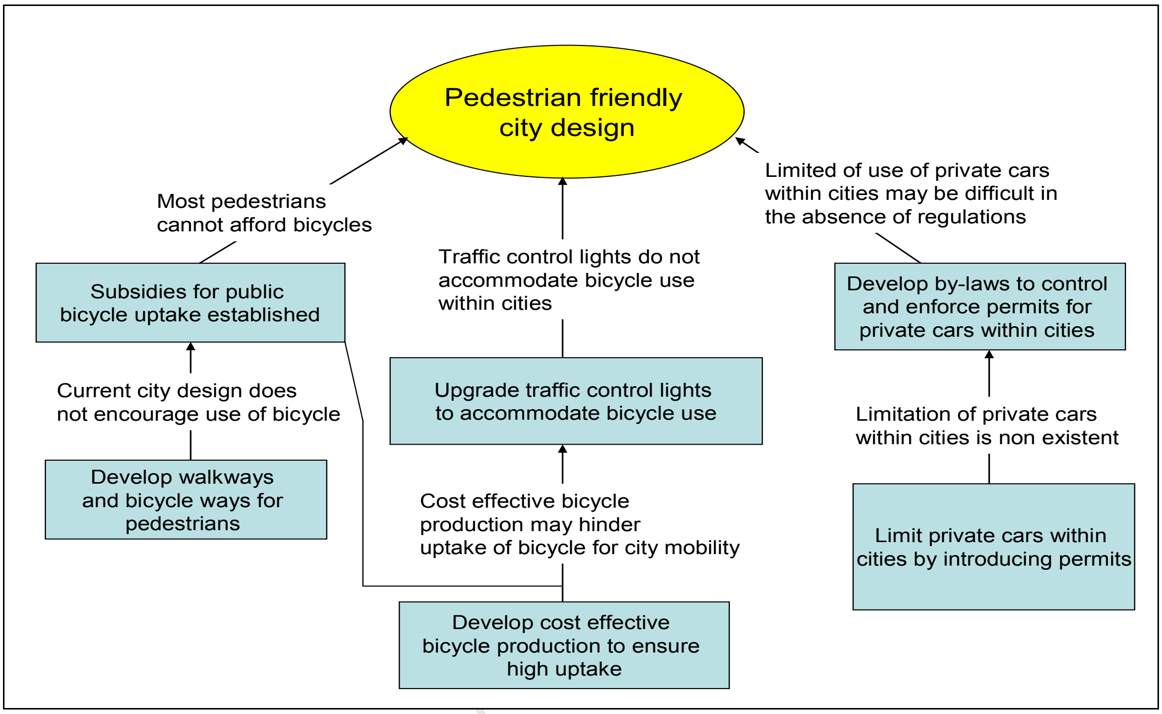
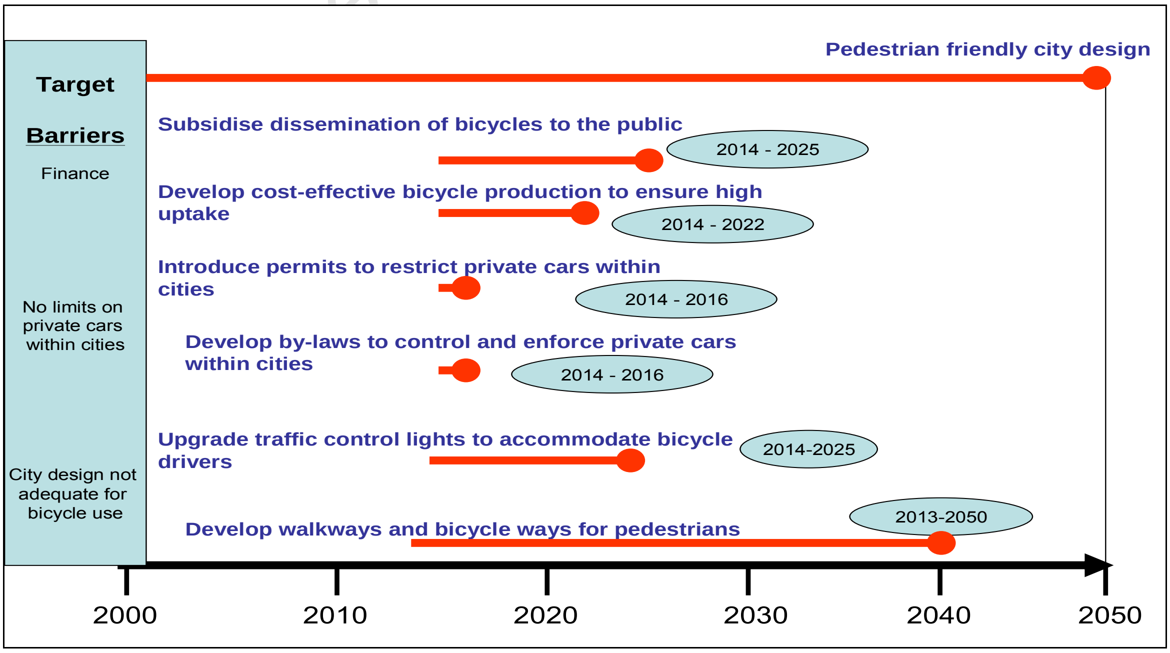
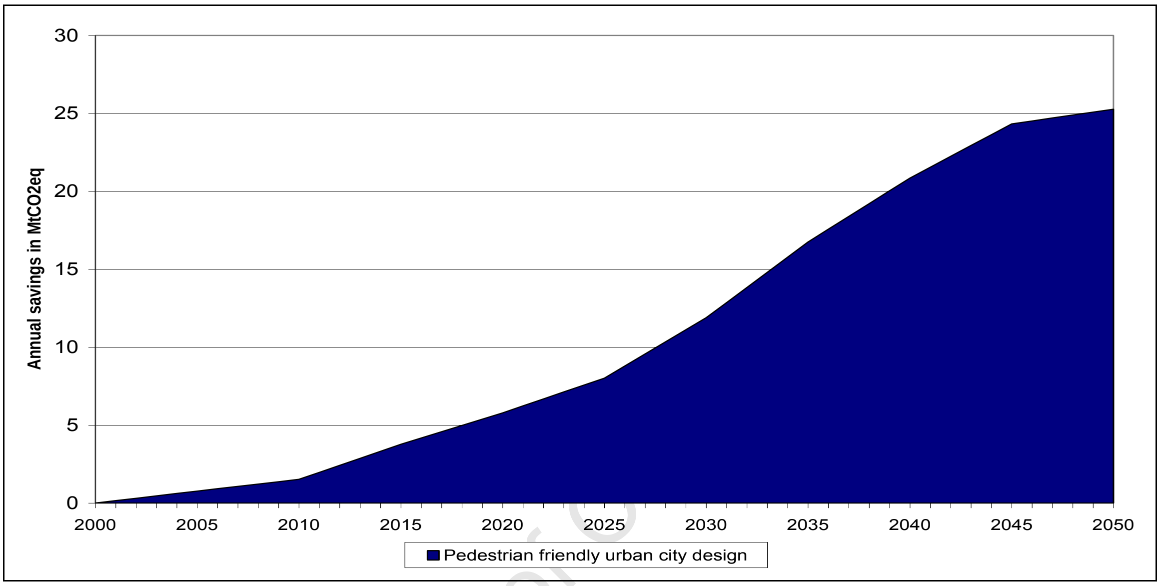


Figure 5.24: Implementation plan for the ZA50B LCS scenario action "pedestrian friendly urban city design"



Pedestrian friendly urban city design would be able to achieve a saving of 25 $MtCO_2$-eq by 2050 (Figure 5.25). Implementation of by-laws to restrict vehicles in CBDs as well as to introduce cost-effective bicycles that are subsidized for city inhabitants would contribute significantly to these emission savings.

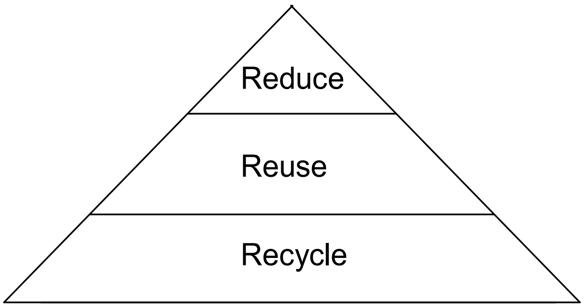
Figure 5.25: Savings in $MtCO_2$-eq for the action "Pedestrian friendly urban city design"



5.4.3 Action B3: Adoption of waste minimization principles

This action implies the adoption of the three waste minimization principles referred to as the 3R's (Reduce, Reuse and Recycle). Their order of importance is shown by the pyramid-shaped waste minimization hierarchy in Figure 5.26.

Figure 5.26: Waste Minimization Hierarchy



Current waste management practices in South Africa do not allow for efficient waste minimization (Figure 5.27). The challenge starts at the front end, where waste is disposed. Disposed waste is currently not separated into different waste categories. As a result, valuable waste material that could have been easily reused or recycled ends up in the landfill site. In addition, packaging material is hardly reused, and it too ends up in the landfill site. This calls for radical change in waste management in South Africa. The first step is to develop waste separation regulations. This must be followed by a comprehensive waste collection system that accommodates separated waste. In some areas where waste separation is impossible, waste transfer stations should be developed to allow for large scale waste separation. Wastewater treatment plants, landfill sites and waste biomass can and should be used to generate electricity (AGAMA 2003).

Studies have shown that the theoretical potential for generating electricity from waste in South Africa is equivalent to 207 MW from wastewater and about 693 MW from solid waste (AGAMA 2003). This study has therefore assumed that, if waste management is geared towards minimization principles, and if other forms of biomass are used to increase the contribution of biomass for electricity generation, then 5% of electricity generation could be met by biomass incineration and by the anaerobic digestion of wastewater. Other carbon displacement gains can be achieved by reusing material, mostly packaging, and by recycling material such as plastics, thus reducing fossil fuel dependency. Implementation of mitigation options associated with the adoption of waste minimization principles is presented in Figure 5.28.

Figure 5.27: Adoption of waste minimization principles (obstacles and mitigation options)

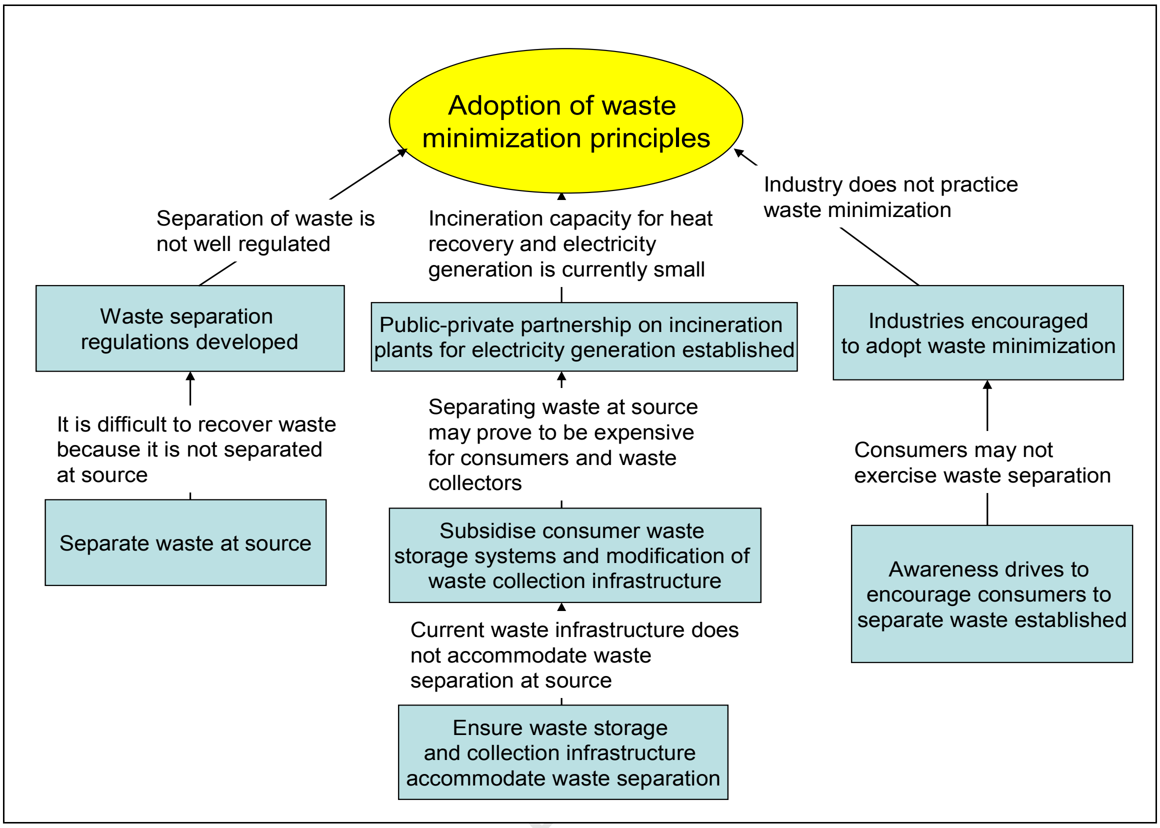
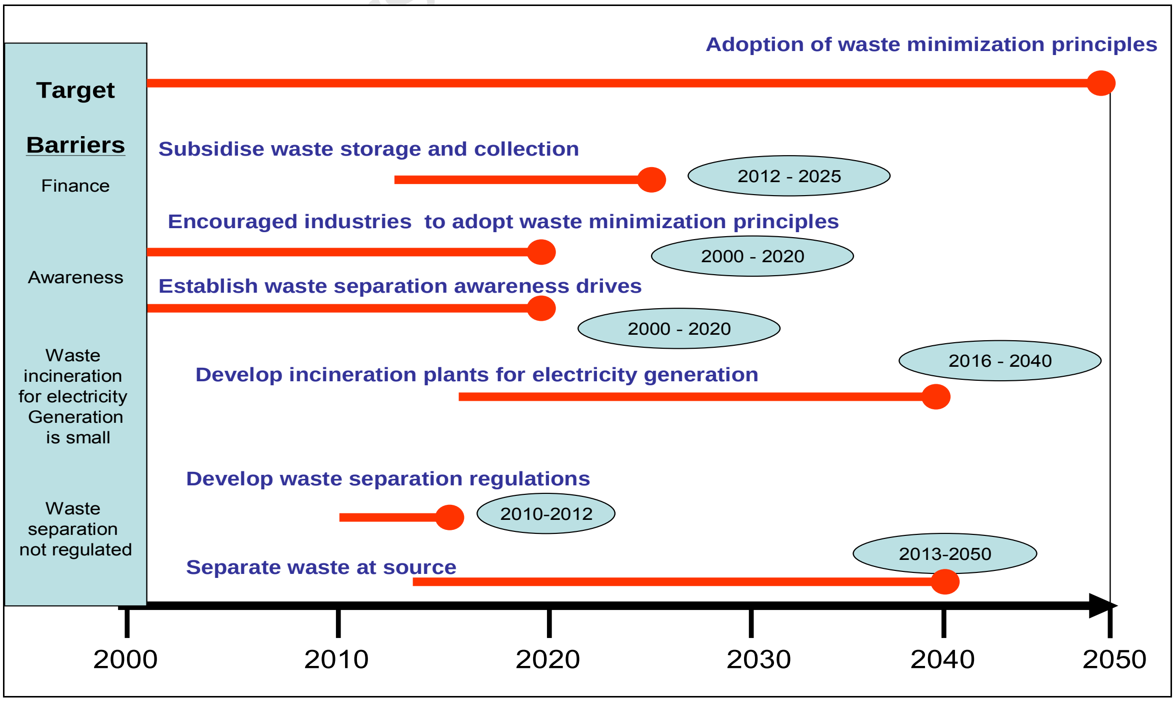


Figure 5.28: Implementation plan for the ZA50B LCS scenario action "Adoption of waste minimization principles"



Since this LCS action is related to power generation, the BCM model lumps the results of this action together with the LCS action "low-carbon electricity generation" (see Figure 5.22). It is assumed that biomass will be able to contribute a modest 5% towards electricity generation by 2050, resulting in a coal displacement of 5% for power generation.

5.4.4 Action B4: Minimum carbon-driven consumer spending

Generally, consumers are often unaware of carbon related information associated with the products they consume (Figure 5.29). This is attributed to a lack of awareness on the part of consumers. It is also compounded by the absence of legislation compelling manufacturers and retailers to label such information on products. Labels on products with carbon related information means that consumers are likely to make smart climate-centric choices by choosing low carbon goods and services. This also forces companies to move towards offering low carbon goods and services through improved energy efficiency production processes and localized processing. The challenge is that the information on the labels will need to be verified. If such verification is not done, labelling will be subject to manipulation. Therefore, standards for calculating the emissions for specific industries as well as verification methods need to be developed and adopted. Once information has been verified, a company can be issued with a certificate valid for a certain period. In this way, the consumer can have confidence in the information presented on the label, as the verification process provides a form of authentication.

Energy consuming products would require meters to ensure the verification of energy consumption and carbon related information on their labels. This means that smart meters would need to be developed to enable the visualization of energy savings and carbon related data. Public-private partnerships are needed with regard to the development and production of such meters. In order to ensure consistency and comparability, standards for measurement and operation of such meters need to be developed too. Government can introduce incentives for companies that manufacture the best performing low carbon goods and services. Smart meters will also aid consumers to monitor energy consumption and efficiency during the application of appliances they use, both in the residential and commercial sectors. This would be accompanied by consumer awareness drives on environmental information, including a massive smart meter diffusion drive funded by a public-private partnership. Assuming a 100% diffusion of smart meters in both residential and commercial environments in the next ten years, it is realistic to assume an annual energy consumption saving of 0.2% going to 2050. An implementation plan for this action is presented in Figure 5.30.

Figure 5.29: Obstacles and mitigation options associated with the ZA50B LCS scenario action "minimum carbon-driven consumer spending"

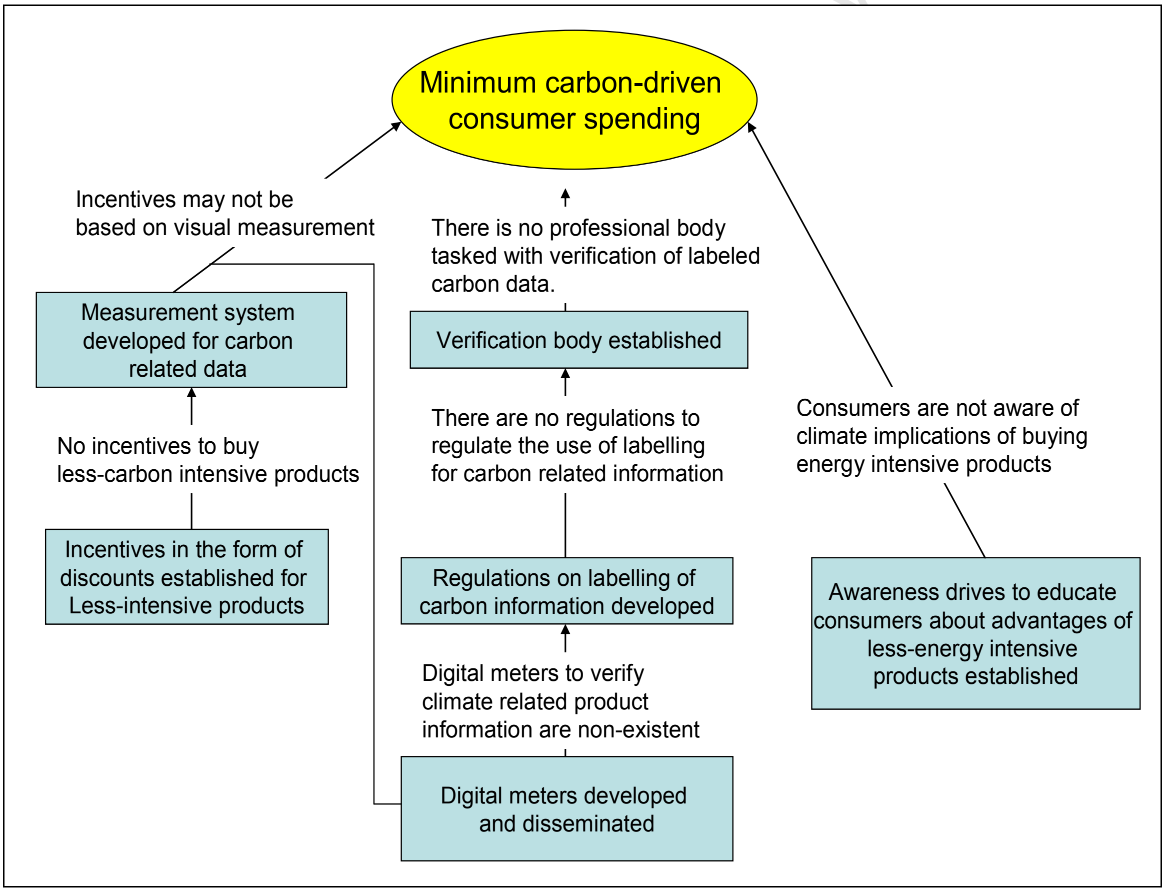
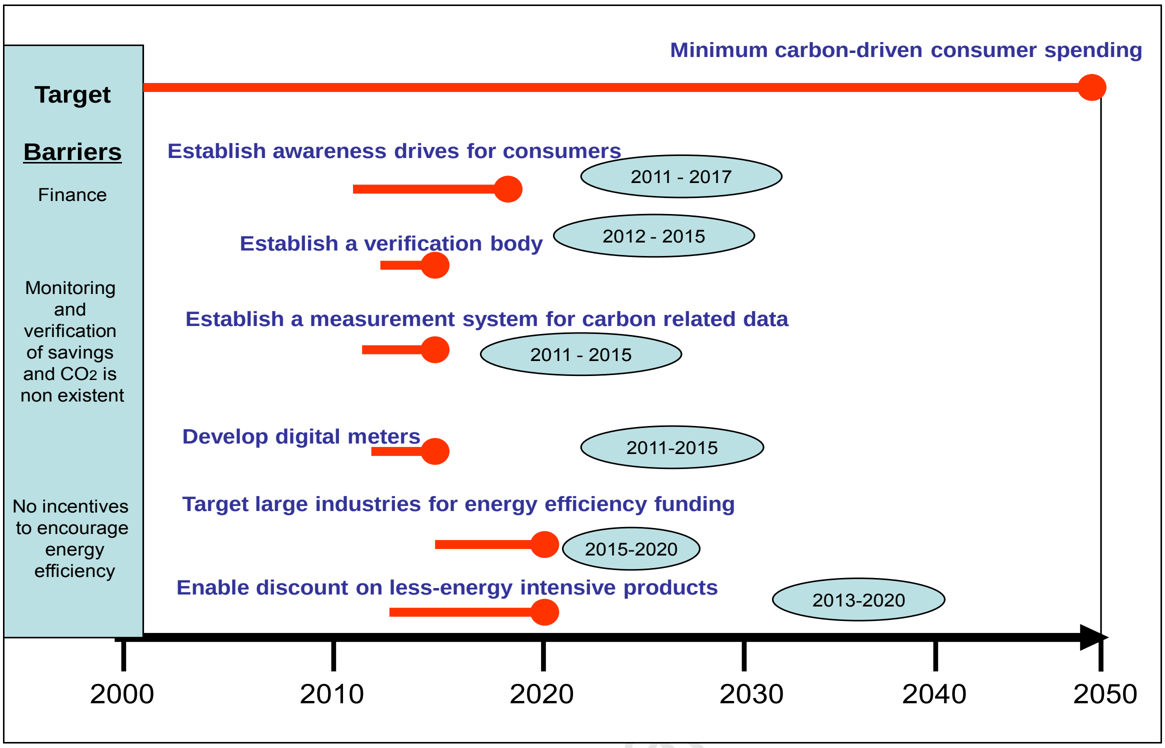
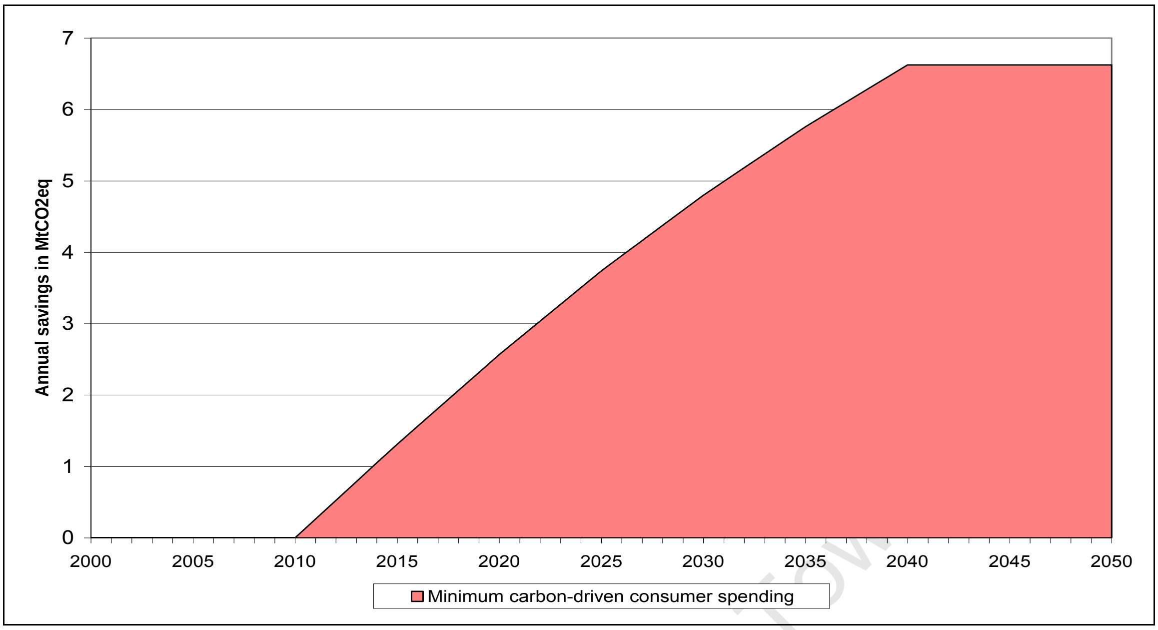


Figure 5.30: Implementation plan for the action "minimum carbon-driven consumer spending"



This action results in a total emission saving of 177 $MtCO_2$-eq, with an annual savings peak of 6.6 $MtCO_2$-eq by 2040, remaining at that level until 2050 (Figure 5.31). The savings under this action are largely attributed to consumer targeted awareness drives on energy efficient goods and services. Also, measurement and verification of energy savings and emissions through an established independent body ensures that goods and services report credible information on their goods and services. It is likely that more savings will accrue from these actions, as this study has assumed a modest annual energy consumption saving of 0.2%

Figure 5.31: Emission savings in $MtCO_2$-eq associated with the LCS action "minimum carbon-driven consumer spending"



5.4.5 Action B5: Leadership in low-carbon society

Improved leadership in low-carbon society results in continued awareness about low-carbon centric lifestyles and general awareness about environmental issues. Such awareness would involve education programmes on media streams to educate the public about low carbon societies. With leadership mainly from government, a low-carbon society curriculum would be developed. This implies that teachers would need to be trained on such curriculum, and that a continued assessment of the effectiveness of LCs education would need to be implemented (see Figure 5.32 and Figure 5.33). In terms of this action, government needs to develop low carbon advisors that will advise communities and businesses on the impacts of climate change as well as on available methods to mitigate climate change. It is difficult to quantify the impacts of this action; however, its contribution certainly stretches across all sectors.

Figure 5.32: Obstacles and mitigation options associated with ZA50B LCS scenario action "Leadership in low carbon society"

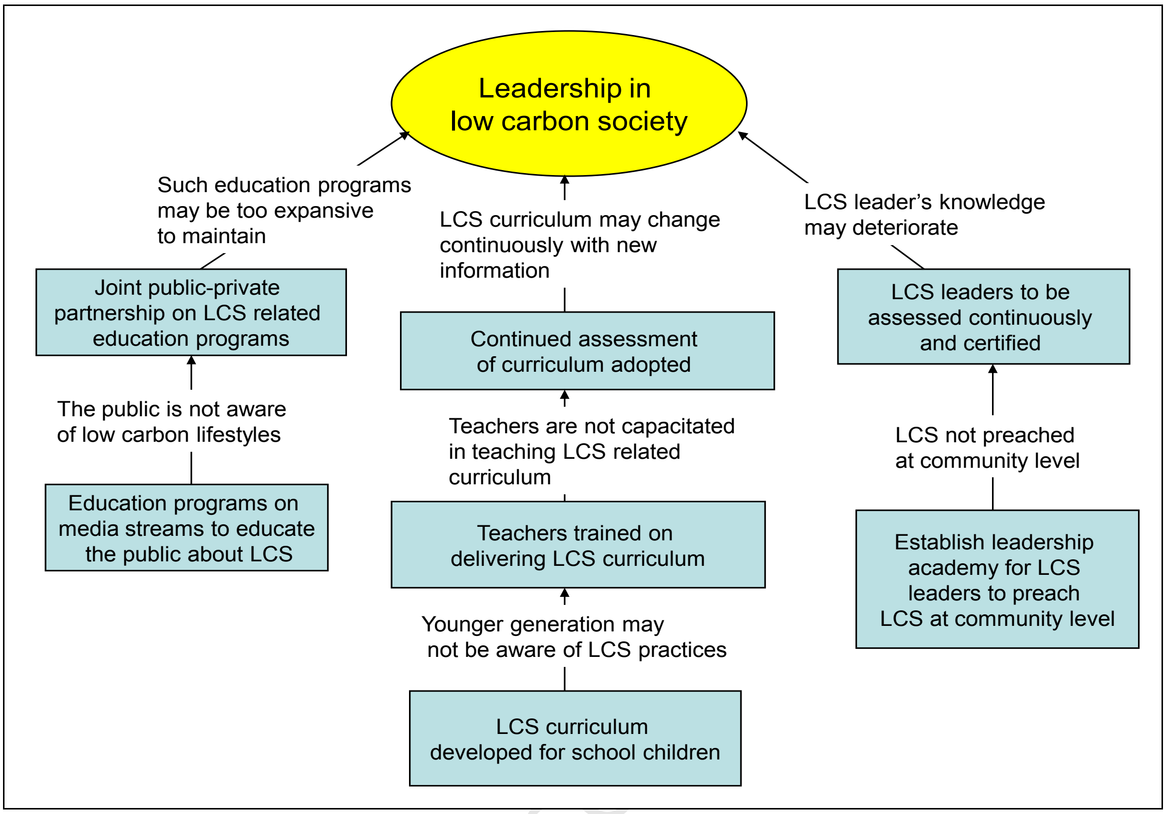
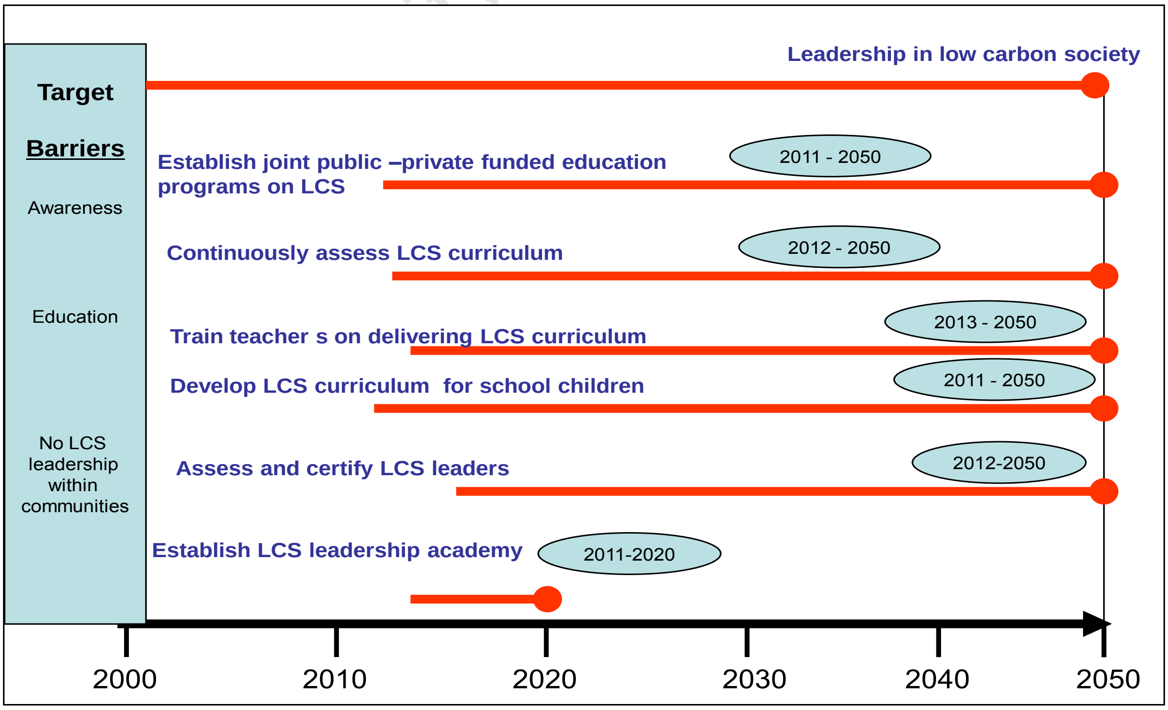


Figure 5.33: Implementation plan for the action "leadership in low carbon society"



However, it is evident from Figure 5.32 and Figure 5.33 that implementation of this action results in reduced period of implementation for this LCS actions. As such, it has an overall impact on the sustainability of the dozen of actions for the ZA50B scenario.

5.4.6 Action B6: Cleaner process heating

Process heating ranks amongst the higher energy intensive service demands in the industrial sector. Most common applications of process heating involve steam generation through coal or oil powered boilers. The generated steam is passed through a jacketed pipe system into process units for heating. Some large scale industrial complexes do not practice heat recovery in process units that generate heat in this way (e.g. reaction units that gives off heat as well as condensate recovery). As a result, an opportunity is lost to reduce heating requirements in steam-based systems. Condensate recovery, coupled with sound preventative maintenance, is essential for improved efficiency in steam systems. A study by the Energy Research Institute (ERI) showed that it is possible to achieve savings of up to 1.4% in energy efficiency with a payback period of about 0.8 years (ERI 2002). In addition, fuel savings can reach 10% for oil as well as 15% for coal. Fuel switching is also beneficial from the climate point of view. There have been a few successful cases of fuel switch from coal and oil into natural gas for process heating. A good example is the Cleaner Development Mechanisms (CDM) registered project called the Lawley fuel switch project. This project is realizing annual average Certified Emission Reduction (CERs) credits of about 19159 tCO_2/y as well as total CERs totalling 153272 tCO_2 by 2012 (Witi & Chaturvedi 2009). In this study, it is assumed that 50% of heating requirements would be met by natural gas by 2050.

There are certain obstacles associated with implementation of this action (Figure 5.34). Firstly, most industries do not have preventative maintenance systems in place. This results in poor maintenance planning and reduced equipment performance. The preventative maintenance systems that currently exist in the market are expensive. However, this can be reversed by developing desk-top maintenance systems using accessible applications such as Microsoft Access. Secondly, some companies are still unaware of the existence of cleaner development mechanisms and the benefits associated with these. This is clearly demonstrated by the evident lack of participation by South Africa in CDM, compared to other developing countries (UNEP 2002). Hence, bodies such as the Designated National Authority (DNA) can play a pivotal role in assisting and encouraging industry to embark on CDM projects. If industry is made aware of the processes to be followed and the benefits associated with CDM projects, implementation rates are guaranteed to increase. The implementation plan for the identified mitigation options is presented in Figure 5.35.

Figure 5.34: Obstacles and mitigation options for the LCS action "cleaner process heating"

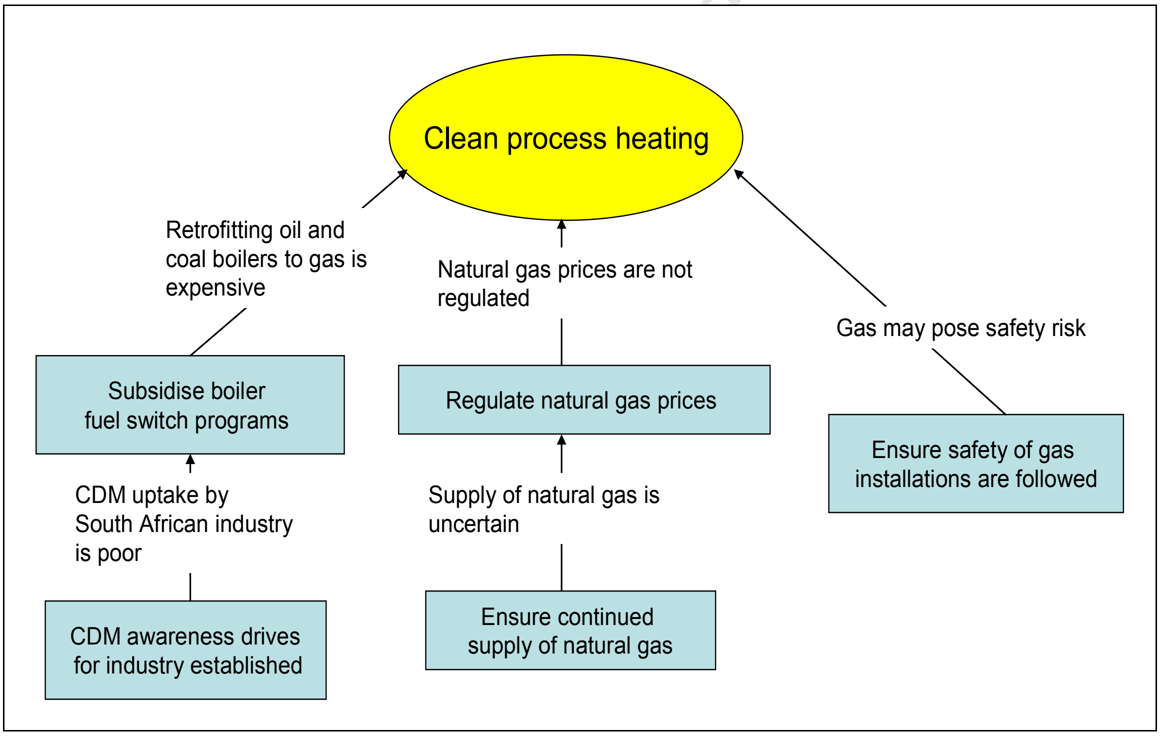
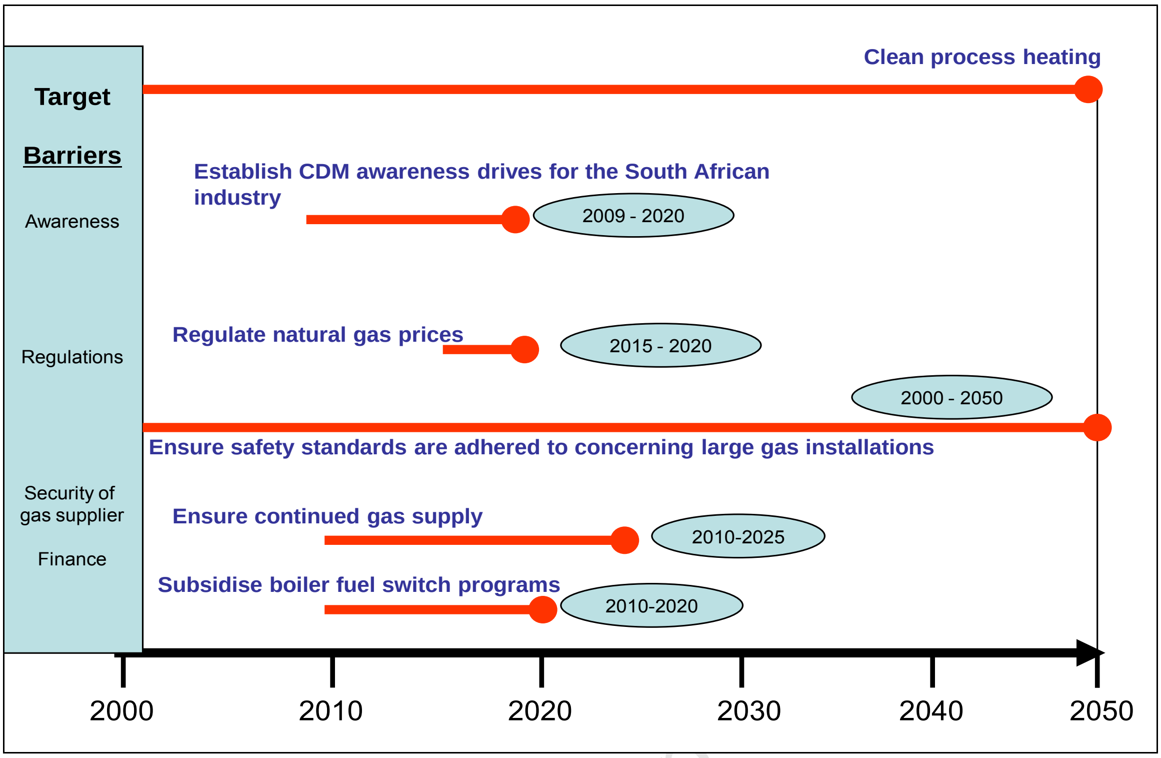
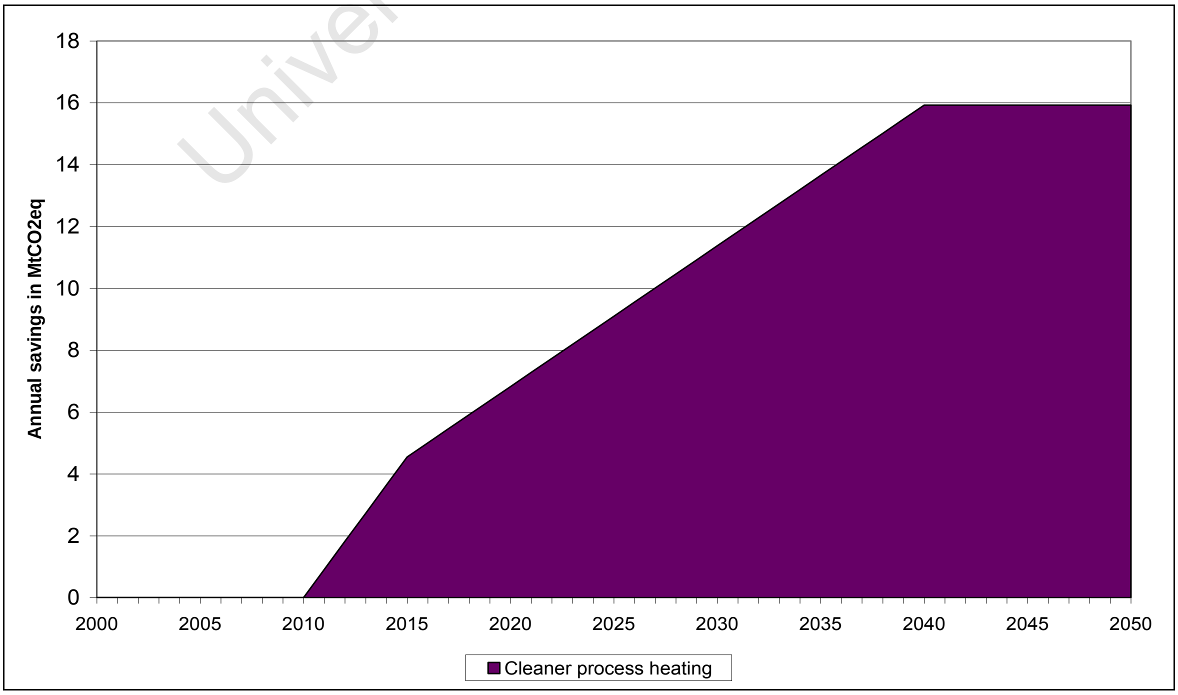


Figure 5.35: Implementation plan for "clean process heating"



Cleaner process heating results in a savings total of 434.53 $MtCO_2$-eq in the study period, whilst peak savings reach a value of 15.93 $MtCO_2$-eq as early as 2040, remaining at that level until 2050 (Figure 5.36).

Figure 5.36: Emissions savings in $MtCO_2$-eq for the action "clean process heating"



Favourable gas prices and subsidies for boiler fuel switch programmes are key drivers for the observed emission reductions. A combination of CDM awareness drives and subsidy programmes can ensure that emission savings accelerate as early as 2010, with further gains obtained after the regulation of gas prices by 2015.

5.4.7 Action B7: Second generation fuels

Fuel cell technology that uses hydrogen is considered a clean fuel that is less dependent on fossil fuels and thus carbon neutral. However, there are different views in the literature on the prospective use of hydrogen as a fuel. On one hand, some experts believe that it will take some time before these fuel cells are introduced as a suitable replacement. Experts (mainly in Europe) believe that hydrogen will be able to replace fossil fuels by 2020 (Wurster 2003). Vanderschuren et al. (2008) estimates that the long lead time for infrastructure developments associated with hydrogen will mean delays of between 10 to 15 years (Figure 5.37). This implies that, if South Africa is to build such an infrastructure, it will need to invest in it now. Experts estimate that, if South Africa invests in a hydrogen infrastructure by 2009, a 10% crude oil reduction can easily be achieved by 2030. In view of this, this study has assumed that a 15% crude oil reduction is achieved by 2050.

Compressed air technology (CAT) is also a new development in alternative propulsion systems for vehicles, with a prototype car demonstration showing good energy use as well as thermodynamic performance. It is believed that these cars have a driving range of about 2000 km (Theaircar 2008). Due to limited information on these cars, however, it is difficult to estimate its contribution in the future.

Another form of second generation fuels is biofuels. Biofuels are made from animal fats, vegetable oil, rapeseed oil, recycled cooking waste oils and any other seed oils. South Africa has adopted a blending approach for biofuels, blending them into fuels based on fossil fuels. In this case, the DME has proposed a petrol-ethanol blend with 8% bio-ethanol, 2% biodiesel for diesel and an average market penetration of 4.5% of liquid transport fuels by 2013 (DME 2007). According to Haw and Hughes (2007b), a 20% ethanol blend is considered the maximum volume that can be used in the fuel blend before significant modifications are required in the engine. Vanderschuren et al. (2008) expect that South Africa will only achieve a fossil fuel displacement of 7%. Arable land is limited to about 14% of the total land available and only 10% of this land is irrigated with 60% of the national water supply (DME 2007). Therefore, any additional irrigation requirements related to the production of biofuels may result in serious water stress on the national water supply system. However, with the surplus crop production experienced in recent years, it is possible to produce bioethanol to meet 5% of national petrol demand (DME 2007). In addition, South Africa is estimated to have approximately 3 million hectares (ha) of land that could be used for biofuels. If all this land were used, 15% of diesel requirements would be met by biofuels. Studies have shown that the potential to reduce GHGs depends on how they are produced (Fargione et al. 2008; Searchinger et al. 2008). These studies have concluded that clearing of carbon-rich habitats to produce biofuels will increase GHG emissions. However, biofuels produced from degraded croplands including waste biomass would reduce GHGs and furthermore not compete with food production. The implementation plan for second generation fuels is presented in Figure 5.38.

Figure 5.37: Obstacles and mitigation options associated with second generation fuels

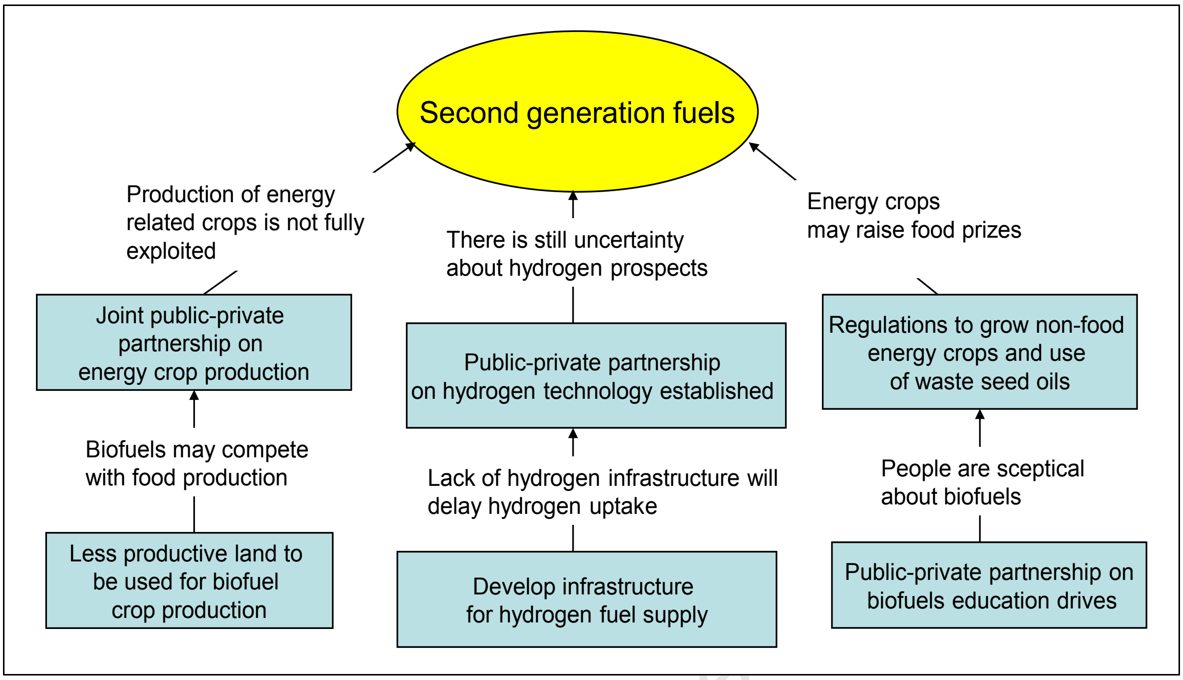
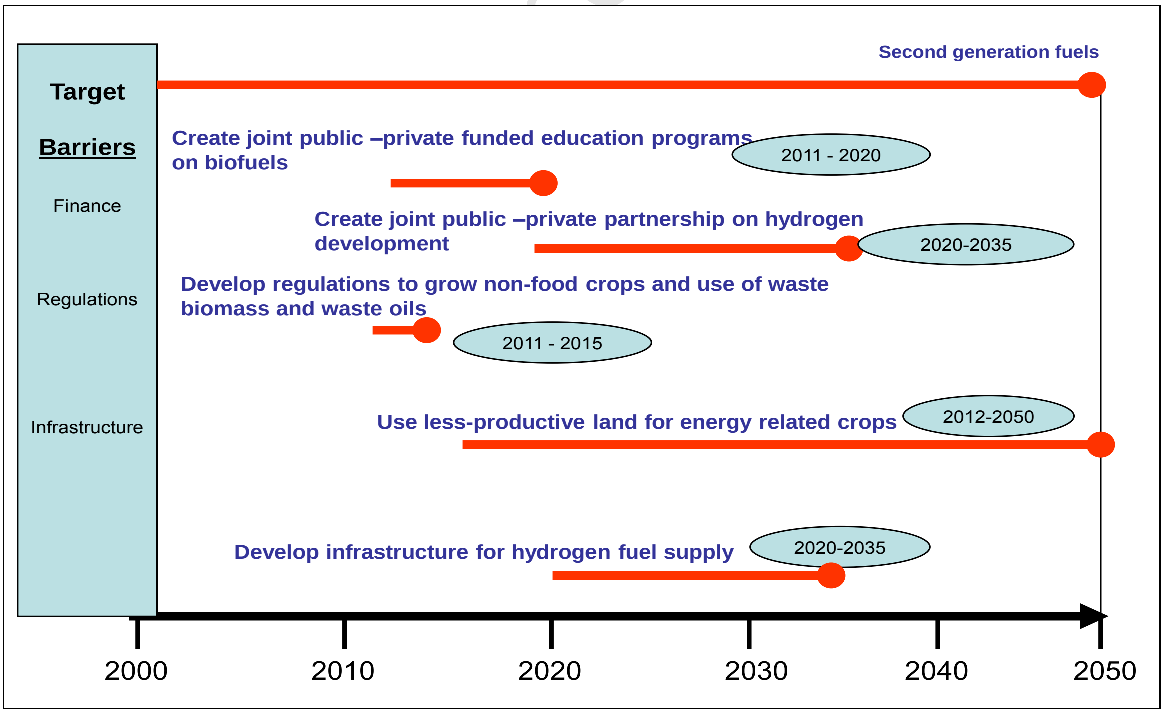
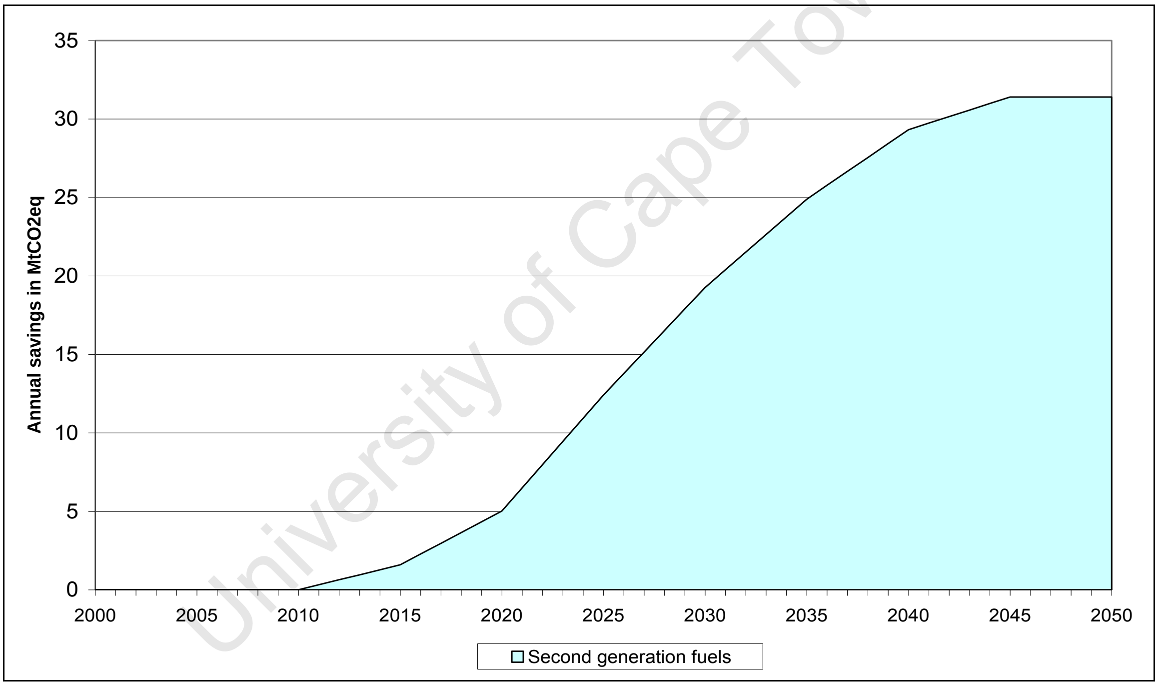


Figure 5.38: Implementation plan for the action "second generation fuels"



Implementation of second generation fuels as early as 2011 results in peak energy savings of 31 $MtCO_2$-eq by 2045, remaining at that level until 2050. By that stage, biofuels will be contributing 53% to the total emissions savings whilst biofuels contributes to the rest of the savings (Figure 5.39). The early implementation lies mostly in the use of biofuels, as the hydrogen technology may only become available by 2025. With the potential use of biofuels being limited by the amount of land available, the tension between growing food versus fuel, as well as a theoretical blending ratio of 7%, the CO_2 savings are likely to remain low until hydrogen is introduced. After 2025, however, savings increase from 12 $MtCO_2$-eq to 31 $MtCO_2$-eq by 2045. As indicated earlier, hydrogen would require the infrastructure to be developed as early as 2010-2012.

Figure 5.39: Emission savings in $MtCO_2$-eq from the implementation of second generation fuels



5.5 LCS actions common to both scenarios

Actions that are common to both the A and B scenarios are those that are seen as critical, and those whose implementation goes beyond climate change mitigation. For example, energy efficient lighting assists in demand-side management, whilst climate conscious manufacturing contributes towards improvements in energy consumption in the industry sector. As such, it is difficult to confine these actions to a single low carbon pathway. Even if a different LCS development pathway was to be conceptualized, these actions will still be relevant.

5.5.1 Action AB8: Carbon-neutral water heating

In electrified urban households, both high and low income, water heating is met mostly by electricity with minimal use of solar water heaters (SWHs). This is based on the fact that there is very little application of SWHs in South Africa despite the efforts by some municipalities, such as the City of Cape Town (CCT), which is investigating policies on subsidizing the installation of SWHs (Haw and Hughes 2007b; CCT 2007). Also, because of the high capital costs of solar water systems and the absence of subsidies, penetration rates in respect of SWHs are currently very low and in fact almost stagnant. According to Winkler (2006), it would possible to reach penetration rates of up to 60% for SWH by 2030 with a good and mature subsidy scheme. Thus, it is safe to assume that, by 2050, a penetration rate of 100% for SWH could be achieved. Another obstacle to address in this regard is to ensure that local capacity to produce SWH is improved. Figures 5.40 and 5.41 summarise the direct and indirect options of dealing with SWHs, showing the possible implementation timelines.

Figure 5.40: Direct and indirect options (in response to obstacles) associated with carbon-neutral water heating

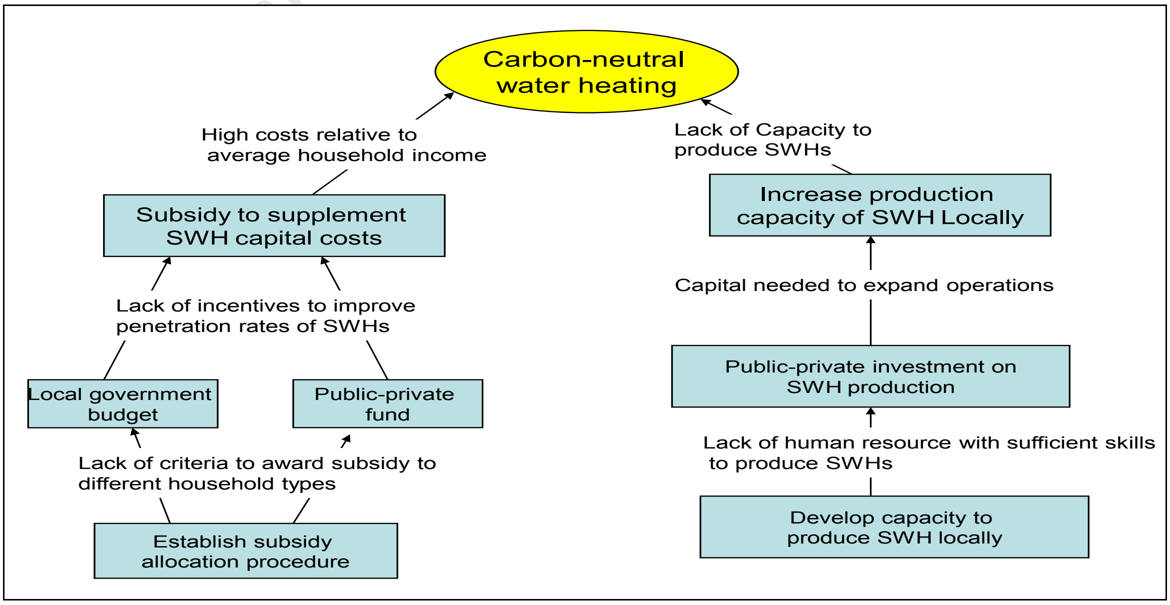
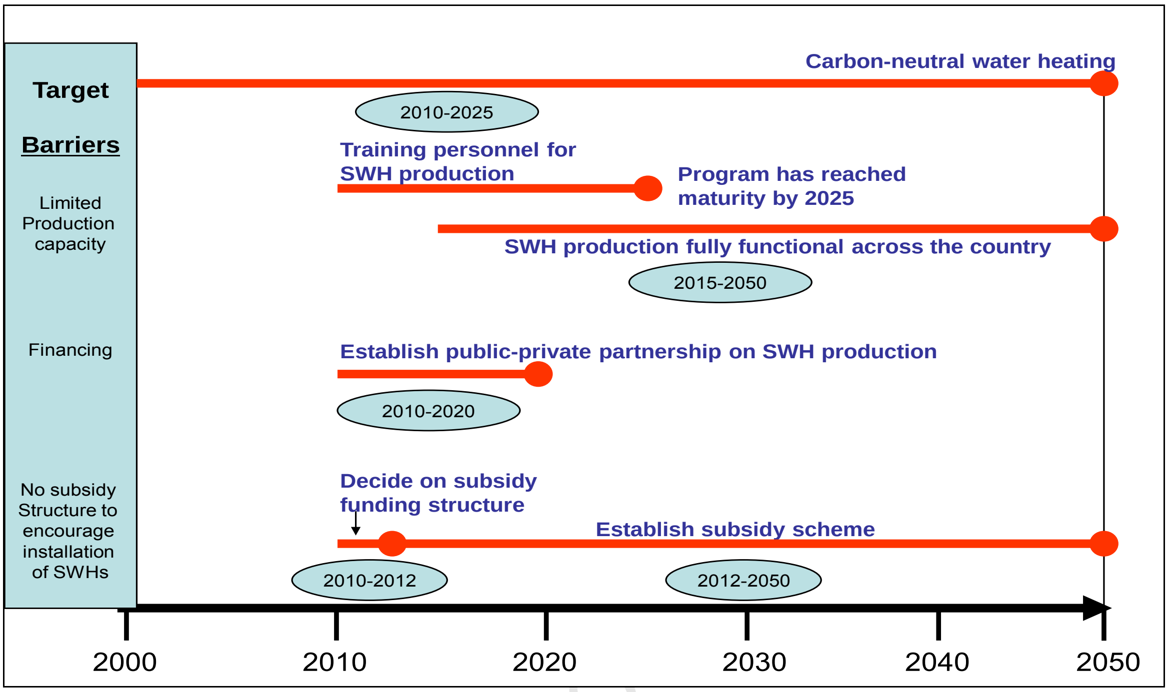


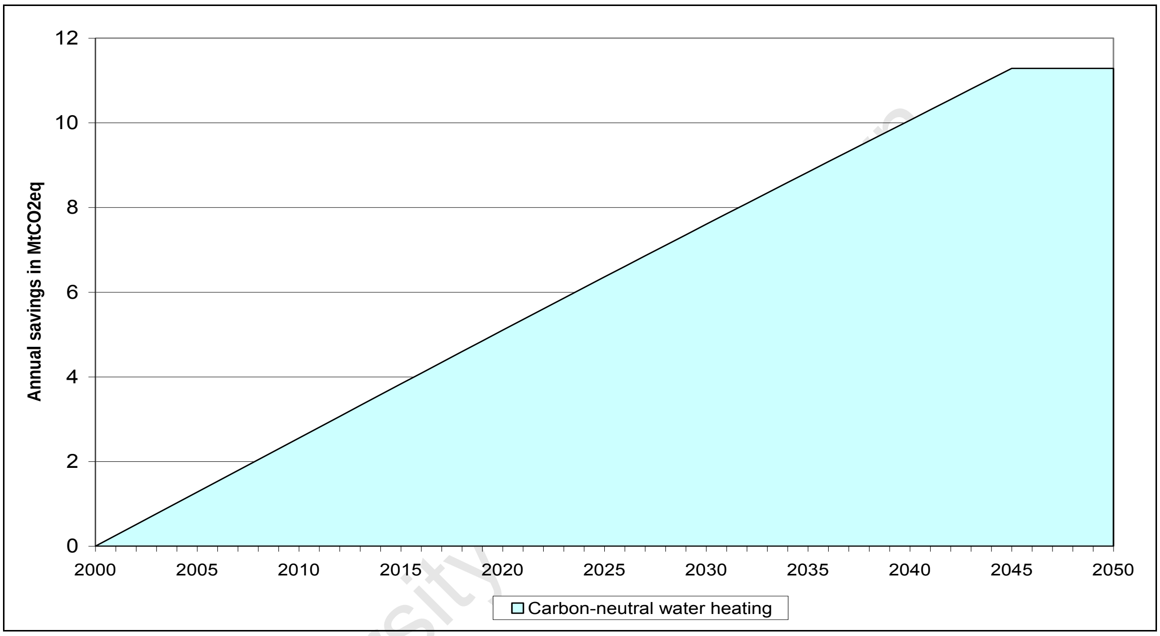
Figure 5.41: Implementation plan for carbon-neutral water heating in South Africa, showing the implementation of indirect and direct options in relation to specific timeframes



Production of SWHs should be fully functional by 2015, over and above current production, with manufacturing centres financially supported by government in public-private partnerships. Discussions on how these partnerships are to be established and function should start as early as 2010 to stimulate financing of countrywide production by 2015. Installation of SWHs should be supported by way of subsidies. Thus, government should decide on a funding structure that assists poor households in particular to effect high penetration rates of SWHs. By 2012, the subsidy scheme should be established and running to ensure guarantees for massive production of SWH by 2015 over and above current production. To address the challenge of limited SWH production capacity, a capacity building programme for SWH production should be initiated by 2010 and self-sustainable by 2025.

Over the 50-year period, a moderate CO_2 emission reduction in the total amount of 318 $MtCO_2$-eq is achieved by means of the implementation of SWHs. Emission savings peaks at 11.3$MtCO_2$-eq by 2045 and remain at that level until 2050, as the assumed penetration level of SWH is reached (Figure 5.42). Significant savings in emissions are achieved through the implementation of SWH in poor households, particularly in rural areas as well as in the implementation and enforcement of energy efficient building standards for new buildings.

Figure 5.42: CO_2 emission reductions related to the implementation of carbon-neutral water heating in $MtCO_2$-eq



5.5.2 Action AB9: Greener settlements

According to Winkler et al. (2006), space heating in the Urban Higher Income Electrified (UHE) household category is met almost entirely by electricity, with little met by paraffin. The City of Cape Town reports that 75% of energy requirements for space heating are met by electricity, while the remainder is met by paraffin (CCT 2007). For low-income un-electrified households, Haw and Hughes (2007a) have shown that wood and coal are the two prominent fuels applied. Their analysis reveals that coal contributes 33% towards space heating energy requirements, while wood provides the remainder. Often the wood is applied in an open fire outside the household to limit the risk of inhaling smoke.

Furthermore, most thermal energy (heat) inside a house escapes through the roof. However, this can be avoided by installing ceilings with insulation (Spalding-Fetcher et al. 2002; Winkler et al. 2006). According to Winkler et al. (2006), through this intervention it is possible to achieve 42% in energy savings. This equates to an annual energy savings of 1.68%. However, obstacles associated with achieving space heating includes the high capital costs of erecting ceilings, particularly for low income households, inefficient methods of using coal-fired heaters, which tend to generate gaseous emissions including CO_2, and use of biomass due to a lack of access to electricity. The solutions (indirect options) to these obstacles are indicated in Figure 5.43. Figure 5.44 shows timelines for the implementation of these options in an effort to achieve energy efficiency in space heating by 2050.

Figure 5.43: Direct and Indirect Options (in response to obstacles) associated with green structures and settlements

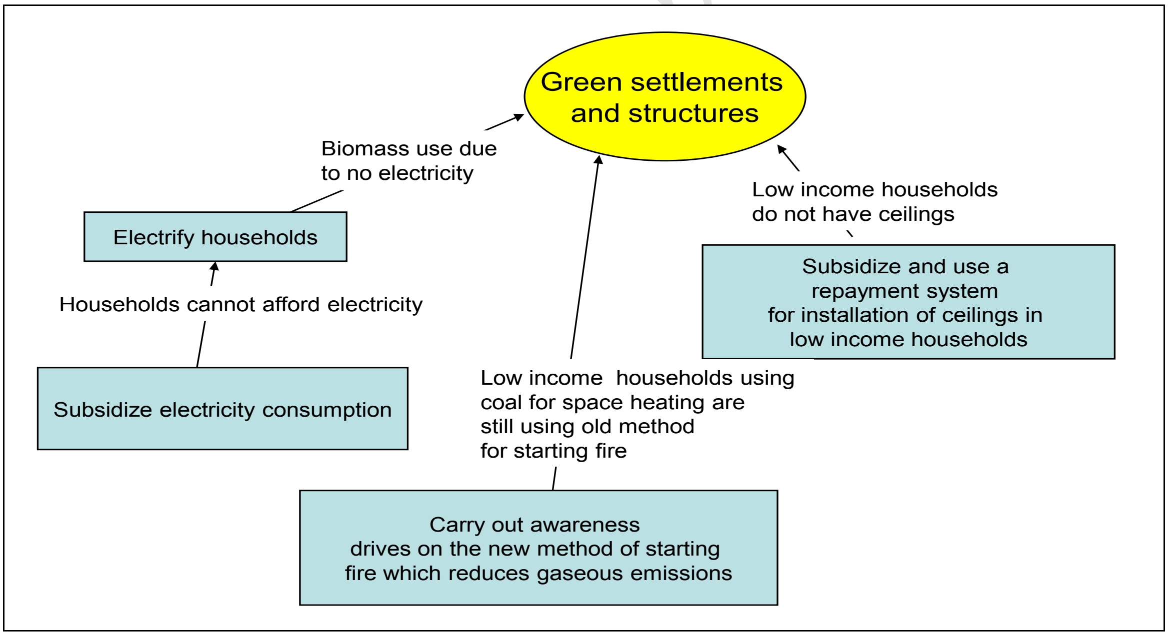
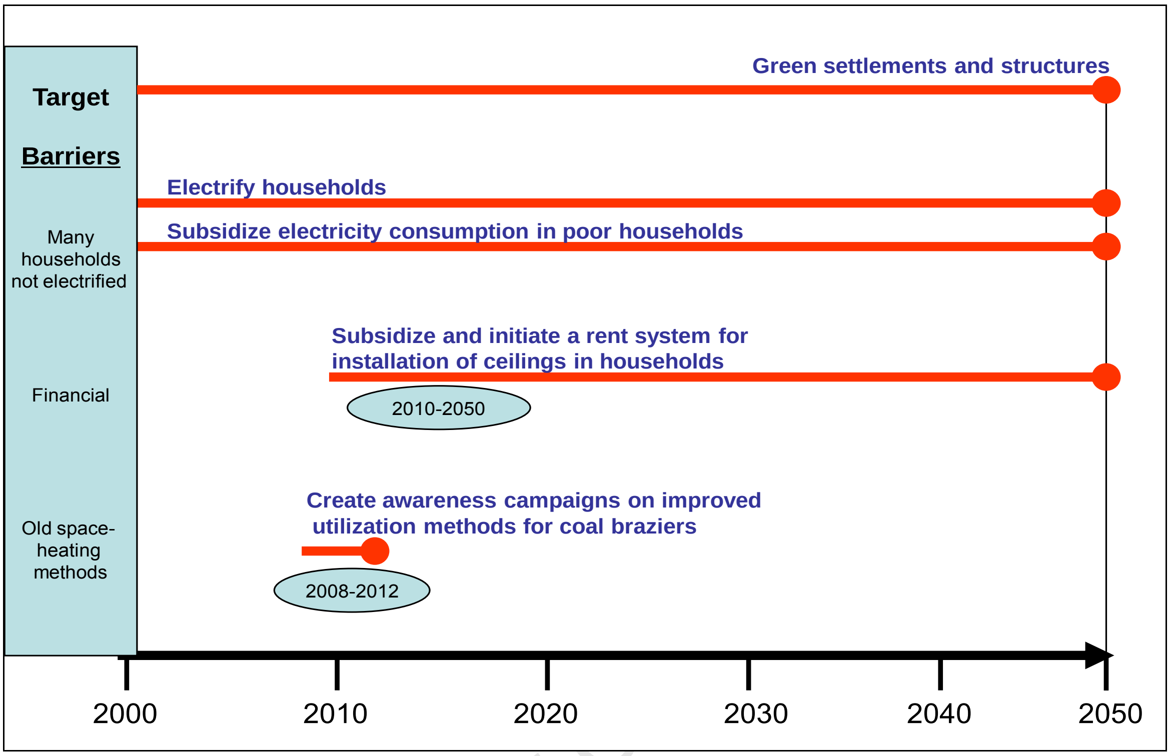


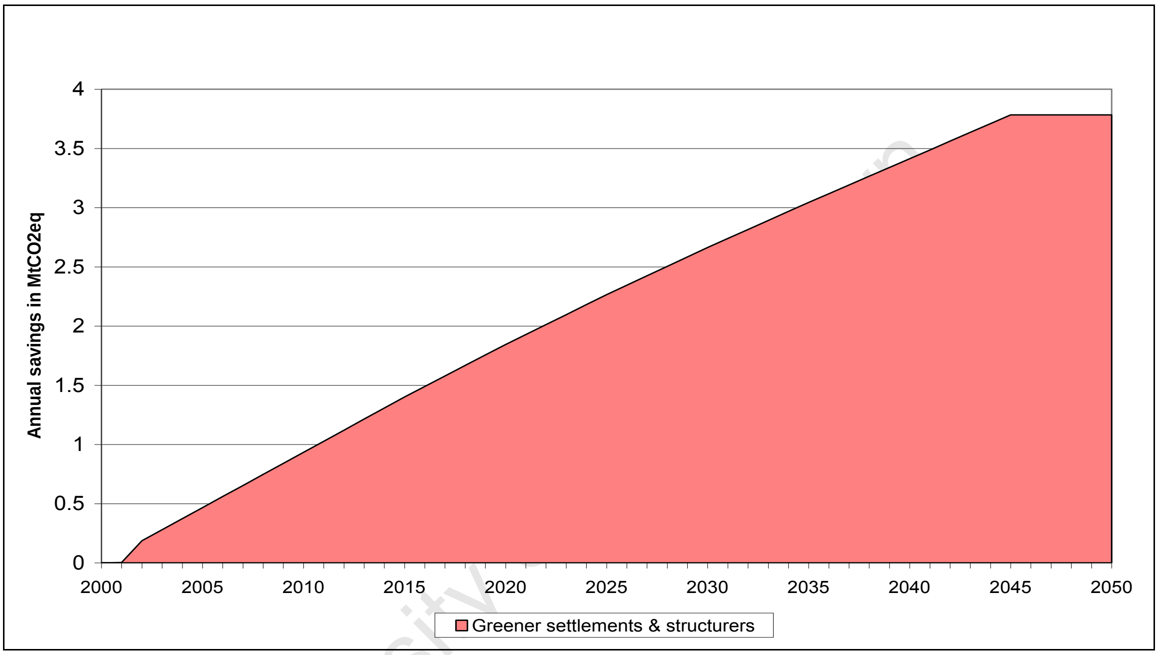
Figure 5.44: Implementation plan for energy efficiency in warming for South Africa, showing the implementation of indirect and direct options in relation to specific timeframes



To address the challenges faced by un-electrified households, the policy to ensure universal access to electricity needs to be fully implemented. The implementation plan presented in Figure 5.44 proposes that the current electrification programme must be accelerated. Also, the current electricity subsidy to poor households must be continued. Poor households use other fuel carriers for space heating, which are often dirty and result in adverse health impacts. Therefore, there are added benefits from moving away from dirty fuels. To achieve high energy efficiencies in space heating, the installation of ceilings in households must be subsidised and a rent system must be initiated by 2010. The rent system will ensure that a working fund is established and that more ceilings are installed. Furthermore, continued awareness campaigns on the efficient use of coal braziers for space heating and cooking, such as the "Basa Njengo Magogo" campaign, should gain momentum and reach maturity by 2012. These campaigns also play a major role in improving indoor air quality.

Emission savings associated with greener settlements total 110 $MtCO_2$-eq over the 50year period. Furthermore, emission savings peak at 3.78 $MtCO_2$-eq by 2045, and remain at that level until 2050 (Figure 5.45). In this case, the BCM has assumed that the installation of ceilings in households will reach saturation (100% penetration) by 2045.

Figure 5.45: CO_2 emissions savings related to the implementation of Greener settlements in $MtCO_2$-eq



5.5.3 Action AB10: Energy efficient lighting (use of CFLs)

The replacement of incandescent lights with compact fluorescent light bulbs (CFLs) can result in major energy savings. This is evident particularly in initiatives such as those of the Western Cape, which saw a massive roll-out of CFLs as a demand-side management strategy. Haw and Hughes (2007a) provide penetration rates of CFLs in both urban and rural households. They believe that it is possible to achieve high penetration rates above 80%. Markets can also be used to phase out incandescent lights. However, there obstacles involved in the implementation of CFLs, such as the high price of CFLs particularly for low income households, and limited public knowledge about the safety precautions and the safe disposal of CFLs. Figure 5.46 shows some indirect options that can be applied to deal with the obstacles associated with the increased use of CFLs. These include using the markets to phase out inefficient lighting, public awareness drives on safe handling and disposal of CFL lighting, and a massive roll-out of CFLs. Figure 5.47 shows the timeframes for the implementation of these indirect options.

Figure 5.46: Direct and indirect options (in response to obstacles) associated with achieving energy efficient lighting

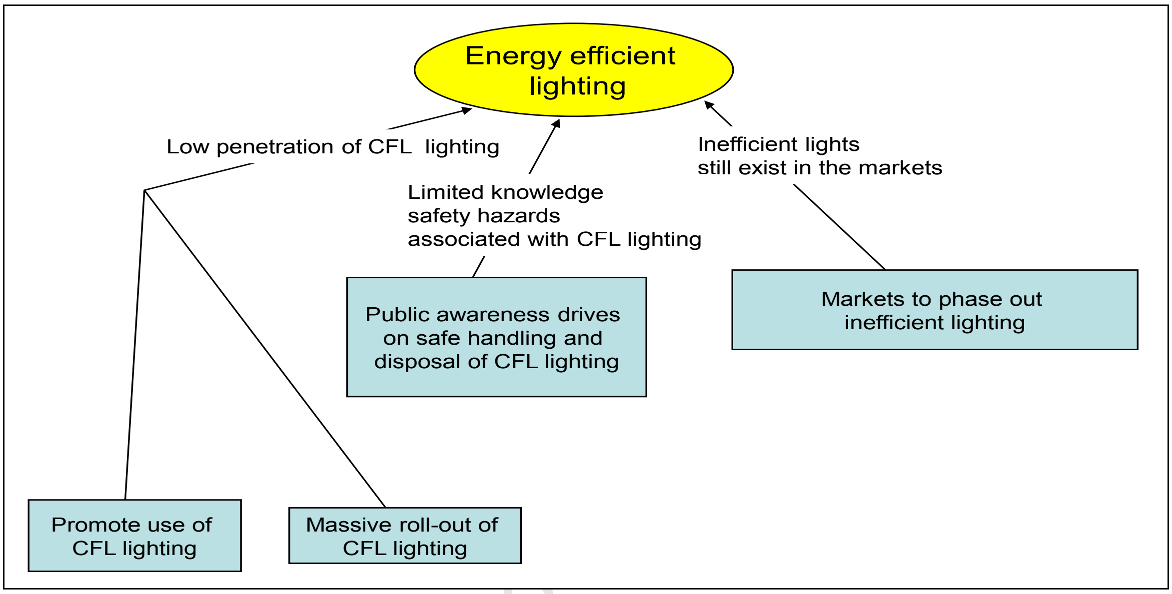
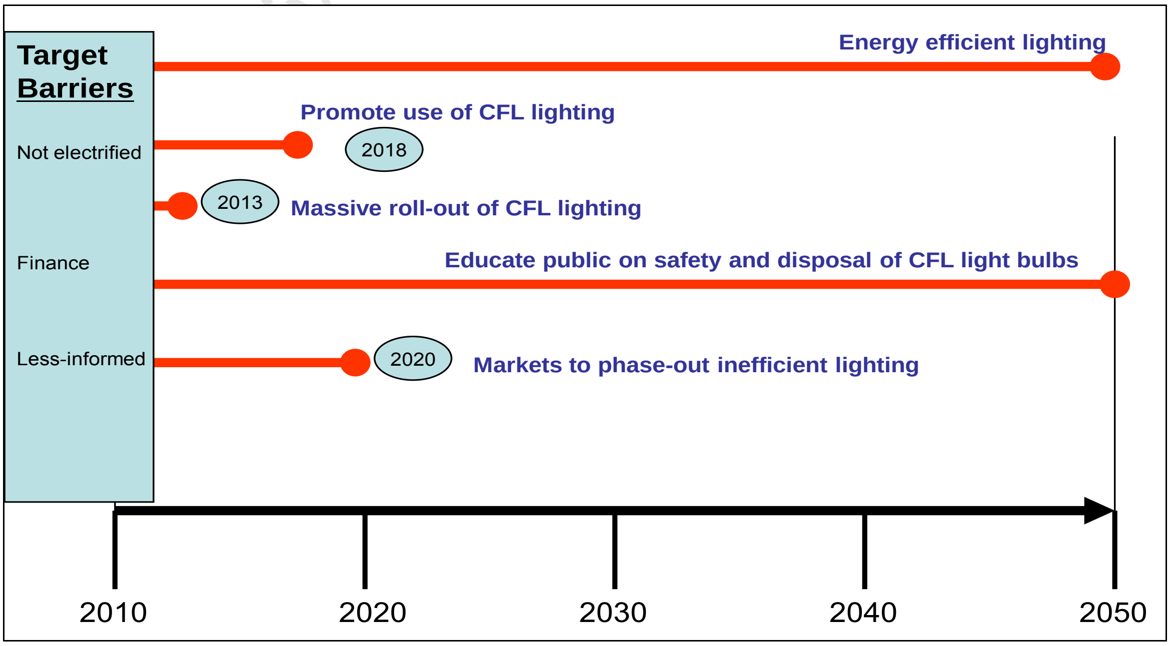
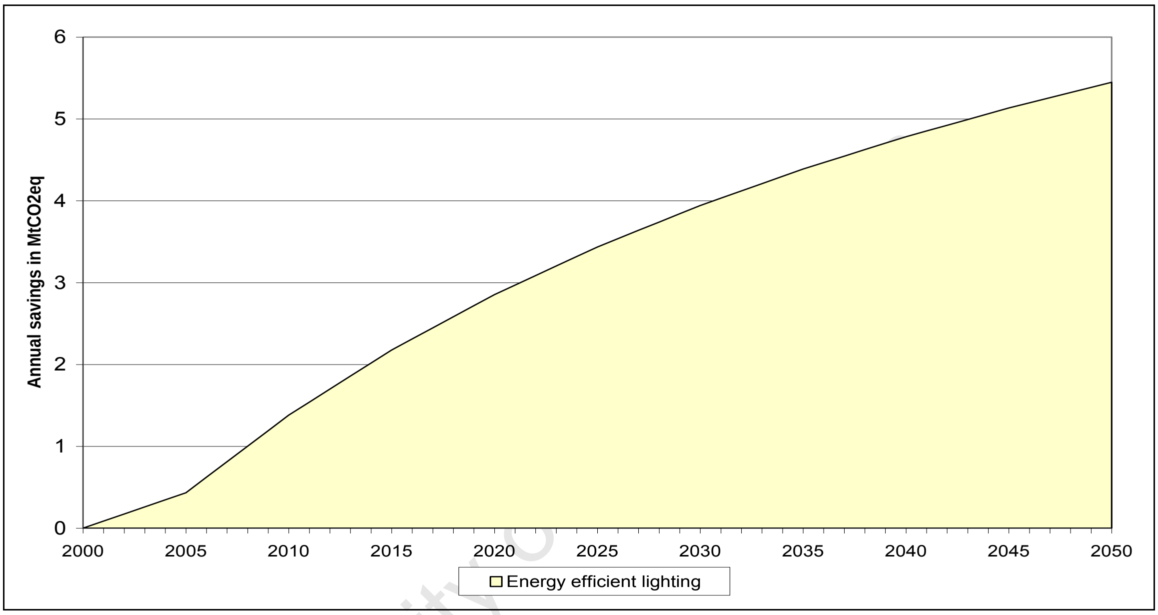


Figure 5.47: Implementation plan for energy efficient lighting for South Africa, showing the implementation of indirect and direct options in relation to specific timeframes



In respect of this action, emission savings reach a total amount of 159 $MtCO_2$-eq over the study period. Savings continue increasing over the period, with a maximum of 5.45 $MtCO_2$-eq in the final year, 2050 (Figure 5.58). Key contributing factors involve phasing out of inefficient incandescent light bulbs by 2020 and conducting nationwide awareness drives on the use of compact fluorescent light bulbs (CFLs).

Figure 5.48: Emission savings in $MtCO_2$-eq for "energy efficient lighting"



5.5.4 Action AB11: Climate sensitive commercial sector

Space cooling in the commercial sector consumes more energy than other end uses. Research on energy efficiency in the commercial sector has identified a number of existing measures that can be readily implemented. These measures include switching off air-conditioning units when there are no occupants, preventing cold and hot water mixing, ventilation by outside air and night cooling as well as implementation of computerized energy management systems. According to Winkler et al. (2006), it is possible to have 35% efficiency gains per square meter by 2030 if all these measures are implemented. In this study, it is assumed that these measures result in 15% efficiency improvements in HVAC systems, increasing to 30% by 2050.

Obstacles associated with implementing this action include a lack of awareness about these measures (Figure 5.49). Also, energy services are not recognized as a mainstream business activity. As such, the monetary savings through improved energy efficiency are not taken seriously. However, Winkler et al. (2006) have shown that if these measures are implemented successfully, a payback period equivalent to 3 years can be realized on investment spent to realize such measures. Other actions that can be implemented to overcome such obstacles include:

- Raising awareness in the commercial sector about efficient air-conditioning and HVAC systems
- Implementation of building energy management systems
- Installation of efficient air conditioning systems and HVAC systems
- Introduction of a subsidy system for major cooling operations on the installation of efficient air conditioning and HVAC systems

Figure 5.50 presents an implementation plan to achieve a climate sensitive commercial sector.

Figure 5.49: Obstacles and mitigation options to achieve a climate sensitive commercial sector

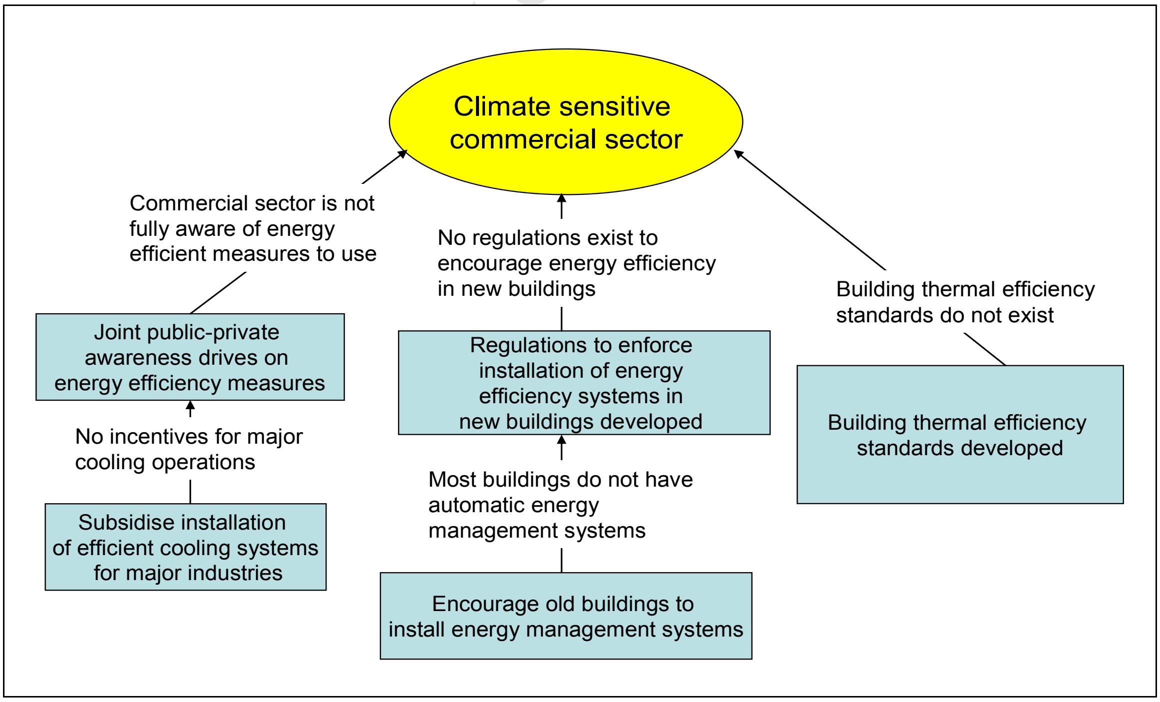
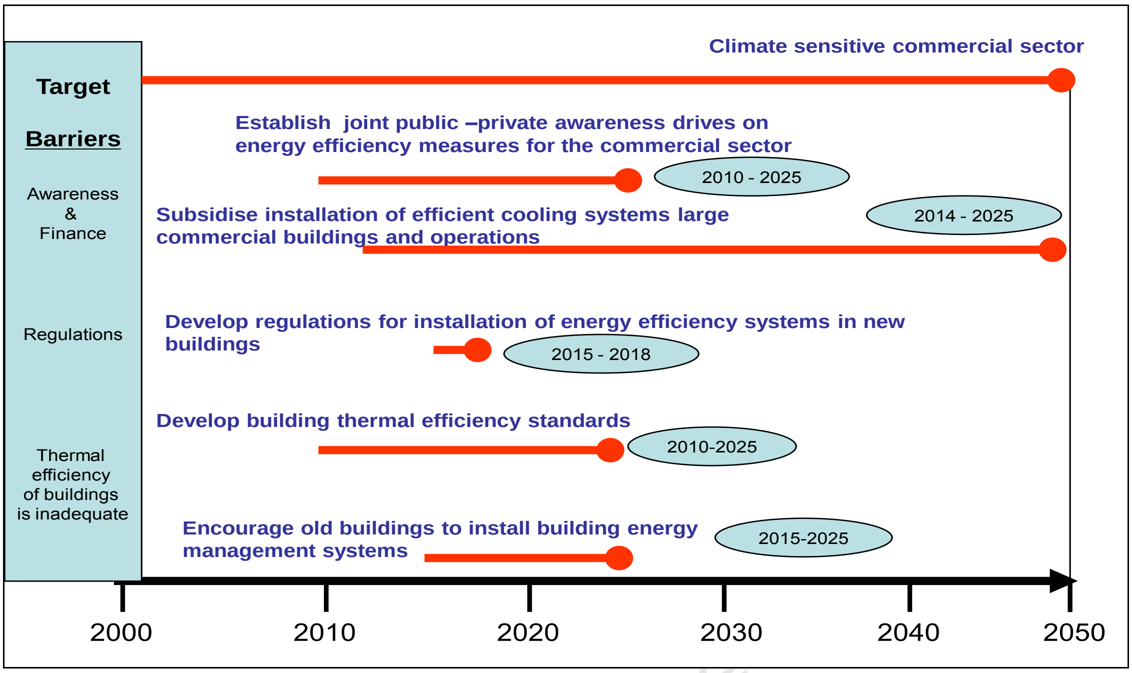
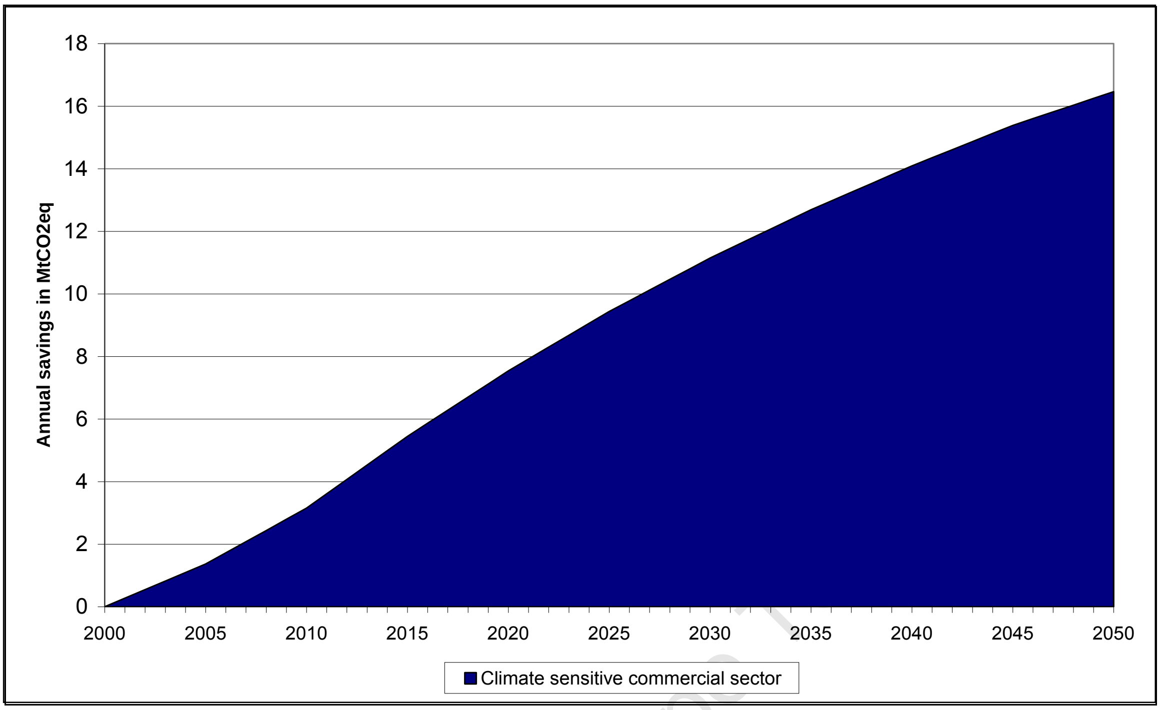


Figure 5.50: Implementation plan for the LCS action "climate sensitive commercial sector



As observed from Figure 5.51, this action results in a total emission savings of 450 $MtCO_2$-eq across the study period with a peak annual CO_2 savings of 16.46 $MtCO_2$-eq by 2050. Initially, the energy savings are sustained by partnerships targeting large cooling installations in the commercial sector between 2010 and 2050. During this period, building thermal efficiency standards ensure consistent emission savings. Further emission savings are realized by installing energy management systems in old buildings, which are traditionally built in an energy efficient manner. Regulations governing the installation of energy management systems in new buildings ensure that new buildings achieve savings from initial stages. Emission reductions under this action follow a smooth curve until 2050 because of continued increases in commercial space in both scenarios.

Figure 5.51: Emission savings in ($MtCO_2$-eq) from the implementation of the action "climate sensitive commercial sector"



5.5.5 Action AB12: Climate conscious manufacturing

This action implies that companies and industries must move towards trading in low carbon markets and selling low carbon goods and services through energy efficient manufacturing processes. By means of continued improvements of industry, guided by an environmentally conscious leadership and supported by government, energy intensity per production volume in each industry sub sector will have reduced by a minimum of 30% when compared to 2000 levels. This is based on an assumed energy consumption reduction of 0.5% each year. Such reductions can be supported by the publication of climate change related information associated with the products produced. Such exercise can be easily implemented by public relations units of businesses. A system needs to be put in place in each industry to undertake such activity.

With increasing numbers of climate conscious consumers, the publication of such information will present a competitive edge for industries who publicly disclose information of CO_2 emissions related with their products. To ensure the legitimacy and validity of such information, however, an independent body will need to be developed to perform independent audits. Also, different industries will have different methodologies of computing CO_2 related information. Therefore, CO_2 computation standards will have to be developed to ensure consistency and comparability across industries and sectors. Following the independent audits, the auditor can then certify the industry under review for a limited period of time (e.g. a year); thereafter, another independent audit will have to be undertaken. Government may also decide to incentivise industries that voluntarily implement energy efficient measures. Figure 5.52 and Figure 5.53 summarise the mitigation options and the implementation plan for climate conscious manufacturing.

Figure 5.52: Obstacles and mitigation options associated with the action "climate conscious manufacturing"

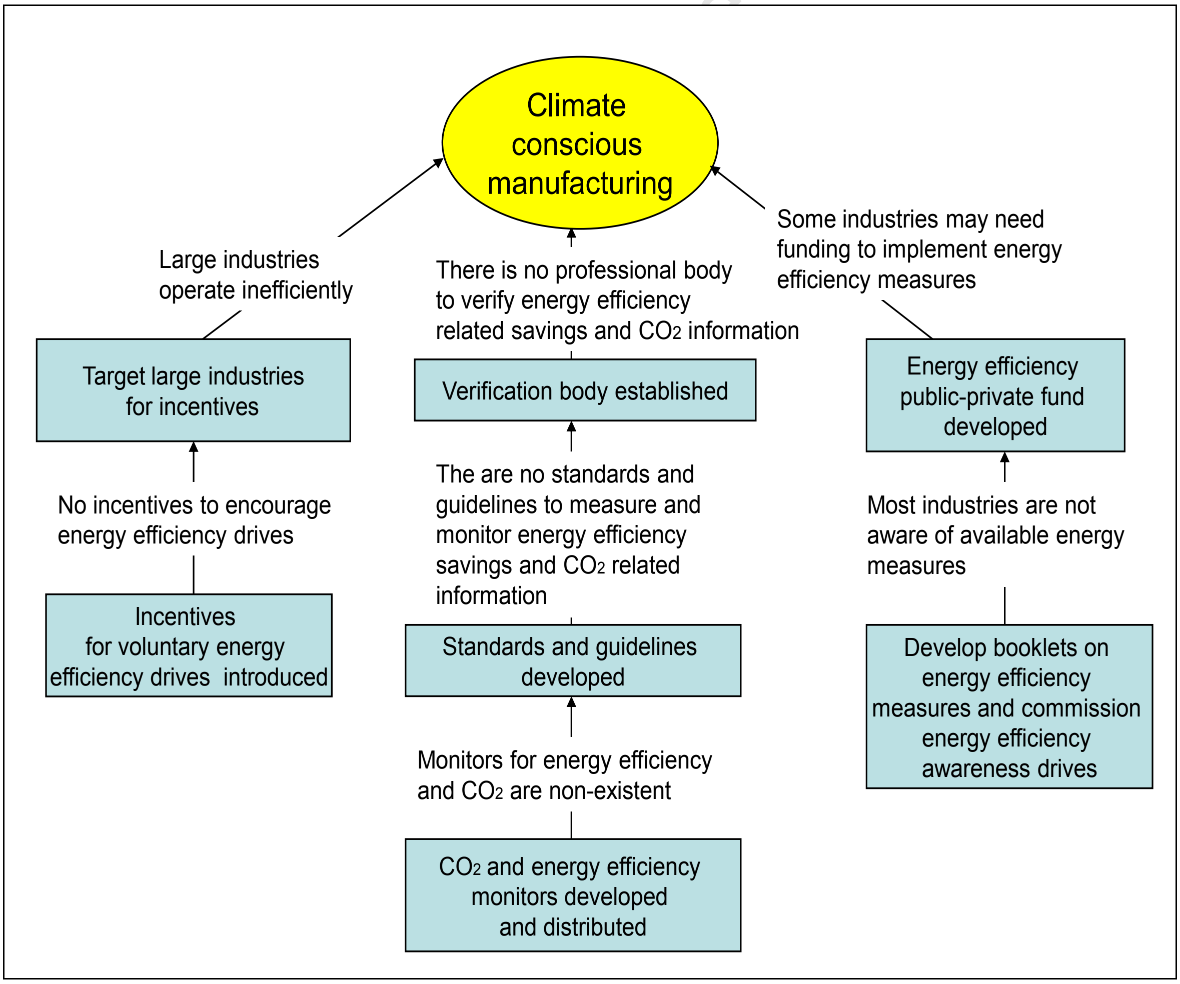


Figure 5.53: Implementation plan for the "climate conscious manufacturing" action

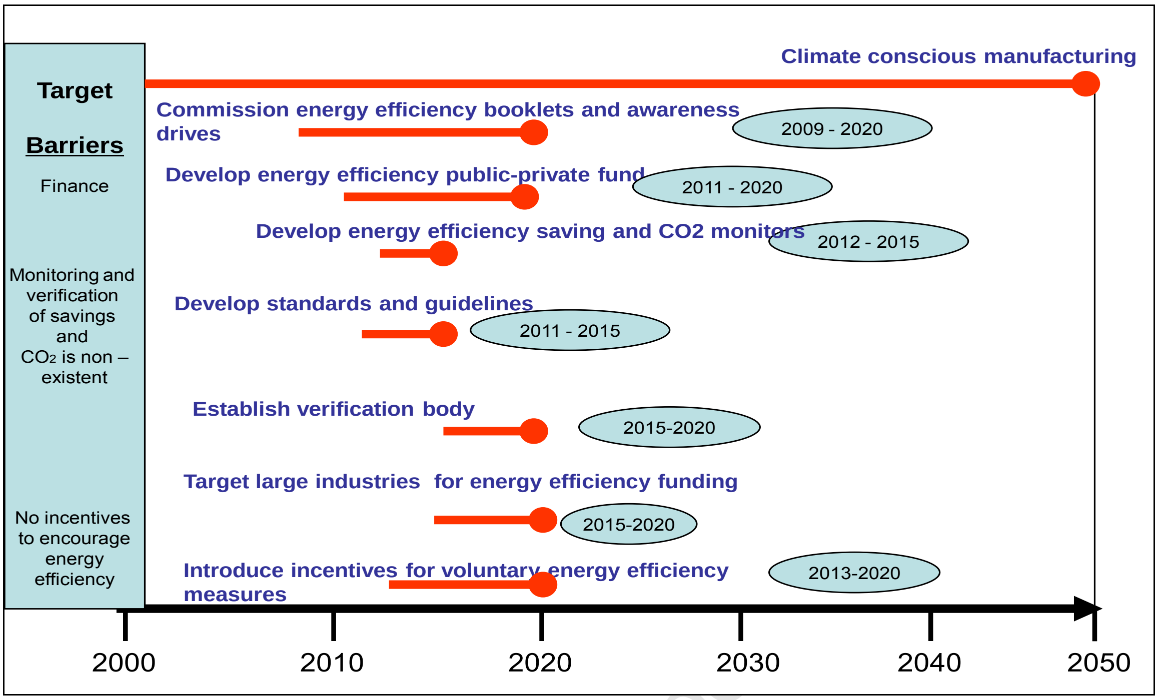
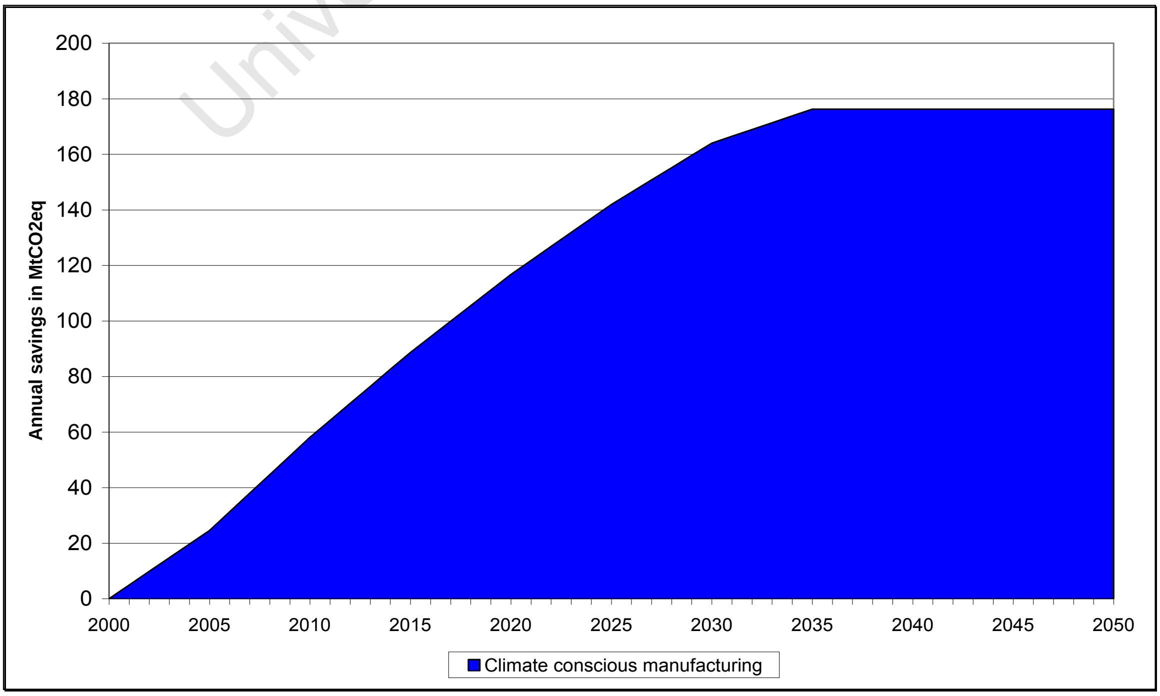


Figure 5.54 shows the results from the BCM model for this action. The BCM results show a peak savings value of 176 $MtCO_2$-eq by 2035, remaining at that level until 2050, in line with saturation in energy efficiency gains.

Figure 5.54: Emissions savings in $MtCO_2$-eq for "climate conscious manufacturing"



The implementation of this action peaks very early (2035) due to early implementation of options (mitigation options). Policy signals (energy efficiency accords) as well joint public-private partnerships coupled with energy efficiency drives pave the way for early adoption of energy efficiency measures.

5.6 A quantitative analysis of emission reduction goals (Forecasting approach)

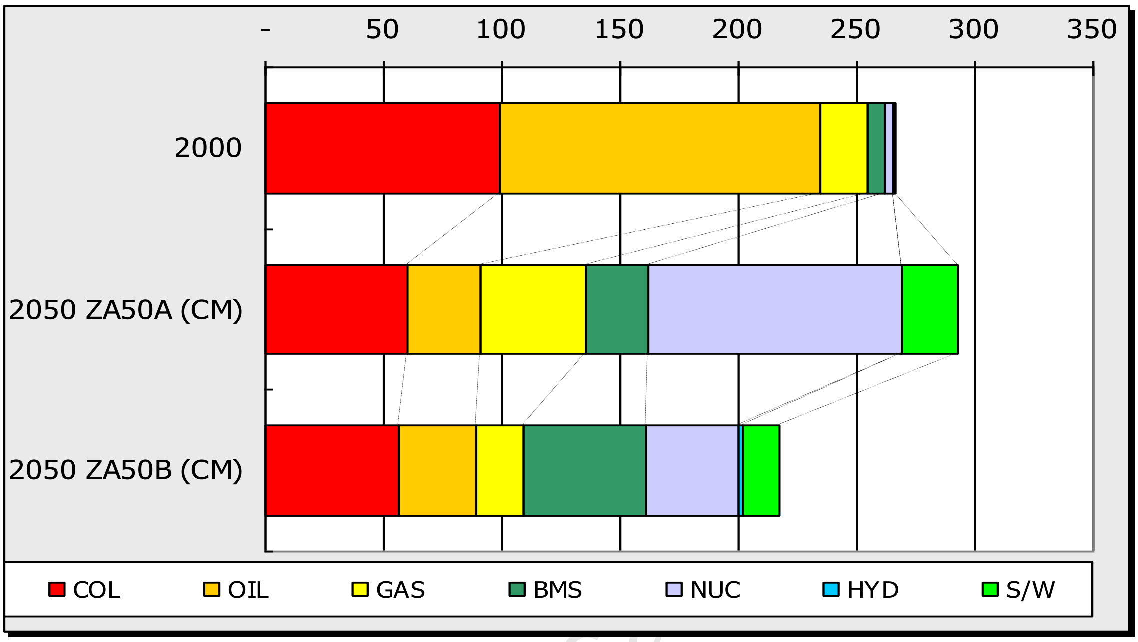
This section uses the ESS tool and the LCS actions developed in Sections 5.3 to 5.4 to quantify emission reduction goals for each LCS scenario. This is a forecasting approach whose outputs (determined emissions goals) are compared with the combined results of the backcasting analysis. The forecasting approach does not take into account the constraint analysis used by the BCM, nor does it consider the indirect options to deal with obstacles. It only uses the energy consumption reduction rates and the penetration rates of measures employed in the chosen LCS actions. In addition, emission reductions from the chosen actions are compared to 2000 emission levels.

5.6.1 Energy consumption and emissions in 2050 for ZA50A and ZA50B scenarios

Figure 5.55 shows the total primary energy consumption (in Mtoe) for LCS scenarios ZA50A and ZA50B. Consumption in ZA50A increases from 261 Mtoe in 2000 to 293 Mtoe by 2050. This is attributed to the high share of nuclear fuels (50% by 2050) in power generation and the increased gas usage in petroleum industries and process heating in the industrial sector, thus contributing 15% towards total primary energy consumption. Renewable energies also feature in scenario ZA50A due to a 30% share in power generation and as well as application in the commercial sector.

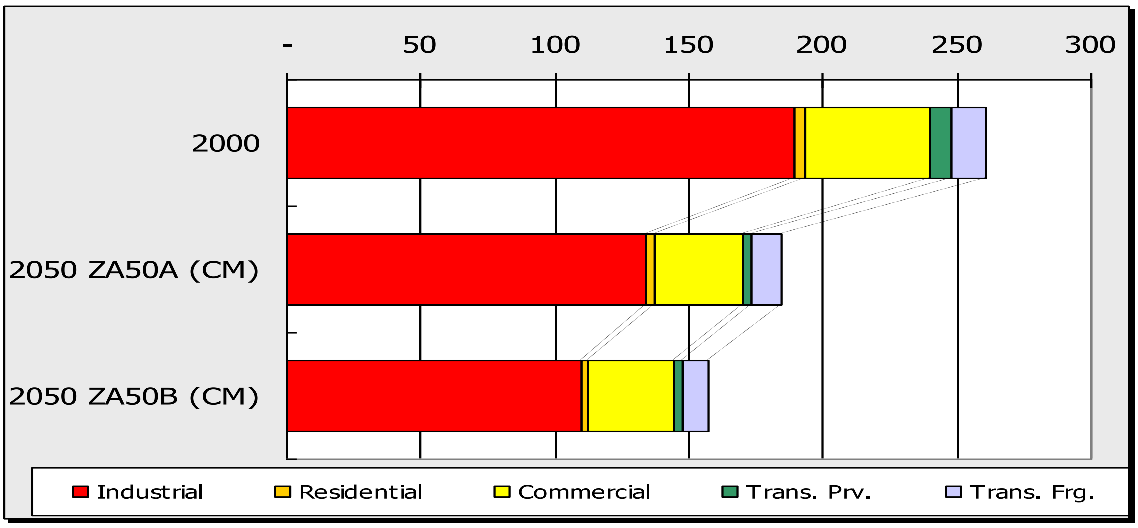
For scenario ZA50B, primary energy consumption reduces from 261 Mtoe in the base year to 217 Mtoe by 2050. Use of renewable energy sources for power generation, commercial, residential and the transport sector contributes to displacement of conventional primary fuels. Biomass uptake for power generation and reducing oil dependence also plays a key role.

Figure 5.55: Total primary energy consumption



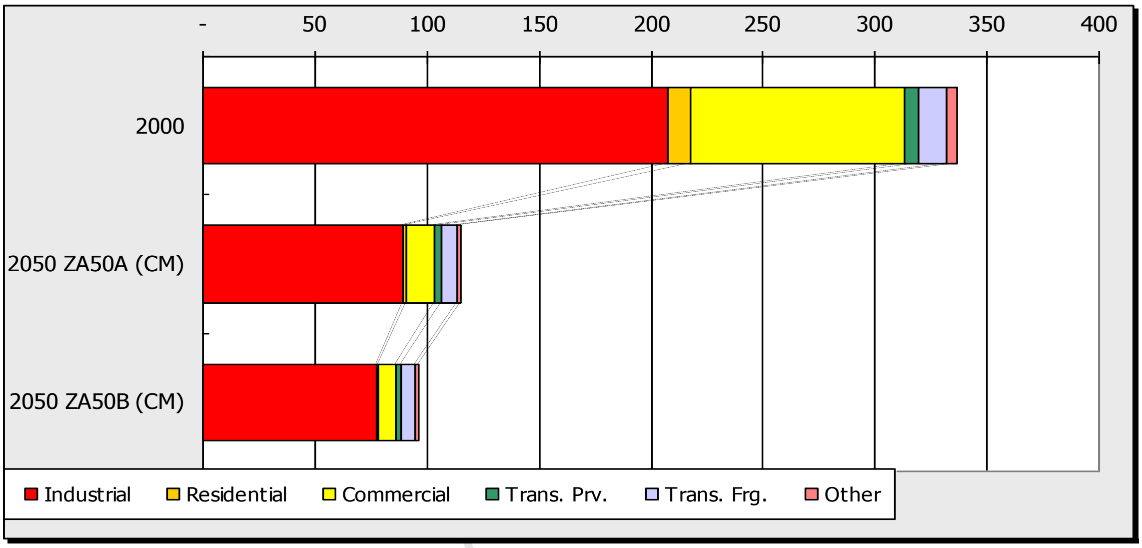
Assessment of energy consumption by end-use sectors shows that the industrial sector realizes most consumption reductions, followed by the commercial and transport sectors (Figure 5.56). The residential sector has modest savings in both scenarios, even though scenario ZA50B performs better than ZA50A.

Figure 5.56: Total secondary energy consumption



Emissions reduce from 337 $MtCO_2$-eq to 115 $MtCO_2$-eq (66% reduction) for scenario ZA50A and 96$MtCO_2$-eq (72%) for scenario ZA50B (Figure 5.57). The industrial sector is responsible for most reductions (57% for scenario ZA50A and 63% for scenario ZA50B). The commercial sector results in the second largest emission reductions, followed by the transport and residential sectors.

Figure 5.57: Total CO_2 emissions by sector



5.7 Conclusion

In Chapter 5, two methodology steps have been achieved. Firstly, in sections 5.3, 5.4 and 5.5, each mitigation action is thoroughly investigated in the BCM model based on technical assessment of the options as well as assessing the barriers associated with implementation of the technical options. The solutions to the barriers have a bearing on the implementation plan for each mitigation action. Annex 5 provides the input data used in the BCM model for each of the mitigation options associated with each scenario whilst annex A and B demonstrates how this input data is fed into the BCM model. Secondly, using ESS tool and the technical options associated with its scenario, a minimum theoretical emission reduction goal of 65% based on ZA50A LCS actions by 2050, and a maximum of 72% reductions based on the ZA50B pathway are set.

The BCM model integrated with ESS tool allows for the generation of decomposition analysis results by end use sector. This is shown in chapter 6 (section 6.1) where the integrated BCM model produce results of energy demand, power supply analysis, CO_2 emissions associated with the demand and a CO_2 factor analysis to determine the key drivers of change in emissions. This CO_2 factor analysis is based on the kaya identity expressed by equation 3.2 in the methodology chapter. In chapter 5, the mitigation analysis of each LCS action was examined. As such section 6.2 is done outside the BCM model where the cumulative impact of all LCS actions are combined and analyzed using an excel spreadsheet. These emissions are also normalized so that they are comparable to the emission reduction goals as set by the ESS tool.

Also, the BCM model has a functionality to calculate penetration rates of all specified mitigation options in the model. This allows for the preparation of a mitigation option penetration plot. The BCM model assign a penetration rate for each mitigation option based on a scale of 0 to 1. The mitigation option penetration plot is an shows a cumulative penetration rate plot taking into account all modelled mitigation options for each scenario. This is demonstrated in section 6.3.

CHAPTER 6

6 Quantitative mitigation analysis of actions

6.1 Sectoral mitigation analysis

This section examines the impact of supply-side and demand-side LCS mitigation options on the various energy sectors, namely, residential, industrial and commercial sectors as well as the transport sector. The transport sector is divided into two sectors, namely, passenger transport and freight transport. This makes it possible to deal with sub-sector specific mitigation options (e.g. transport mode shift) in an unbiased manner. A comparison is made between the base year (2000) and the future LCS period (2050) for which the LCS scenarios are demonstrated. The observed energy demand trends and the related carbon emissions are explained in detail. In all cases, the mitigation analysis focused on both primary fuels and secondary fuels (i.e. coal, oil, gas, nuclear, renewable energy, hydro and electricity).

Section 6.1 also conducts a carbon emission decomposition analysis (factor analysis), which was explained in detail in Chapter 4; all the factors used in the factor analysis help to reduce emissions in scenarios ZA50A and ZA50B. Factor (D) explains changes in service demand in units of passenger-km private cars as well as ton-km for freight transport, which are the driving force for emissions. Factor (E/D) unpacks changes in energy intensities for both scenarios. C'/E looks at CO_2 intensity in the end-use sector by isolating measures in the transformation sector. Lastly, C/C' assesses carbon intensity changes in the end-use sector because of measures in the transformation sector. The following sections compares each of these factors in both scenarios for all end-use sectors modelled in this study. Appendix D presents the data used for the carbon emission decomposition analysis.

6.1.1 Residential energy and emissions analysis

In terms of scenarios ZA50A and ZA50B, residential energy consumption is reduced from 3.88 Mtoe in 2000 to 3.1 Mtoe and 2.33 Mtoe by 2050 respectively (Figure 6.1). Reductions in energy consumption are a result of movement away from coal and biomass towards electricity, coupled with improvements in energy efficiency by introducing energy efficiency building standards and efficient space heating and cooling, as well as water heating using solar energy. Electricity consumption is also reduced significantly because society is moving towards cleaner fuels. For example, in scenario ZA50A, it is assumed that 50% of cooking service demand will be met by LPG gas by 2050. Electricity consumption in scenario ZA50B is significantly reduced through the introduction of appliance labelling, the implementation of energy efficient lighting and the use of improvements in space heating.

The implication of the CO_2 emissions for residential energy consumption, as related to the two LCS scenarios, is depicted in Figure 6.2. Emissions are reduced from 10 $MtCO_2$-eq to 1.42 $MtCO_2$-eq for scenario ZA50A and to 1.00 $MtCO_2$-eq for scenario ZA50B. As observed from Figure 6.2, CO_2 emissions in the base year are attributed to the use of electricity mainly for space heating, cooking, water heating, and general household appliances. Mitigation options such as improvements in thermal efficiency, as well as carbon capture and storage, are responsible for these significant emission reductions.

Figure 6.1: Residential energy consumption (base year and 2050 LCS scenarios)

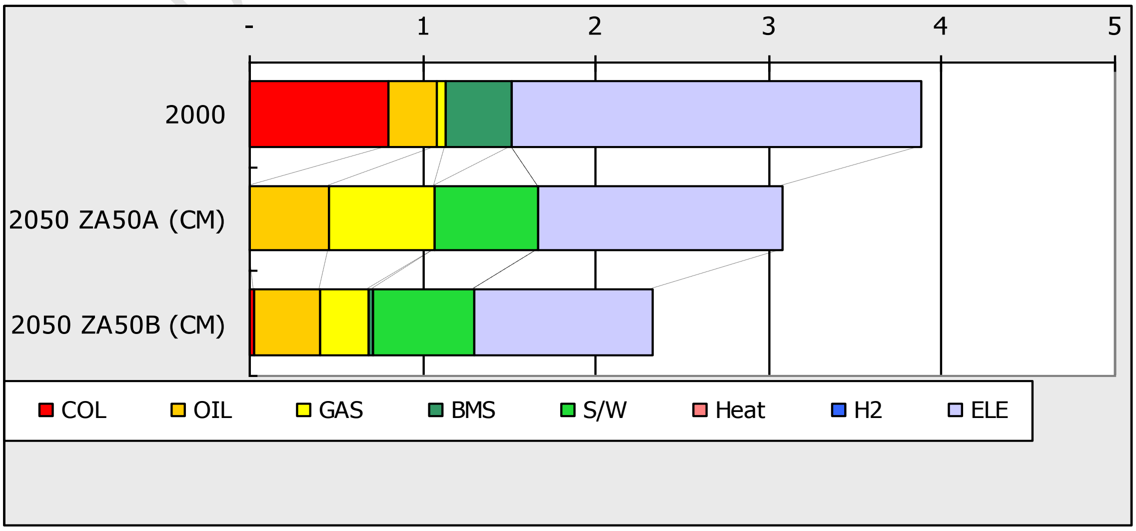


Figure 6.2: Residential CO_2 emissions (base year and 2050 LCS scenarios)

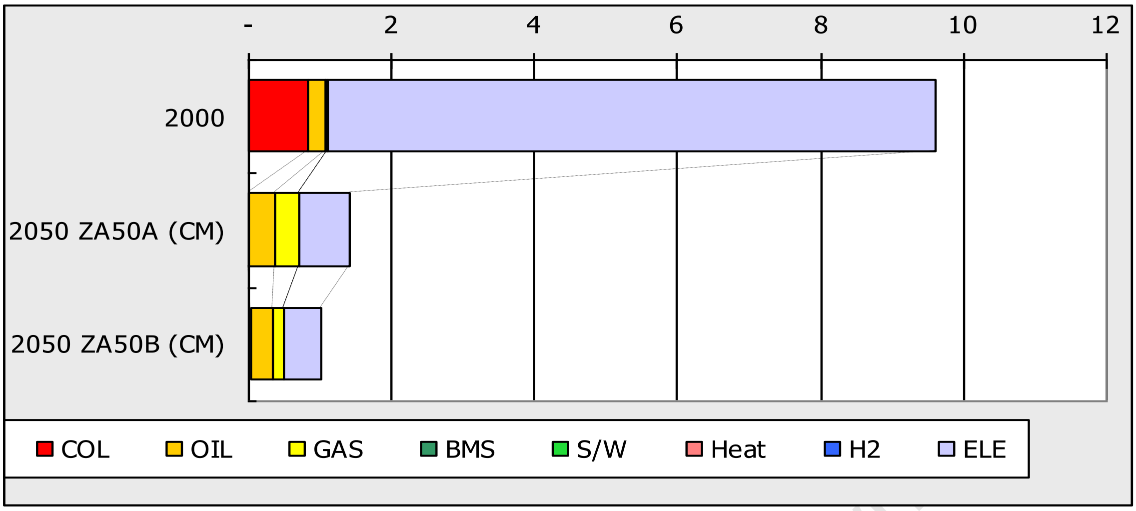
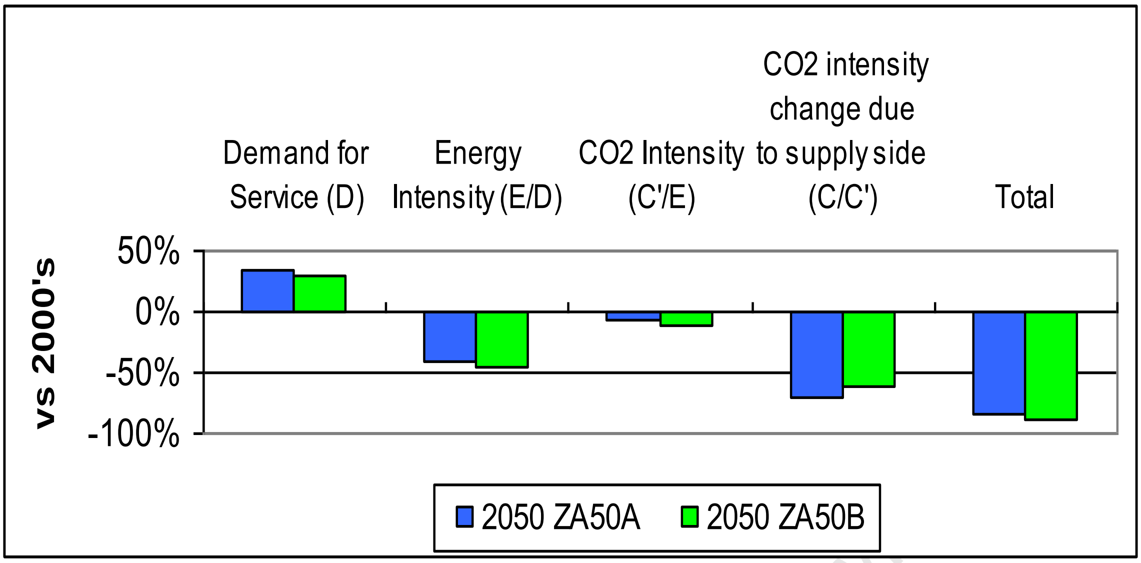


Figure 6.3 illustrates the factor analysis of CO_2 emissions in 2050 and 2000 for both LCS scenarios (ZA50A and ZA50B). Reductions in the demand for space heating due to the diffusion of well-insulated settlements, the diffusion of CFLs and the phase-out of inefficient light bulbs, as well as better orientation of settlements to exploit natural heating, all contribute to reducing factor (D), the driving force in both scenarios. Energy efficient technologies such as CFLs help to reduce energy intensity (E/D). The reduction rate of E/D in scenario ZA50B is slightly larger due to the increasing use of energy efficient appliances through labelling interventions. Use of SWHs and the increasing use of electricity largely due to extended electrification drives all contribute to reduced carbon intensity (C/E') in the residential sector in both scenarios. Also, the reduction in C/C' is the largest factor in reducing emissions. It is larger in ZA50A than in ZA50B due to a high share of nuclear energy and due to the use of carbon capture and storage. In total, scenario ZA50B performs slightly better than scenario ZA50A largely due to less energy intensity and, to a lesser extent, reduced carbon intensity.

Figure 6.3: Residential factor analysis of CO_2 emissions



6.1.2 Industrial energy and emissions analysis

As illustrated in Figure 6.4, energy consumption in the industrial sector is reduced from 190 Mtoe in the base year 2000 to 87 Mtoe for ZA50A and 77 Mtoe for ZA50B by 2050. Coal consumption is reduced through industrial energy efficiency drives as well as substitution with gas for process heating. Oil consumption is reduced significantly because it is being replaced by gas for process heating. Because of steady economic growth associated with scenario ZA50A, electricity consumption remains the same as that in the base year. In scenario ZA50B, however, electricity consumption is slightly lower due to energy efficiency improvements.

An assessment of emissions depicted in Figure 6.5 shows that the industrial sector emissions are reduced from 207 $MtCO_2$-eq in the base year to 87 $MtCO_2$-eq for scenario ZA50A and 77 $MtCO_2$-eq for scenario ZA50B. Most emission reductions are attributed to reductions in electricity and oil consumption. Interestingly, gas related emissions in scenario ZA50A are observed to be higher than in the base year due to an increased share of gas in liquid fuels production by 2050.

Figure 6.4: Industrial energy consumption (base year and 2050 LCS scenarios)

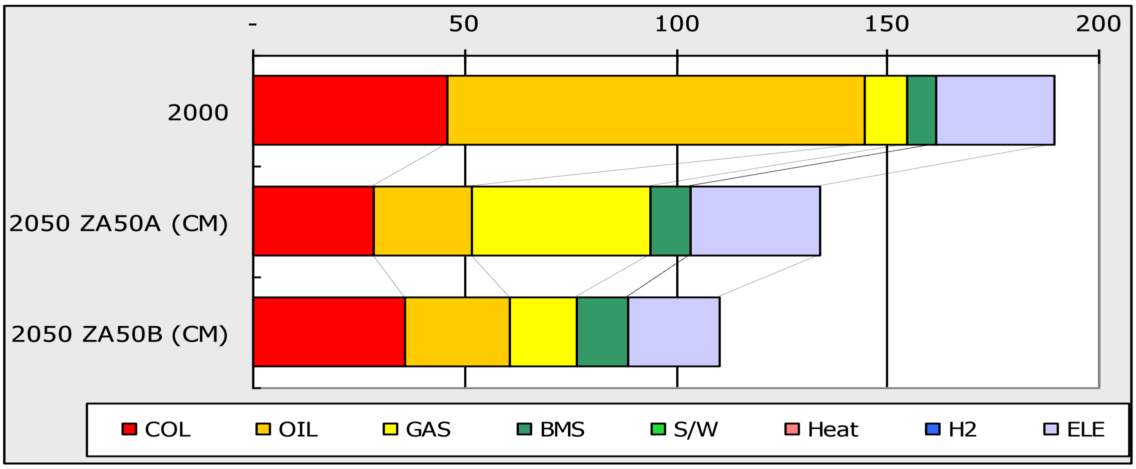
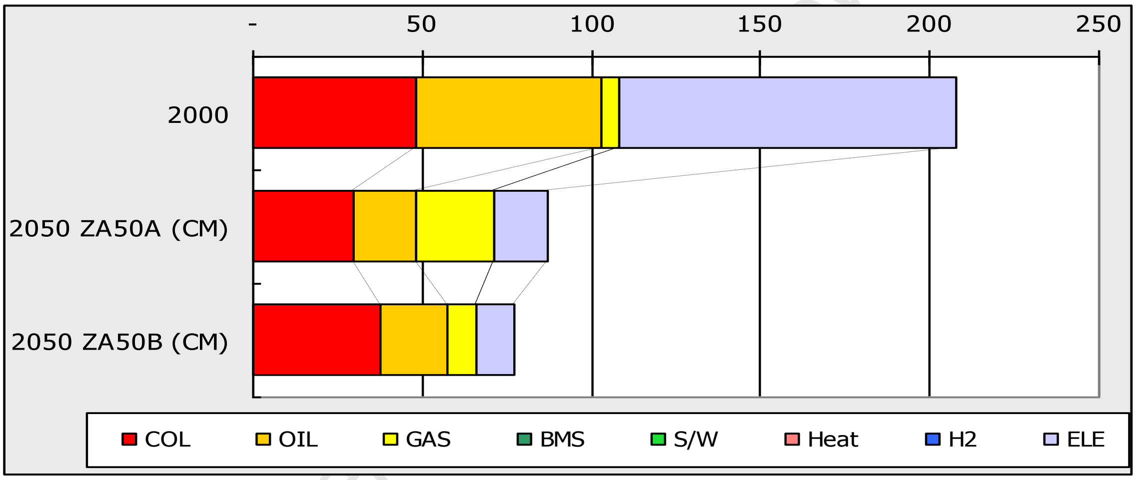
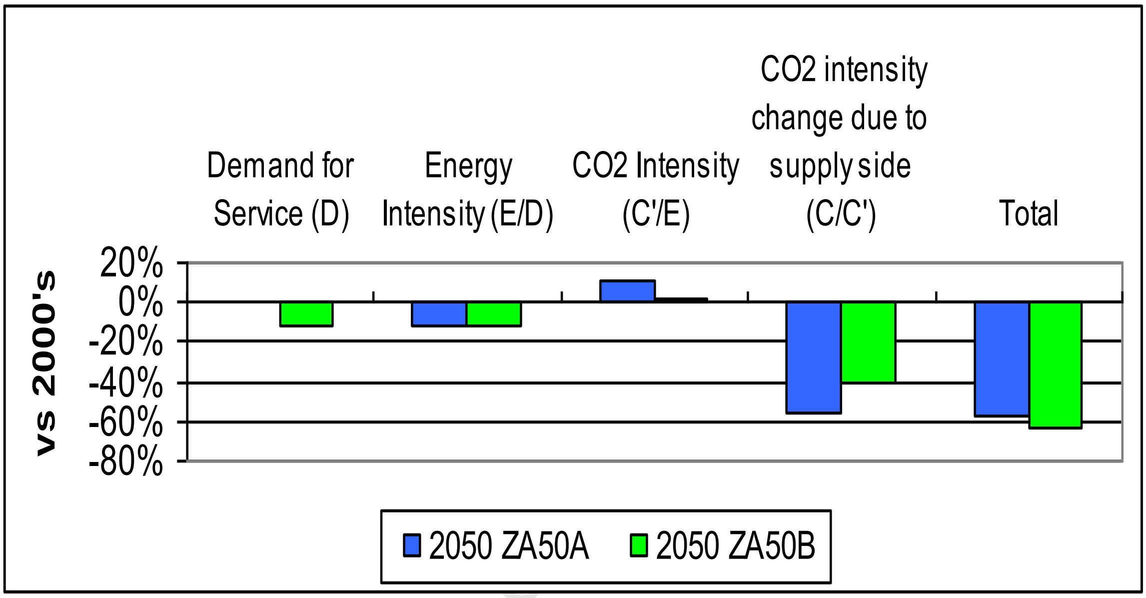


Figure 6.5: Industrial CO_2 emissions (base year and 2050 LCS scenarios)



A factor analysis for the industrial sector is shown in Figure 6.6. In addition to climate conscious manufacturing, a LCS action common to both scenarios, the ZA50B scenario also encourages clean process heating, which involves switching to another fuel for steam generation. The change in D is observed to be large (12%) in scenario ZA50B due to low economic growth, as compared to scenario ZA50A. Energy intensity (E/D) is reduced through industry-wide energy efficiency measures. Since both LCS scenarios share common industrial related LCS actions, changes in energy intensity for both scenarios are identical. C'/E for scenario ZA50A is high due to a high demand for goods and services under a steady increase in economic growth. C/C' is also observed to be higher in ZA50A due to a high share of nuclear and coal-fired power generation with improved thermal efficiency as well as carbon capture and storage. Once again, ZA50B performs slightly better than ZA50A for the industrial sector due to reduced service demand because of low economic growth. As in the residential sector, the largest reduction in CO_2 emissions is due to reduced intensity in response to changes in the transformation sector, i.e. changes in energy supply drive the results.

Figure 6.6: Industrial factor analysis of $C0_2$ emissions



6.1.3 Commercial energy and emissions analysis

Through LCS action mitigation options, energy consumption in the commercial sector will be reduced from 46 Mtoe to 32 Mtoe for ZA50A and 31 Mtoe for ZA50B (Figure 6.7). Oil consumption is significantly reduced because of fuel switching measures for process heating, space warming and water heating. Through energy efficiency measures, gas consumption is reduced more significantly in scenario ZA50B, mostly because society is moving towards a greater use of solar energy for water heating. Electricity consumption is reduced moderately because of energy efficiency and because of a movement towards solar energy, especially for water heating.

As observed from Figure 6.8, most emissions in the base year can be attributed to electricity consumption. A combination of demand-side mitigation options, such as energy efficiency, and supply-side measures, such as thermal efficiency and carbon capture and storage, reduces CO_2 emissions in the base year from 96 $MtCO_2$-eq to 11 $MtCO_2$-eq for scenario ZA50A and 7 $MtCO_2$-eq for scenario ZA50B.

Figure 6.7: Commercial energy consumption (base year and 2050 LCS scenarios)

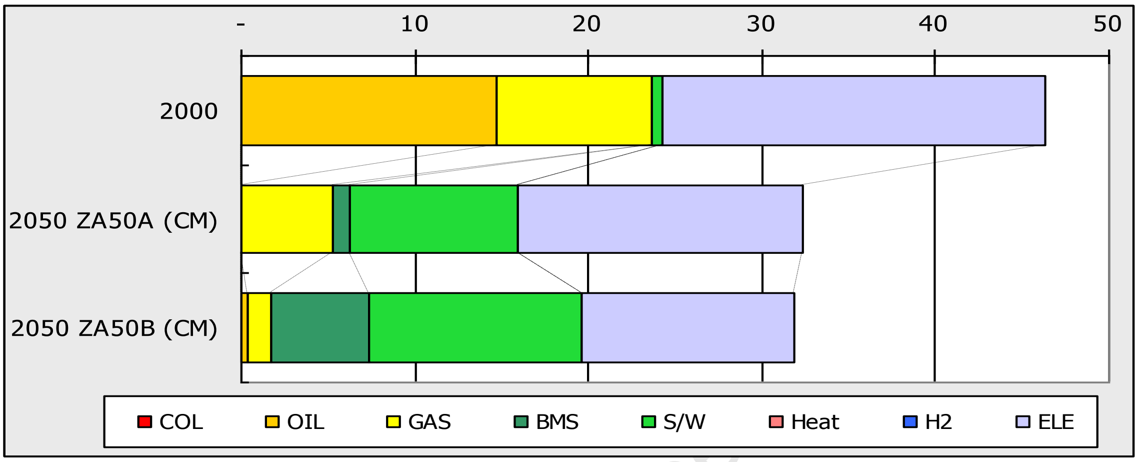
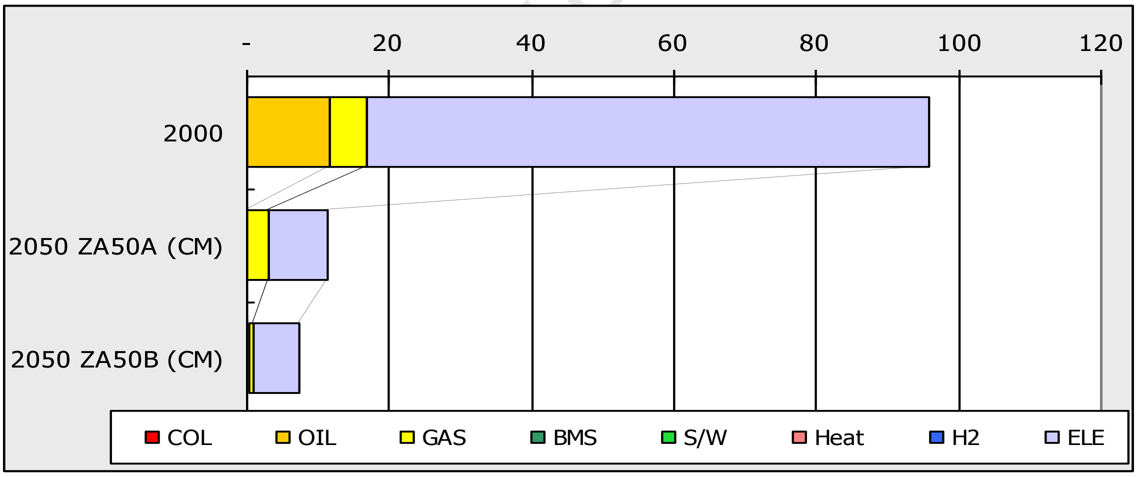
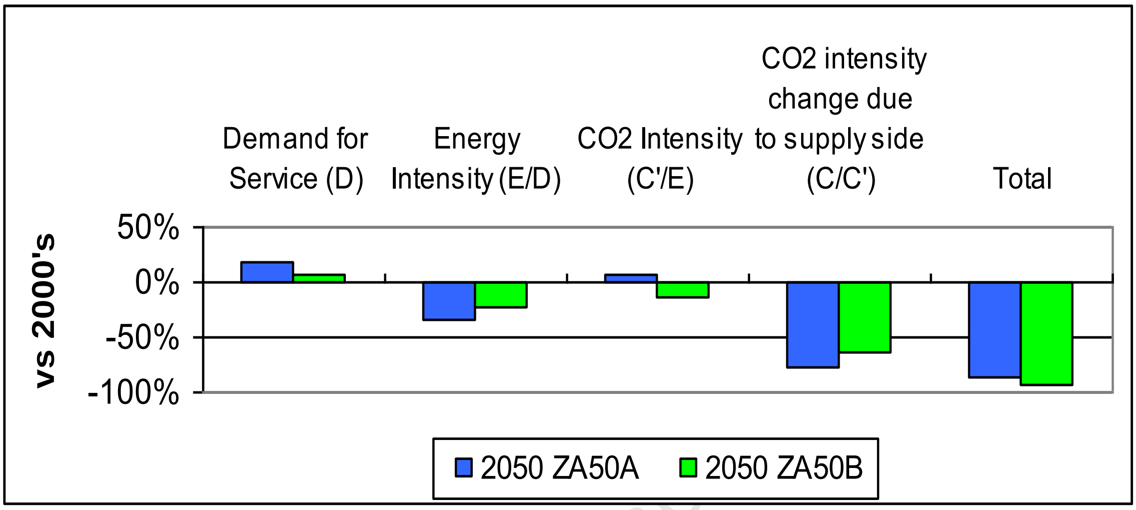


Figure 6.8: Commercial CO_2 emissions (base year and 2050 LCS scenarios)



In the commercial sector, changes in service demand result in an increase in D for both scenarios (Figure 6.9). D for scenario ZA50A increases more significantly due to an assumed steady increase in commercial space, related to steady economic growth. Even though service demand also increases in scenario ZA50B, D is much lower due to stagnant economic growth. Changes in energy intensity (E/D) are larger in ZA50A, mainly due to high savings per square meter. However, ZA50B performs better in terms of changes in carbon intensity due to minimum requirements for commercial space, as compared to ZA50A. Changes in carbon intensity due to transformation measures (C/C') is once again related to a higher share of nuclear power and CCS, resulting in the biggest contributions to total CO_2 reductions in the commercial sector.

Figure 6.9: Commercial factor analysis of $C0_2$ emissions



6.1.4 Passenger transport energy and emissions analysis

In the base year, oil consumption dominates energy consumption in the passenger transport sector (Figure 6.10). In the base year, total energy consumption amounts to 7.84 Mtoe, with oil contributing just over 64% to the total. With LCS action mitigation options, this energy consumption is reduced to 3.79 Mtoe for ZA50A and 3.47 Mtoe for ZA50B. A number of measures, such as improving road efficiency, imposing tax on large vehicles, barring cars from entering major city centers all contribute to reduced energy consumption. Penetration of electric vehicle also contributes moderately to oil displacement. Introducing second generation fuels such as biofuels and hydrogen will also contribute towards oil displacement.

In the passenger transport sector, emissions from the base year are reduced from 6.63 $MtCO_2$-eq to 2.54 $MtCO_2$-eq for scenario ZA50A and 2.37 $MtCO_2$-eq for scenario ZA50B (Figure 6.11). The introduction of second generation fuels and the creation of pedestrian friendly cities in scenario ZA50B will contribute to lower emissions, coupled with lower economic growth rate.

Supply-side mitigation options, such as carbon capture and storage for synfuels, have a significant impact on emission reduction in both scenarios. However, oil displacement by improving road efficiency, moving towards diesel, moving towards smaller cars and improving public transport has a significant impact on reducing oil consumption (60% for scenario ZA50A and 67% for scenario ZA50B).

Figure 6.10: Passenger transport energy consumption (base year and 2050 LCS scenarios)

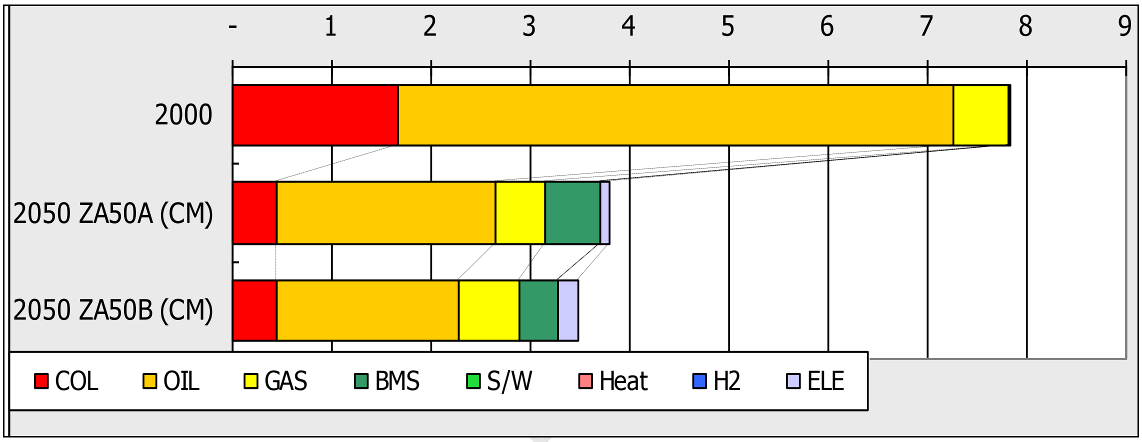
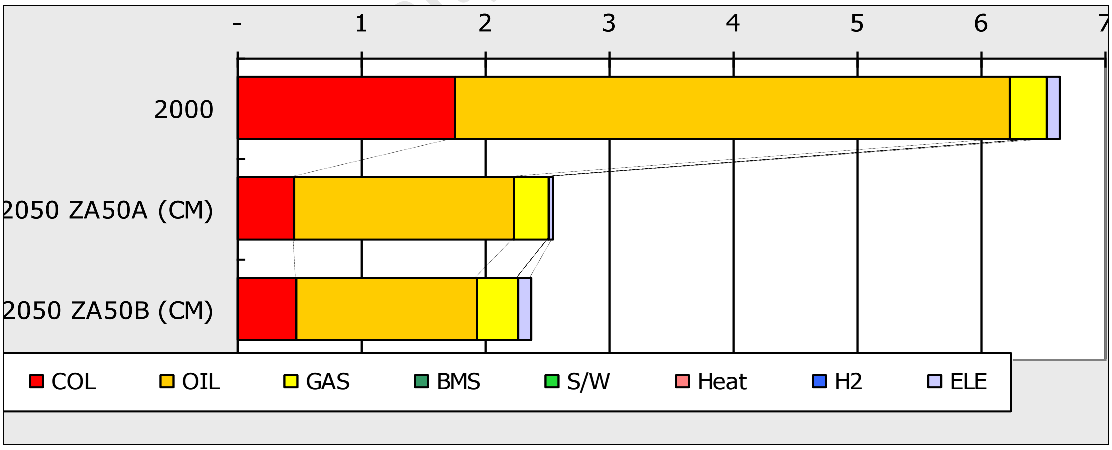
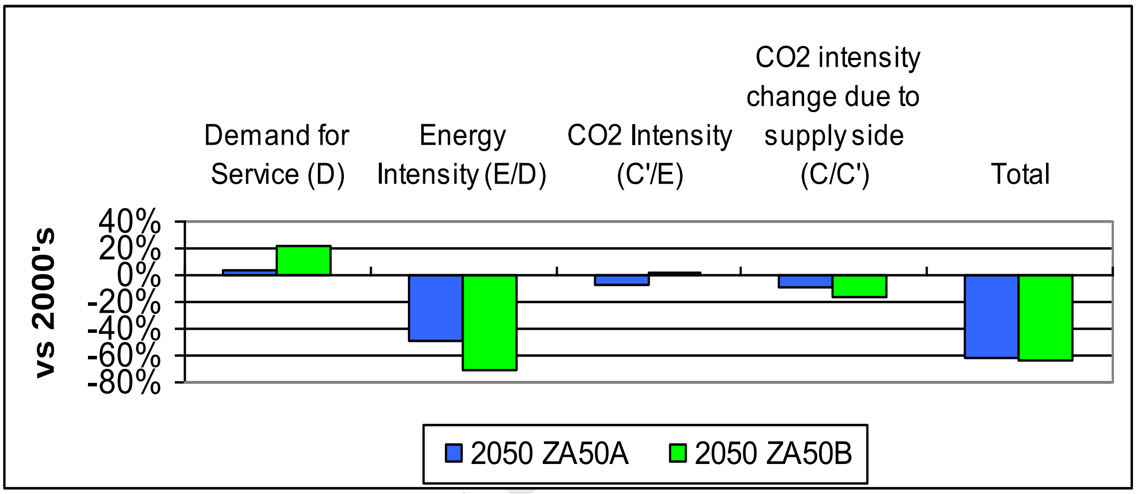


Figure 6.11: Passenger transport CO_2 emissions (base year and 2050 LCS scenarios)



Changes in service demand for passenger transport result in an increase in D for scenario ZA50B due to the availability of second generation fuels (Figure 6.12). Energy intensity changes (E/D) for scenario ZA50B are larger due to a move towards pedestrian friendly cities. Energy intensity changes for ZA50A can be attributed to a shift in transport mode. In terms of carbon intensity changes (C'/E), ZA50A performs better due to demand-side LCS actions, such as modal shift and road efficiency. This sector differs from others in that supply-side changes do not contribute most to the total, but to a reduction in energy intensity. This can be attributed to the reduced electricity contribution to passenger transport related LCS actions in both scenarios. However, the introduction of second generation fuels such as biofuels and hydrogen results in higher carbon intensity changes (C/C') due to supply-side mitigation options for scenario ZA50B.

Figure 6.12: Passenger transport factor analysis of CO_2 emissions



6.1.5 Freight transport energy and emissions analysis

Energy consumption in the passenger transportation sector decreases moderately from 13.4 Mtoe in the base year to 11.2 Mtoe by 2050 for scenario ZA50A and 9.74 Mtoe for scenario ZA50B (Figure 6.13). Scenario ZA50A uses a significant amount of electricity due to a road transport shift to rail (30% shift by 2050). Due to slow economic growth in scenario ZA50B, energy consumption is also lower than that of scenario ZA50A. Under scenario ZA50B, small road freight vehicles also use electricity to move within cities.

LCS measures contribute moderately to emission reductions for the freight transport sector (Figure 6.14). Base year emissions of 13.4 $MtCO_2$-eq are reduced to 11.2 $MtCO_2$-eq by 2050 for scenario ZA50A and 9.74 $MtCO_2$-eq for scenario ZA50B. Minor carbon emission savings for scenario ZA50A can be largely explained by the steady economic growth for scenario ZA50A. Oil dependence is reduced through improved supply chain management as well as improved transport logistics. Shifting from road to rail also contributes moderately to the reduction of oil dependence. In addition, road to pipeline transport powered by electricity also reduces oil dependence by 10%. Supply-side mitigation options such as carbon capture and storage for both synfuels as well as electricity generation also play a role.

Figure 6.13: Freight transport energy consumption (base year and 2050 LCS scenarios)

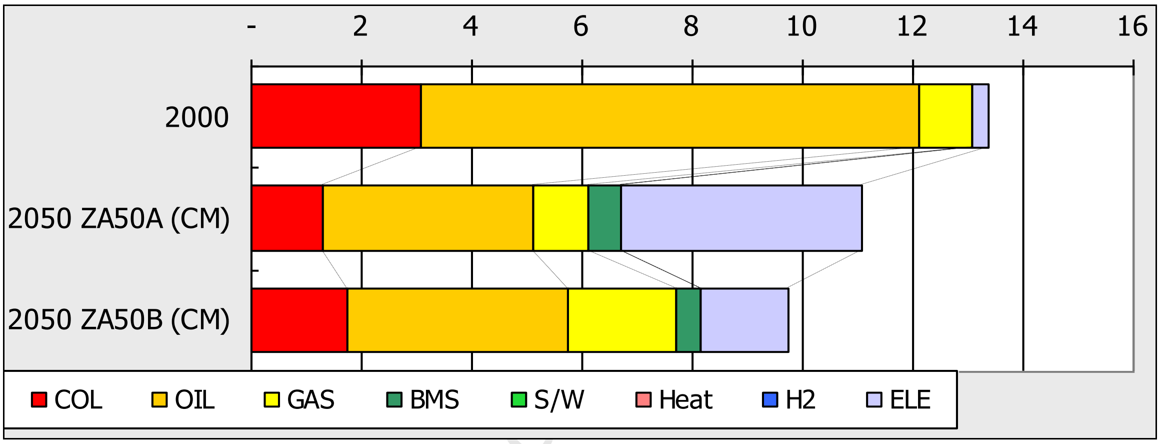
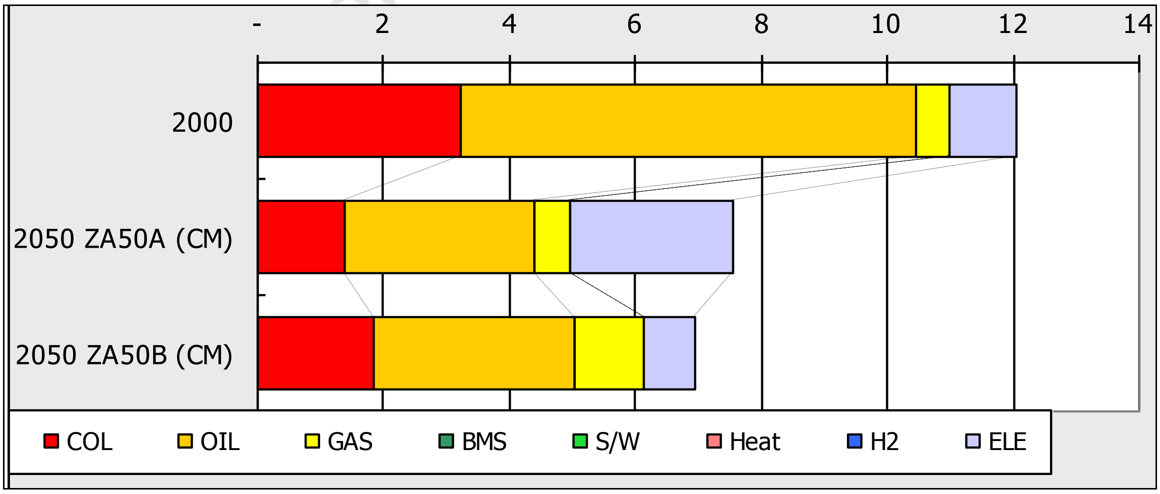
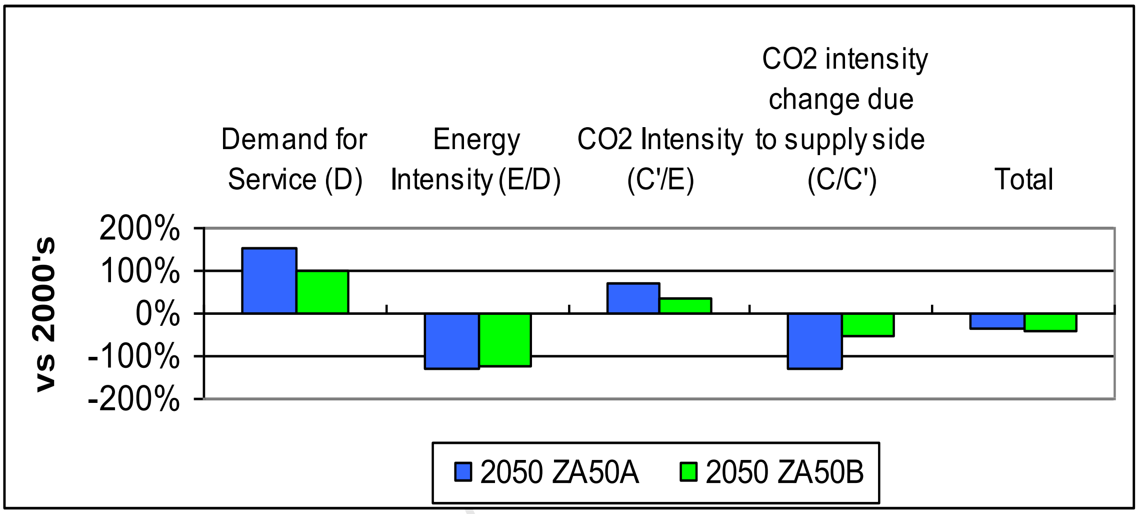


Figure 6.14: Freight transport CO_2 emissions (base year and 2050 LCS scenarios)



As shown in Figure 6.15, an analysis of service demand changes (D) shows an increase in both LCS scenarios, with ZA50A showing a higher demand growth (150%). However, energy intensity changes (E/D) are observed to be higher in scenario ZA50A due to improved freight transport logistics. As for passenger transport, energy intensity is the biggest factor. In the case of ZA50B, changes in E/D are due to the production and consumption of localized goods and services as well as lower economic growth (1%). Carbon intensity changes (C'/E) also show higher increases for scenario ZA50A due to consistent economic growth. An increased share of gas for liquid fuels production results in reduced carbon intensity (C/C') for scenario ZA50A.

Figure 6.15: Freight transport factor analysis of $C0_2$ emissions



6.1.6 Power generation analysis

As shown in Figure 6.16 and Figure 6.17, in the base year, energy supply for power generation is dominated by coal at 14.9 Mtoe (92.5%) with a small contribution of 0.9 Mtoe (5.7%) by nuclear. As consistent economic growth is assumed in scenario ZA50A, energy consumption for power generation increases by 441% (71 Mtoe) by 2050. For scenario ZA50B, energy consumption for power generation increases by 270% (43 Mtoe). Nuclear (50%) dominates scenario ZA50A, whereas renewable energy sources dominate scenario ZA50B (40%). In addition, adoption of waste minimization principles ensures that the share of biomass for scenario ZA50B equals 5%. In both scenarios, contribution from coal is kept at a minimum of 20%. This is based on an assumption that there no more coal-fired power generation plants will be built after Kusile and Medupi and that most of the current coal power stations will have well exceeded their life expectancy. Scenario ZA50A uses conventional nuclear technologies, whereas scenario ZA50B focuses on pebble-bed modular reactor (PBMR) technology, as security of power under this scenario focuses on local (municipal level) needs as opposed to national power needs.

Figure 6.16: Primary energy consumption for power generation (base year and 2050 LCS scenarios)

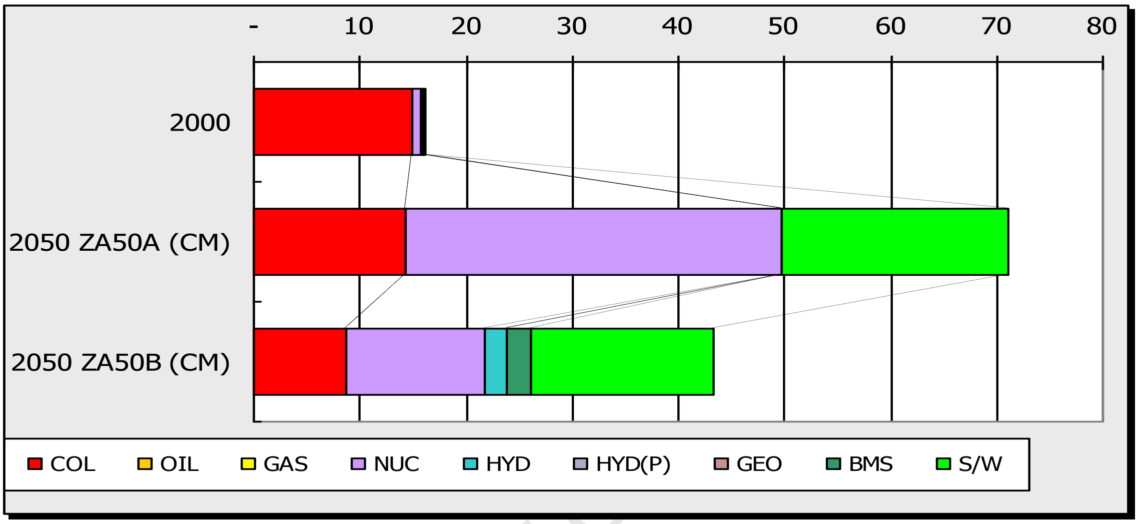
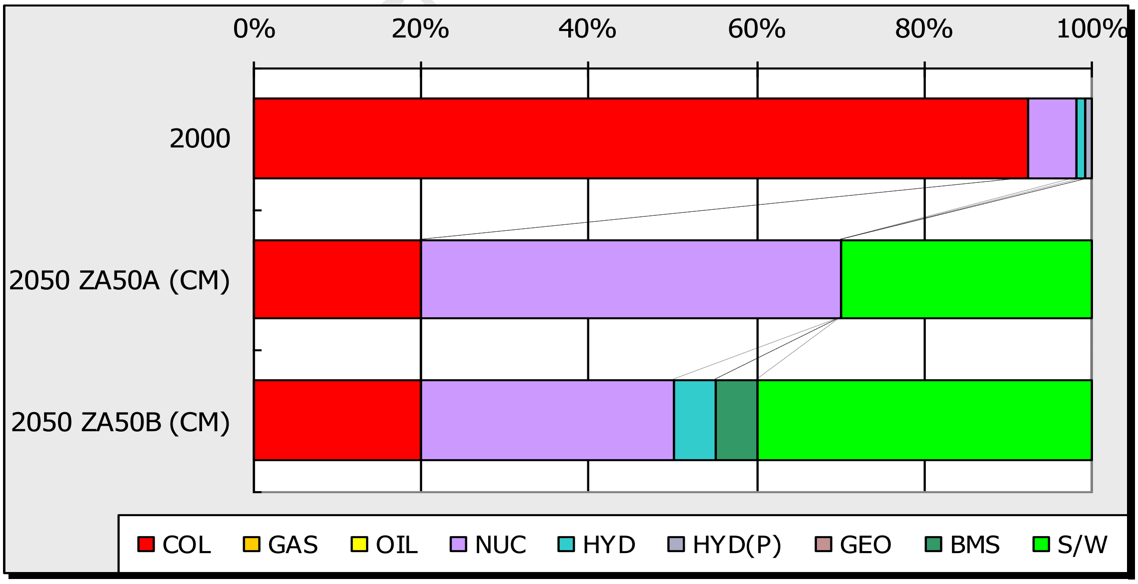


Figure 6.17: Energy mix for power generation (base year and 2050 LCS scenarios)

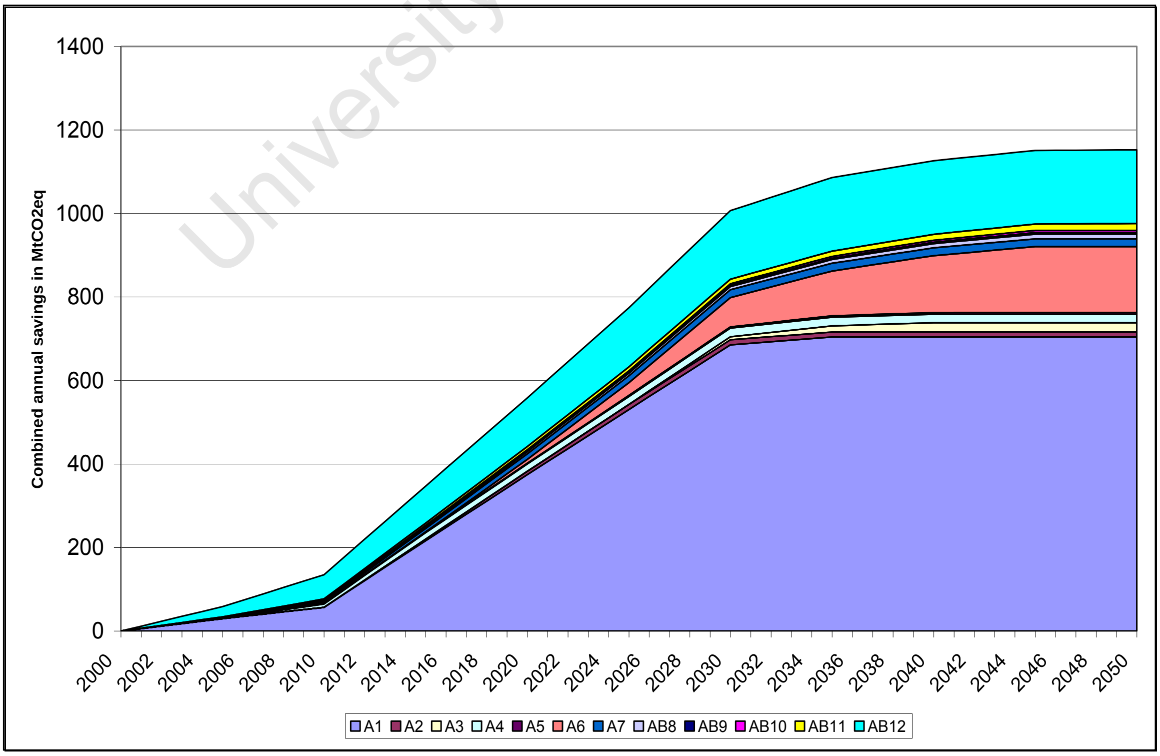


6.2 *Overall LCS scenario emission reduction assessment*

6.2.1 Overall emission reduction for scenario ZA50A

Figure 6.18 shows the combined emission savings of scenario 2050A, after implementation of the dozen of actions (12 LCS actions), in $MtCO_2$-eq across the study time horizon (2000-2050) relative to the base year of 2000. In total, 1152 $MtCO_2$-eq will be saved by 2050 with 61% of savings coming from the LCS action "Clean electricity generation" followed by "Climate conscious manufacturing" at 15% and "Cleaner vehicle fuels" at 14%. Other LCS actions of note for scenario ZA50A are "Cleaner synfuels production" (2%), "Climate sensitive transport" (1.8%) and "Transport modal shift" at 1.6%. The LCS action that yields the lowest results is "Greener settlements and structures" at 0.3% (3.78 $MtCO_2$-eq). Furthermore, it seems that emission savings reach the 1000 $MtCO_2$-eq (1006 $MtCO_2$-eq) savings mark by 2030, gradually settling at 1152 $MtCO_2$-eq in 2050 (13% increase between 2030 and 2050).

Figure 6.18: Overall emission reduction for LCS Scenario ZA50A dozen of actions

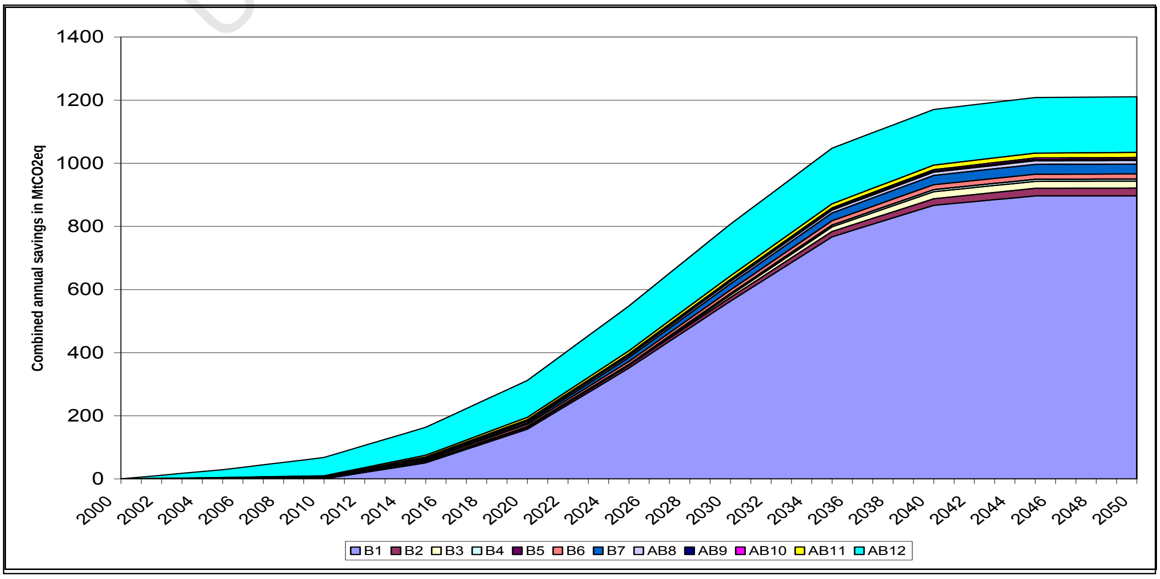


6.2.2 Overall emission reduction for scenario ZA50B

Figure 6.19 shows the combined emissions savings for LCS scenario ZA50B. Emissions savings by 2050 reach a total amount of 1210 MtCO2-eq relative to the base year of 2000. LCS action savings are dominated by the action "Low-carbon electricity generation" at 74%, followed by "Climate conscious manufacturing" (common to both ZA50A and ZA50B scenarios) at 14%. Other LCS actions under this scenario that moderate CO_2emissions savings are "Second generation fuels" (2.6%), "Pedestrian friendly urban city design" (2.1%), "Climate sensitive commercial sector" (1.4%) and "Cleaner process heating" at 1.3%. The LCS action with the lowest savings is "Greener settlements and structures" at 0.32%. This action is also common to both scenarios.

For scenario ZA50B, the 1000 $MtCO_2$-eq savings mark is passed as late as 2035 (1047$MtCO_2$-eq), where after it gradually stabilises at 1210 $MtCO_2$-eq by 2050. This is equivalent to an emissions savings increase of 13.5% during this 15-year period. Also, the BCM savings results for LCS action B1 ("Low carbon electricity generation") appear to be smoother than those from ZA50A. This is because of continued infrastructure development for power generation technologies using biomass as well as hydro.

Figure 6.19: Overall emission reduction for LCS Scenario ZA50B dozen of actions

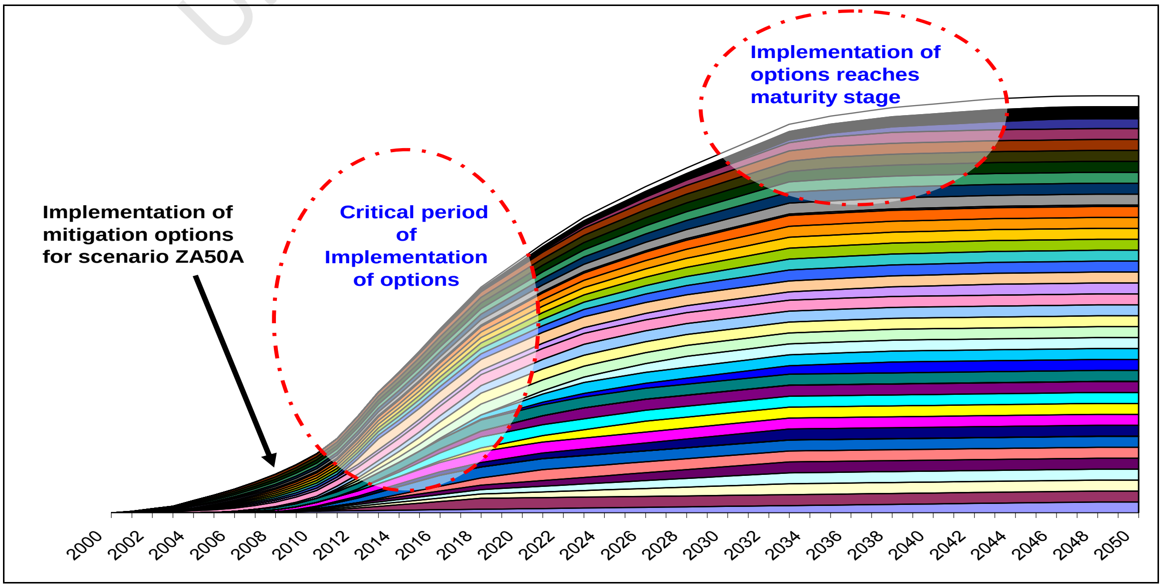


6.3 Penetration rates of LCS scenario actions

6.3.1 Penetration rates for scenario ZA50A

Figure 6.20 shows the implementation of all mitigation options for scenario ZA50A expressed as a function of time and penetration rates (0 to 1). A penetration rate of 1 implies that the mitigation option is fully implemented. These penetration rates are independently enumerated by the BCM. This assessment shows that the critical period for implementation of most options lies between 2010 and 2020. This decadal period has a high rate of emissions savings (76%), followed by the decadal period (2020-2030), where the rate of emissions savings increases to 44%.In addition, 2010-2020 is the period when public-private partnerships need to be formed, feed-in tariffs implemented, piloting of technologies undertaken, manufacturing capacity developed, legislation developed and policy targets clarified and achieved, subsidies developed, tested and implemented. As time progresses, and as long as all the options are implemented efficiently at the critical period stage, the implementation of options eventually reaches maturity between 2030 and 2045. This period has an emissions savings increase rate of only 12.5%. Hence, any details in the implementation will result in delays in meeting ZA50A visions.

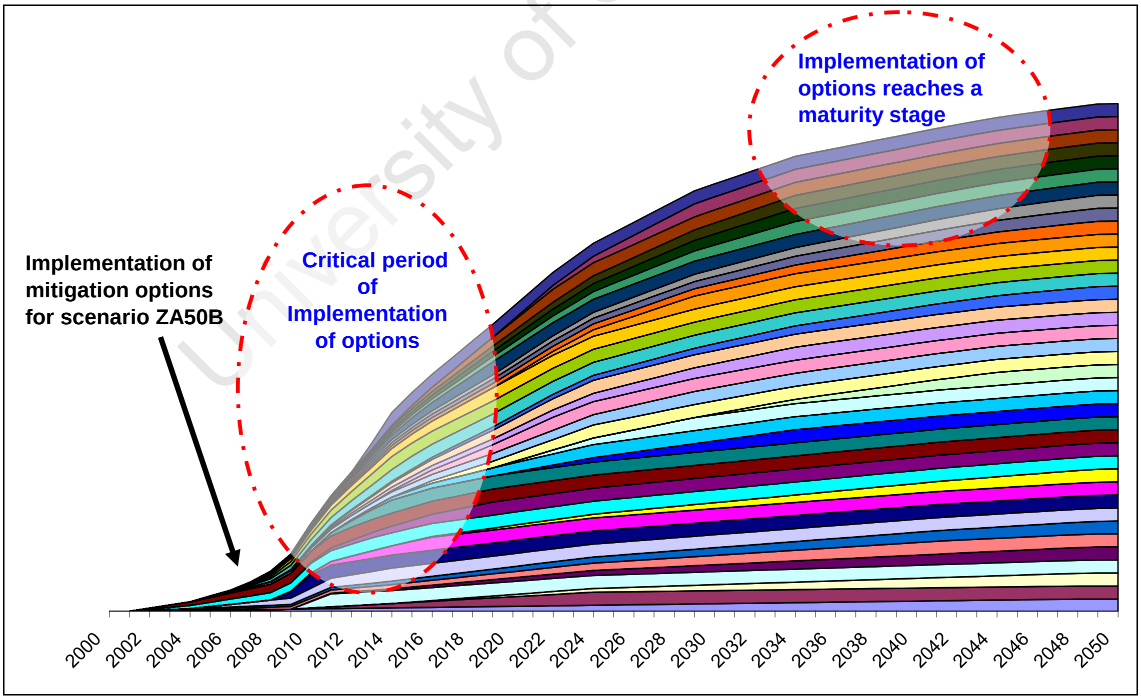
Figure 6.20: Penetration rates of scenario ZA50A options as modelled by the BCM model



6.3.2 Penetration rates for scenario ZA50B

The implementation of mitigation options for scenario ZA50B shows a similar trend as that of scenario ZA50A (Figure 6.21). However, the critical period of implementation for scenario ZA50A LCS options is slightly different (2008-2018). During this period, the emissions savings increase rate is the highest at 79%. Similarly to scenario ZA50A, this period also happens to be the period during which all the foundation work needs to be undertaken, such as public-private partnerships, technical capacity building, awareness drives, development of regulations and subsidies. Maturity is reached slightly later than with scenario ZA50A. Between 2035 and 2045, the emissions savings increase rate is as low as 13%. This is largely attributed to the fact that some significant actions, such as the introduction of second generation fuels which require massive infrastructure development, only comes in after 2030.

Figure 6.21: Penetration rates of scenario ZA50B options as modelled by the BCM model



CHAPTER 7

7 Discussion and interpretation of results

This study has demonstrated how targets might be set and achieved under different low carbon pathways. Emission reduction goals for 2050 relative to 2000 levels for South Africa are estimated to be 65%. This is comparable to studies done in other countries (see Table 7.1). In the South African and Japan contexts, the emission reduction goals are based on the same theoretical basis. In other countries listed in Table 7.1, the goals are based on pledges to curb CO_2 emissions by 2050. In the South African context, furthermore, it is particularly encouraging that scenario ZA50B, which places a greater emphasis on behavioural change, can potentially reduce emissions by up to 72% relative to 2000 levels. The more technology driven scenario (ZA50A) would only be able to realise 66%.

Therefore, a target of 65% is chosen as a conservative value, whilst the target value for scenario ZA50B could be interpreted as an ambitious emission reduction value that might nonetheless be achieved by 2050. Based on the scenario analysis in Chapter 4, Figure 4.9 clearly demonstrates that such emission reduction goals can only be achieved by paying attention to the industrial and commercial sectors and, to a lesser extent, to the transport sector. Education of consumers on low-carbon goods and services also plays a key role, not only in the residential sector, but also across all end-use sectors.

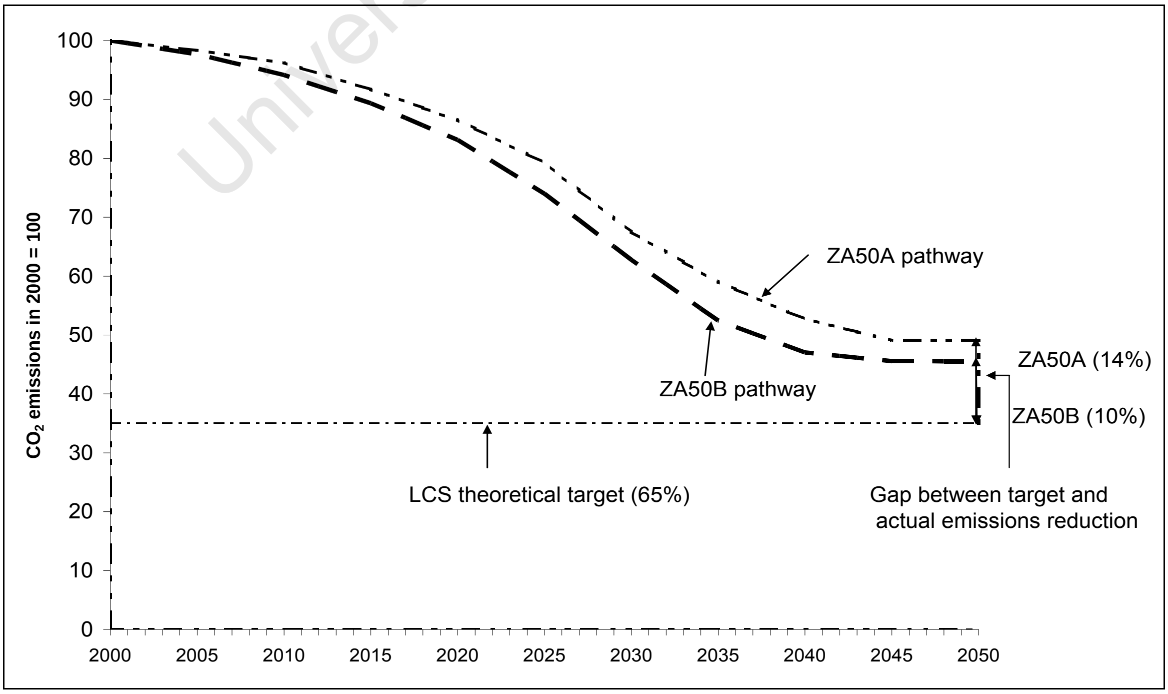
Table 7.1: Long-term emission reduction targets

Name of Country/State	Period of study	Emission Reduction Target	Source
California	60 years	80% relative to 1900 levels	Shimada et al. 2007
Germany	30 years	40% relative to 1990 levels	Erdmenger et al. 2009
Japan	60 years	70% relative	CGER 2007

		to 1990 levels	
New Mexico	50 years	75% relative to 2000 levels	Shimada et al. 2007
South Africa	50 years	65% relative to 2000 levels	This study
United Kingdom	60 years	60% relative to 1990 levels	Mander et al. 2008

The BCM enables the impacts associated with the LCS scenario actions to be visualised. Essentially, it starts with the emission reduction visions presented in 2050, backcasting these to the present (2000) in 5 year increments. Figure 7.1 illustrates the results of the comparison between emission reduction achieved using the BCM model against the theoretical savings shown in Table 7.1. In both LCS scenario pathways (ZA50A and ZA50B), the emission reduction savings fall short of the theoretical target (65%) by 2050. In the case of ZA50A, the gap between the actual savings and the theoretical target is about 14%, whilst in the case of ZA50B the gap is 10%. Across the period of study, ZA50B performs better than ZA50A.

Figure 7.1: Reduction in emissions relative to 2000 levels



In the residential sector, emissions are mainly attributed to the use of electricity for space heating, cooking, water heating and general household appliances. Therefore, the residential sector would benefit from supply-side measures such as carbon capture and storage as well as the use of cleaner fuels. However, demand-side measures such as SWHs, consumer awareness on low-carbon practices, goods and services as well as energy efficiency are critical. Figure 6.2 clearly demonstrates the emission reductions that can be achieved in the residential sector for both scenarios. An 86% emission reduction for scenario ZA50A and 90% for scenario ZA50B can be attributed to switching fuels for cooking, water heating and space heating as well as implementing supply-side measures.

On the demand side, the industrial sector not only produces the most CO_2 emissions in the base year, but it also has the most potential for reducing such emissions. Figure 6.5 shows that the industrial sector emissions can be reduced from 207 $MtCO_2$-eq in the base year to 87 $MtCO_2$-eq for scenario ZA50A and 77 $MtCO_2$-eq for scenario ZA50B. The main contributing factors would be reductions in electricity and oil consumption. These emission savings depend largely on a visible and large scale energy efficiency campaign that is well funded, maintained and monitored.

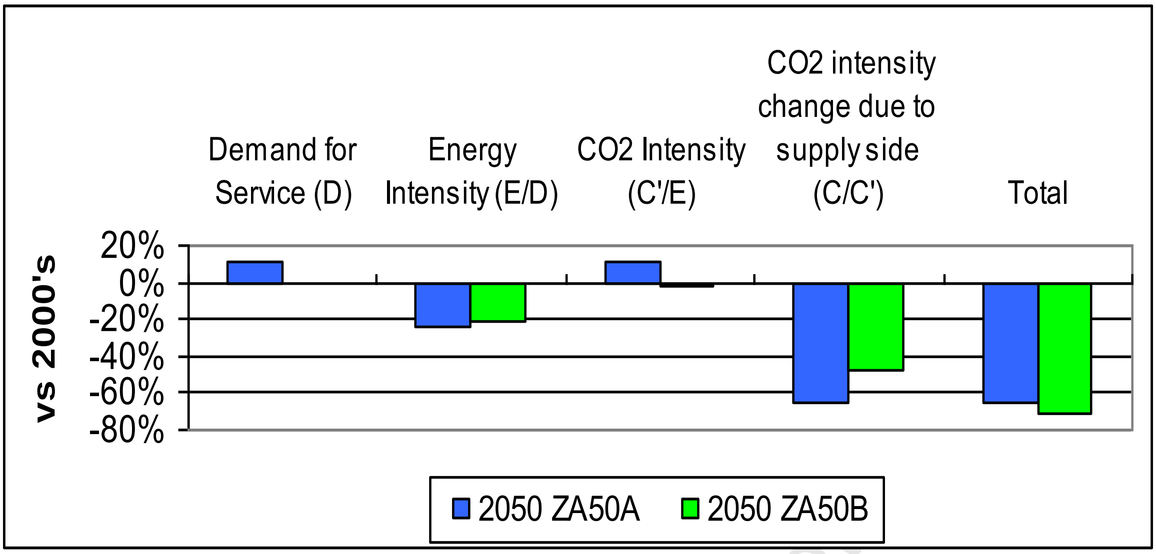
In the commercial sector, thermal efficiency as well as demand-side measures such as carbon capture and storage will result in significant emission reduction. Figure 6.8 shows how emissions could be reduced from 96 $MtCO_2$-eq to 11 $MtCO_2$-eq for scenario ZA50A and 7 $MtCO_2$-eq for scenario ZA50B. Savings for scenario ZA50A are relatively less than savings in scenario ZA50B due to demand for commercial space.

A combination of supply-side and demand-side measures, including economic conditions, all contribute to emissions saving in the passenger transport sector. As observed from Figure 6.11, emissions can be reduced from 6.63 $MtCO_2$-eq to 2.54 $MtCO_2$-eq for scenario ZA50A and 2.37 $MtCO_2$-eq for scenario ZA50B. The largest impact will be made by displacing oil by improving road efficiency, moving towards diesel, using smaller cars and improving public transport, and thus reducing oil consumption dramatically (60% for scenario ZA50A and 67% for scenario ZA50B).

Compared to other end-use sectors, LCS measures contribute only moderately to emission reductions for the freight transport sector. This is clearly illustrated by Figure 6.14 where the base year emissions (13.4 $MtCO_2$-eq) can be reduced to 11.2 $MtCO_2$-eq by 2050 for scenario ZA50A and 9.74 $MtCO_2$-eq for scenario ZA50B. For scenario ZA50A, this can be attributed to assumed steady economic growth, which offsets some of the emission gains. For scenario ZA50B, it is mostly the demand-side measures, such as improved supply chain management and improved transport logistics, which would reduce dependency on oil.

Figure 7.2 shows a factor analysis of CO_2 emissions in 2050 and 2000 for both LCS scenarios (ZA50A and ZA50B). An increase in demand for commercial space and a constant increase in GDP all contribute to an increase in service demand changes (D) for LCS scenario ZA50A. For scenario ZA50B, (D) does not change due an assumed constant GDP. Energy efficiency measures in mainly the industrial and commercial sectors help reduce energy intensity (E/D) in both scenarios. Introduction of renewable energies for end-use applications, such as solar water heating, and increased use of electricity, largely due to extended electrification drives, all contribute to reducing carbon intensity (C/E') in the residential sector in scenario ZA50B. A slight increase for C/E' in scenario ZA50A can be attributed to consistent economic growth. Also, the reduction in C/C' is larger in ZA50A due to the high share of nuclear coupled with the use of carbon capture and storage for synfuels and coal-based power generation. In total, scenario ZA50B performs slightly better than scenario ZA50A, largely due to its lower energy intensity and, to a lesser extent, its reduced carbon intensity. The biggest factor overall is reduced carbon intensity in the power supply, where C/C' dominates. However, in the transport sector, the influence of C/C' is minimal due to assumed low penetration rates of electric vehicles and second generation fuels such as biomass and hydrogen powered cars.

Figure 7.2: Total mitigation factor analysis for LCS scenarios ZA50A and ZA50B



For the technology driven LCS scenario ZA50A, major savings come from the LCS action termed “Cleaner electricity generation” with a 61% contribution. This calls for a drastic change in the current energy mix for power generation, with nuclear energy (50%) and renewable energy (30%) playing a pivotal role. With “Climate conscious manufacturing” resulting in an additional 15% savings, a visible and well maintained energy efficiency programme backed by a partnership between government and the private sector is needed. Other important LCS actions for scenario ZA50A are “Cleaner vehicle fuels” and “Cleaner synfuels production”.

LCS scenario ZA50B, which is focused more on behavioural change, results in emissions savings that are 5% greater than in scenario ZA50A. The most significant savings in ZA50B occur in respect of the power supply, totalling 74% savings through the implementation of LCS action “Low-carbon electricity generation”. In this case, there is a strong emphasis on renewable energy (40%) and nuclear energy (30%). Again, climate conscious manufacturing, which is common to both scenarios, comes second at 14% and the introduction of “Second generation fuels” takes third place (2.6%).

As observed from Figure 6.20, evidence from the penetration of LCS options shows that the critical period of implementation for scenario ZA50A is between 2010 and 2020. This period will result in the highest rate of savings at 76%. This period is also critical for the implementation of mitigation options aimed at addressing obstacles to the implementation of LCS actions. Key mitigation options that need to be implemented include public-private partnerships, feed-in tariffs, legislation, policy targets, manufacturing capacity and general consumer awareness. In the case of scenario ZA50B (see Figure 6.21), the critical period of implementation lies between 2008 and 2018 with a savings rate of 79%. In case of scenario ZA50A, maturity of implementation is reached sometime between 2030 and 2045. This is when the implementation rate is at its lowest at 12.5%. For the ZA50B pathway, the maturity of implementation is later (2035-2045 at 13%), as some LCS actions would only be implemented after 2030.

7.1 Limitations of this study

The quality of the analysis conducted here depends largely on the accuracy of the national energy balances. However, as has been demonstrated elsewhere, the South African energy balances are inaccurate and need to be improved. For instance, the results of the third national GHG inventory for the year 2000 showed a difference of 27% in computed emissions between the reference approach (using energy balances) and the sectoral approach (DEAT 2009). This difference is much higher than the accepted difference of 2%. Therefore, this study encourages the DME not only to improve on the latest energy balances but also to review previous energy balances for consistency and accuracy.

In addition, the LCS modelling framework using the ESS as well BCM modelling tools does not take into account non-energy emissions. Even though the national GHG inventory shows that non-energy emissions have a minimal contribution towards the national total, their contribution, particularly in respect of emissions from industrial processes, may increase in the future with improved economic growth.

This study has not attempted to do an integrated technology/economic-wide cost benefit analysis which would have immensely benefitted the findings of this study. However, an earlier study called the Long-term Mitigation Scenarios (LTMS) has to a greater degree addressed this void even though it never attempted to assess behavioural change aspects. Hence, these two studies can complement each other in this regard.

The BCM model which is at the heart of this study employs a Linear programming methodology to assess all LCS options. This limits the reach and application of this study as external effects and/or feedbacks from other domestic or global actions are not factored in.

The linear programming approach also makes it difficult to conduct a sensitivity analysis in cases where some options are not implemented fully and therefore implemented at fraction of their baseline mitigation potential. Future modifications to the BCM model will have to take this limitation into account.

Furthermore, a study of this nature requires multi-stakeholder involvement to enrich the content and obtain buy-in from those involved. Therefore, this study recommends that for a fully fledged LCS analysis, a multi-stakeholder team must be assembled.

CHAPTER 8

8 Conclusions and recommendations

This study has shown that it is possible to follow a developmental pathway that focuses on behavioural change and that is less carbon-intensive whilst still allowing people to enjoy a comfortable standard of living. The analysis conducted here shows that it is possible to set a reasonable long-term emission reduction goal of 65% relative to 2000 levels by 2050. It was shown that this goal is comparable with those that have been set elsewhere in the world, as argued in Chapter 7. In addition, this assessment will help to inform South Africa on the emission reduction targets that it can agree to as a developing country. Results from the factor analysis shows that major gains in a transition towards a low carbon society are concentrated in the power supply sector and in the industrial sector. However, the results also show that LCS actions aimed at changing behaviour are important too, and that they should not be ignored, particularly for the residential and transport energy service demand sectors.

Furthermore, this assessment may also encourage other developing countries to assess their emission reduction goals carefully and in an informed way without compromising their country's development. However, the study has also shown that such a goal may not be attained even if the best LCS developmental path is followed (ZA50B pathway). This pathway falls short of the goal by 10%. A technology driven developmental pathway can also reduce emissions, even though it also falls short of the goal by 14%.

Decoupling carbon from growth emerged from the analysis of carbon decomposition for all end-use sectors. As such, a factor analysis has shown that, in all end-use sectors, a combination of supply-side and demand-side LCS interventions can reduce emissions. The power supply sector has the highest potential, with supply-side measures such as carbon capture and storage and the use of a cleaner energy mix for electricity generation. Based on the analysis of LCS actions, the study concludes that more attention needs to be paid to altering the energy mix for power generation, making local manufacturing more climate conscious, changing passenger and freight-transport to transport that is greener, and making the commercial sector more climate sensitive.

It is also evident from this study that the implementation is urgent. In both LCS pathways studied, the next ten years (2010-2020), which is termed the "critical period of implementation" sets the tone for whether South Africa reaches its theoretical emission reduction goal or not. Delaying a transition to a LCS will result in a decade or two of delay in achieving the target. Furthermore, as is shown in this study, implementation of LCS actions requires mitigation options to overcome any obstacles that may be encountered. Such obstacles include technological challenges, infrastructure, social systems and governance, as well as environmental awareness or mindsets. Mitigation actions should include tools, such as LCS friendly legislation, awareness campaigns, capacity building, public-private partnerships, and technical capacity development and market reforms. Based on the greater reductions achieved in the behaviour-orientated scenario, this study concludes that the success of becoming a low carbon society lies in consumer education in respect of low carbon services and goods. Also, government involvement in the early stages of implementation will prove vital. This is most evident where government would have to clarify the nuclear waste policy and the licensing of new nuclear reactors. It is also evident from this study that the LCS developmental pathway, which is sensitive to behavioural change, is less energy intensive than the technology driven pathway. Therefore, this study concludes that the society under a behavioural change sensitive pathway is likely to be more resilient to external shocks (e.g. weather patterns) caused by climate change that threaten energy availability.

The creation of a low carbon society is not only about mitigating climate change but also a way of life. As was shown in Chapter 5 in respect of LCS scenario ZA50B, sustaining LCS implementation requires continuous education of society about low carbon lifestyles. As such, this study encourages the government to seriously consider a LCS-based implementation agenda.

Appendices

Appendix A: Quantity and Impacts as applied in the BCM model

Quantity and Impacts: Energy Efficiency

Example: Implementation of ceilings in households

Energy efficiency QI in the BCM model requires energy efficiency target in the final year (67%) as well as the number of years for the implementation of ceilings in households (40 years)

Therefore, efficiency change = 0.67 *40

Quantity and Impacts: Fuel Shift

Example: Replacing biomass with electricity for space heating
Total space heating requirements in base year = 3.8 Mtoe

Standardization way: Max Quantity is always 1
Max Quantity = 1
Fuel Consumption Change (Biomass) = -3.8*50/1
Fuel Consumption Change (Electricity) = 3.8*50/1

Quantity & Impact: Period Shorten

Example: Regulations to limit private cars within cities

11 years are required to penetrate pedestrian-friendly modes of transport (e.g. bicycles) within cities,
But governments introduces regulations to increase the penetration of pedestrian friendly modes of transport within cities and this shortens the time

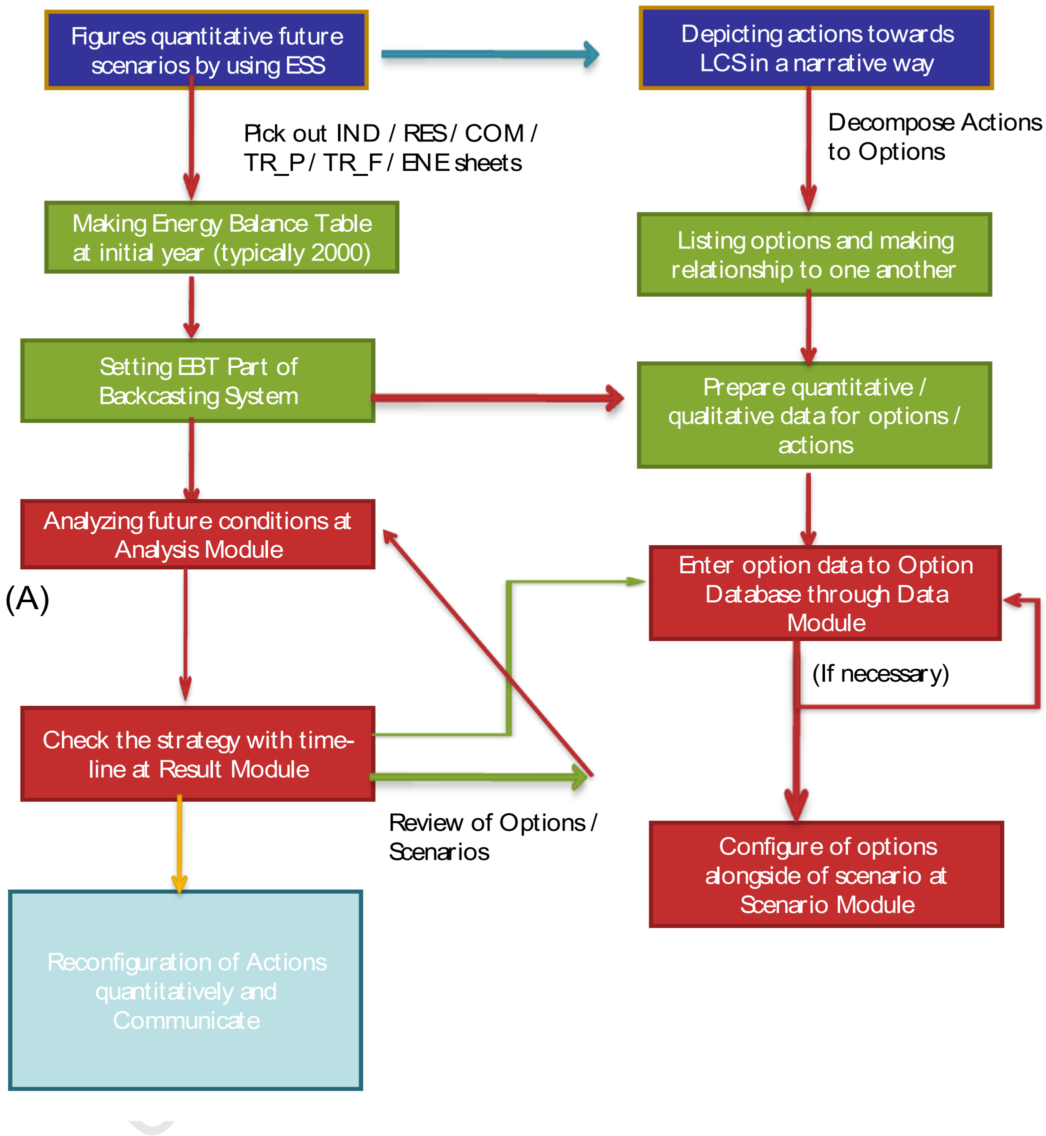
required to achieve full penetration of pedestrian friendly modes of transport by 4 years ($y<x$)

Standardization way: Max Quantity is always 1

Max Quantity = 1

Period shorten in this case = x-y = 30 – 4 = 29 years

Appendix B: Procedure for the Backcasting model (BCM)



Appendix C: Keywords for South Africa's LCS scenarios

Keyword	Scenario ZA50A	Scenario ZA50B
Mindset		
Life purpose	• Individual success	• Social contribution
Residence	• Urban orientation	• Rural orientation
Family	• Independent household	• Cohabitation
Technology inclination	• Vigorous	• circumspect
Population		•
Receipt of foreign workers	• Positive	• As is currently
Emigration	• Increase	• As is currently
Land use and cities		•
Migration	• Focused in large cities	• Decentralization
Urban environments	• High concentration in central business districts • Increase in land use in urban areas	• Decline in urban population • Sluggish city expansion
Rural areas	• Significant decrease in rural population	• Slow population decrease • Small town development
Lifestyle & Household		•
Work	• Number of highly qualified professionals increases • Income levels improved but employees overworked	• Work shared equally • Income levels improves gradually
Free time	• Career development	• Time spent with family
Housing	• Complex-type of housing	• Single stand type of housing
Consumption	• Fast replacement rates of commodities	• Maintenance and proper operation of commodities results in lifetime cycles
Economy		•
Growth rate	• Per capita GDP growth rate: 2%	• Per capita growth rate: 1%
Technology development	• Rapid	• Not as rapid as in scenario ZA50A
Industry		•
Market	• Deregulated	• Fare degree of regulation
Primary Industry	• Dependent on imports	• Recovery of GDP share • Investment in agriculture and forestry
Secondary Industry	• Increase in added value • Production facilities moved to countries where labour costs are low	• Declining GDP share • High-mix, low volume production with local brands
Tertiary Industry	• Increase in GDP share • Improved productivity	• Gradual increase in GDP share • Increase in social activities

Appendix D: Statistics and reports used for the model data processing

Liquid fuels

South Africa's liquid fuel supply is unique in that around 27% is produced as synfules, mainly from coal-to-liquids but also with some gas-to-liquids. It is a very minor crude oil producer but nearly tripled production between 2003 and 2004 to account for some 7% of its own crude oil use. About 70 % of liquid fuels are refined from imported crude oil, mostly low grade crude from Saudi Arabia and Iran. With souring oil prices rising to the unimagined territory of over $100/barrel, the looming reality of peak oil which also hint to increase oil prices, political instability in some oil producing nations, indications are that South Africa should start investigating alternative fuel sources.

Electricity

Currently, South Africa's generation capacity stands at approximately 42000 MW with a demand of over 38000 MW. Most of the generation requirements are met by coal as shown on fig.6 with nuclear being the second visible source of energy generation. It is obvious from this description that electricity generation is the major contributor to carbon dioxide emissions. The majority of power stations have been operated well beyond their life expectancy with some plants as old as 50 years. Table A4.1 summarizes generation capacity by energy source.

Figure A4.1: Output of plants as a percentage of electricity supplied.

Source: (NER 2004: 5)

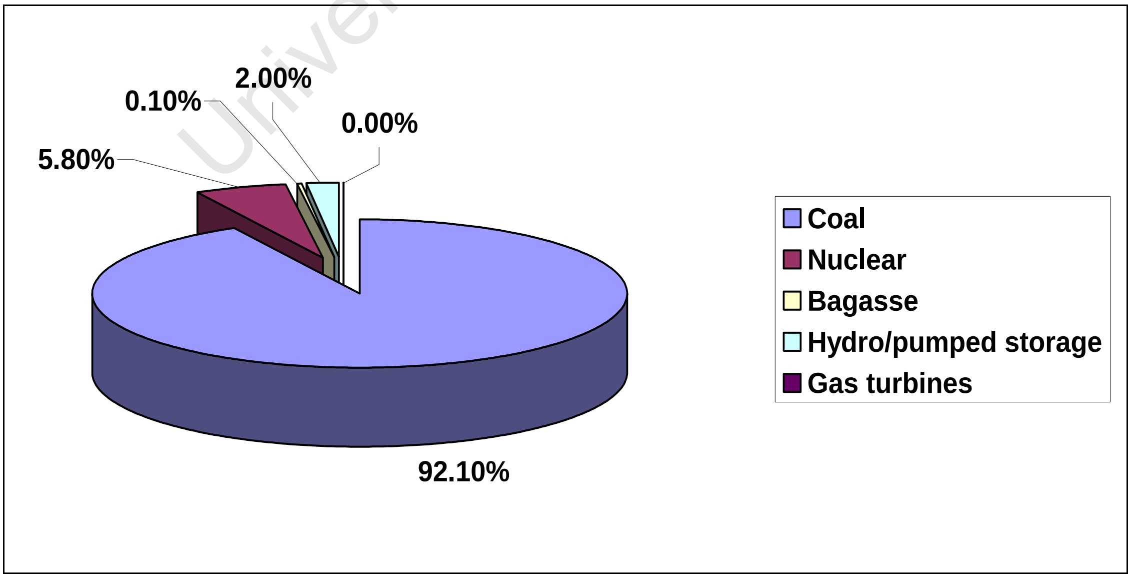


Table A4.1: Existing generation capacity including non-Eskom licensed capacity.

Source NER (2004: 13)

Total installed capacity excluding mothballed capacity (MW)	
Coal	38 209
Nuclear	1 800
Bagasse	105
Hydro/pumped storage	661
Pumped storage	1 400
Gas turbines	342
Mothballed capacity	
Coal	3 541

Renewables

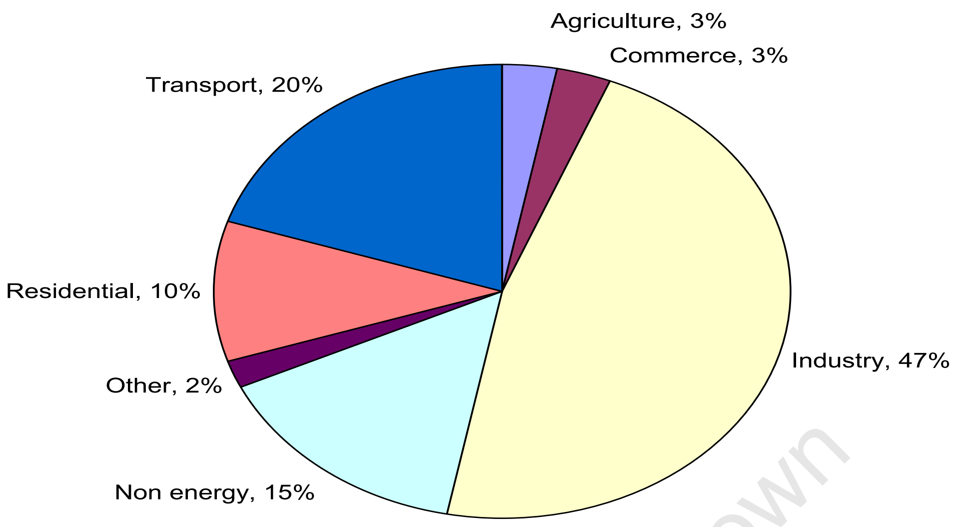
Wind and more importantly solar are seen as potential renewable energy sources for electricity generation. For example, the Department of Minerals and Energy (DME) have made a decision that 10 000 GWh of electricity should be generated from renewables by 2013 even though it is not clear policy-wise, how this would be achieved. Also, the National Energy Regulator of South Africa (NERSA) have gave indication that it would introduce a renewable energy feed-in tariff by February 2009 to stimulate investments in renewable energies.

Demand side

The industrial, transport as well as the residential sectors provides an opportunity for reducing energy consumption. When combined, they contribute almost 80% of energy consumption (see figure A4.2). Currently, a partnership between government and industry has been initiated in the form of an energy efficiency accord to reduce energy consumption in the industry sector by 10%. This is also supplemented by a Demand Side Management programme facilitated by the state utility for reducing energy consumption by approximately 4000 MW by 2025. This is equivalent of displacing one coal fired power station. The national department of transport has also embarked on a public transport recapitalization project aimed at displacing all the old vehicles. This will result in improved energy efficiency of the public transport fleet. There are many interventions proposed for the residential sector. For example, the introduction of solar water heaters (SWH), massive roll-out of compact fluorescent lighting (CFL's), electrification of rural households, improved efficiency of space heating by installing ceilings in low income households.

Figure A4.2: Share of final energy consumption in South Africa, 2000.

Source: Based on (SANEA 2003)



Commecial Sector

The commercial sector predominantly consumes electricity (64%) followed by coal (35%) and gas at 1% (Winkler et al. 2006). According to SANEA (2003), energy consumption in the commercial sector is expected to grow faster than economic output. Currently, this sector consumes only 6% of the national total final energy consumption.

The commercial sector is modelled with disaggregated demand for cooling, lighting, refrigeration, space heating, water heating and 'other'. These demands are met by various demand technologies using different energy carriers. The energy demand in the commercial sector is based on the intensity of demand per area of floor space for a given commercial activity (MJ/m^2). Useful energy intensity is assumed to remain constant throughout the time period 2001 – 2050 for all end uses except for the services grouped as 'other' in which the energy intensity is expected to grow by 0.5% per year. The useful and final energy demand for each activity is given in Table A4.2 below.

Table A4.2: Useful energy intensity in the commercial sector

Source: (Haw and Hughes 2007: 32)

End use	Final energy intensity (MJ/m^2)	Useful energy intensity (MJ/m^2)
Cooling	356.17	1331.01
Lighting	217.51	799.70

End use	Final energy intensity (MJ/m²)	Useful energy intensity (MJ/m²)
Water heating	273.87	239.65
Space heating	205.36	178.96
Refrigeration	48.10	48.10
Other	206.37	206.37

Transport sector

According to Haw and Hughes (2007a), the intensity or demand for fuel changes with each transport mode. Haw and Hughes have recorded the assumed total mileage travelled by each vehicle type along with the intensity. They based the lifetimes of vehicles on the scrapping curves for vehicles in the South African transport fleet. Hence, the assumed life of vehicles is 18 years for all cars, 25 years for trucks, 14 years for buses and 11 years for taxis.

Table A4.3: Intensities of passenger and freight transport

Source: Haw and Hughes (2007a: 46)

Transport intensities (road)			
Passenger transport	**Intensity** (MJ/pass-km)	**Total mileage** (billion vehicle-km)	**Total fuel use** (PJ)
Diesel buses	0.39	0.92	12.66
Petrol taxis (minibus)	0.44	8.82	38.46
Diesel taxis (minibus)	0.29	0.00	0.00
Petrol cars	1.51	62.00	197.23
Diesel cars	1.40	1.82	5.36
Hybrid cars (diesel)	0.59	0.00	0.00
Hybrid cars (petrol)	0.70	0.00	0.00
SUVs diesel	2.04	0.21	0.88
SUVs petrol	2.39	0.23	1.14
Motorcycles	1.80	1.58	2.84
Freight	**(MJ/tonne-km)**		
Light commercial vehicles	1.59	11.34	54.00
Medium commercial vehicles	0.70	6.89	47.92
Heavy commercial vehicles	0.84	5.28	66.62

Residential sector

In the residential sector, energy is mostly related to households rather than to individuals. For example, electricity grid connections are made to households, and monthly expenditure is recorded 'per household' rather than 'per person'. Six household types are defined here, differentiated according to urban/rural, high/low-income and electrified/non-electrified. Winkler et al. (2006) have coded them as follows:

UHE urban higher income electrified household
ULE urban lower income electrified household
ULN urban lower income non-electrified household
RHE rural higher income electrified household
RLE rural lower income electrified household
RLN rural lower income non-electrified household

For this sector, activity levels are defined by the number of households, of which there were 11 205 705 according to the 2001 Census (SSA 2003a). Definitions of 'urban' and 'rural' are technically difficult to make in South Africa, given the existence of 'dense rural settlements' like Bushbuckridge or Winterveld. In fact the Census no longer reports this distinction. Other statistical publications continue to report different patterns of 'urban' and 'non-urban' (e.g. SSA 2000, 2002). For the purposes of evaluating electrification, the National Electricity Regulator distinguishes between urban and rural connections, and this study has assumed a 60:40 split of urban to rural households. (The percentages used in the modelling are 59.61% urban households, 40.39% rural, but reporting them with two decimals would give a false sense of accuracy.)

Table A4.4: Six household types (2000)

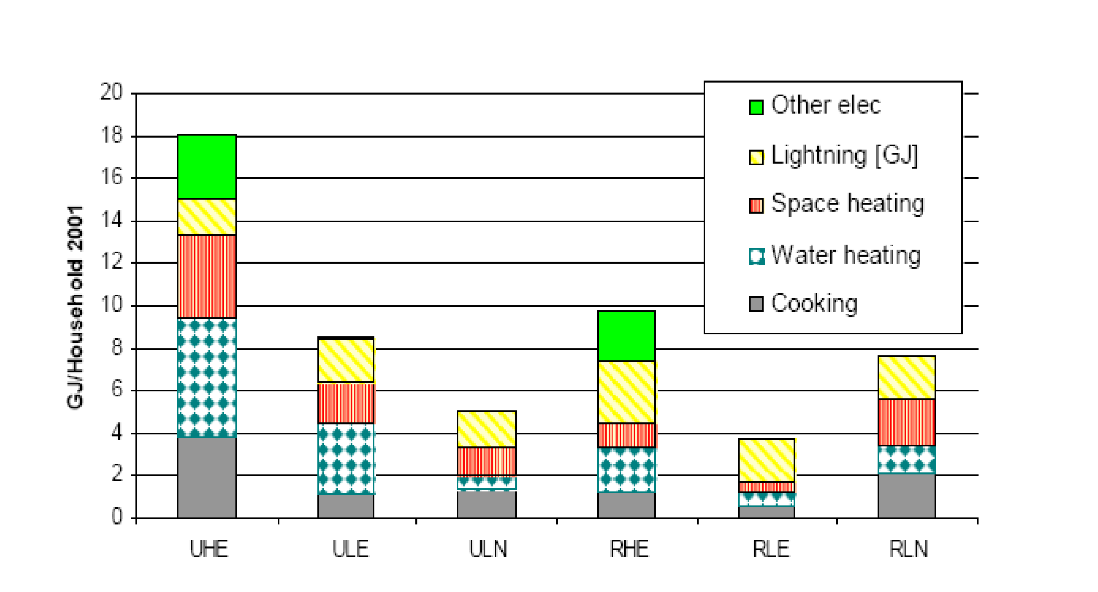
Source: (Witi et al. 2009:27)

Household	Number of households	Share of all households	Notes and assumptions
Urban rich electrified (UHE)	4 074 438	36.4%	Virtually 100% of rich urban households are electrified
Urban poor electrified (ULE)	1 255 728	11.2%	Remainder of urban electrified households must be poor
Urban poor unelectrified (ULN)	1 349 240	12.0%	Rest of urban must be non-electrified
Rural rich electrified (RHE)	1 181 279	10.5%	Assume 84% of rich rural households are electrified
Rural poor unelectrified (RLE)	1 095 449	9.8%	Remainder of rural electrified must be poor
Rural poor unelectrified (RLN)	2 249 571	20.1%	Rest of rural households must be non-electrified; number of households includes the few rich rural not electrified

Figure A4.3 shows energy consumption for different household types. Households are divided into six categories namely, Urban High Income Electrified (UHE), Urban Low Income Electrified (ULE), Urban Low Income Non-electrified (ULN), Rural High Income Electrified (RHE), Rural Low Income Electrified (RLE) and Rural Low Income Non-electrified (RLN).

Figure A4.3: The energy use for different household types.

(Source: Haw & Hughes, 2007: 40)



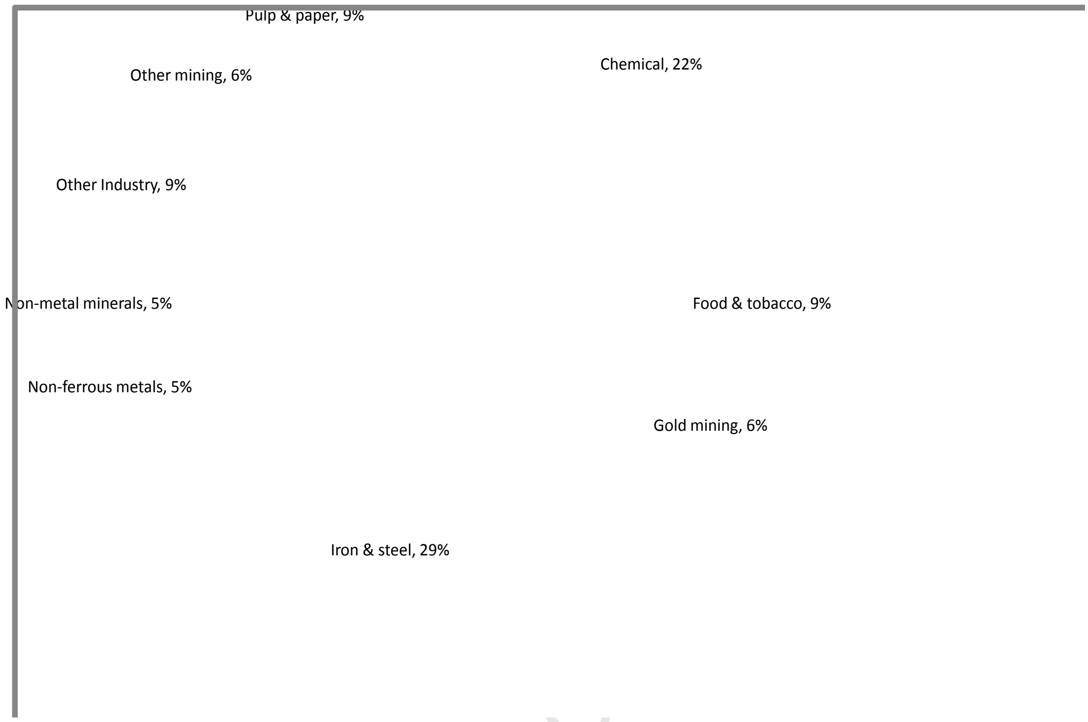
Industrial sector

Industry is the largest user of energy in South Africa in final energy consumption (Winkler et al. 2006). This is clearly illustrated in Figure A4.4 shown below. The main energy consuming sub-sectors are the chemical and petrochemicals, iron and steel followed by pulp and paper, food and tobacco, other industry, Gold mining and non-ferrous metals.

Furthermore, the industrial sector consumes just over 50% of final energy, of which 51% comes from coal, 33% from electricity, 12% from petroluem products and 3% from gas (DME 2005). Studies done locally has shown that a 9-12% energy saving is possible through improved efficiency standards compared to current specific intensity, with significant air pollution reductions and a five year payback period (Dutkiewitz & De Villiers 1995, cited by Winkler et al. 2006). The high energy intensive industries have been largely encouraged by low-cost of energy which has given South Africa a competitive advantage.

Figure A4.4: Final Industrial energy consumption by sub-sector (2001 total: 1302 PJ)

Source: (Winkler et al. 2006: 31)



Appendix E: LCS Mitigation option's data and information

Table A5.1: Summary of ZA50A mitigation options and their implementation

			Sector	Service	Factor	Energy	Effect		Max Q.		Comm.	Term	Life
		LCS mitigation options						unit		unit	[Yr.]	[Yr.]	[Yr.]
1		Implementation of SWH	RES	HTWTR	FSH	COAL	-0.8	Mtoe/unit	1	Mtoe	2000	50	35
1	a				FSH	OIL	-0.2	Mtoe/unit					
1	b				FSH	S/W	1.1	Mtoe/unit					
1	c				FSH	ELE	-0.1	Mtoe/unit					
2		Develop capacity for SWH production	RES	HTWTR					1	Mtoe	2010	15	35
3		Establish Public-private partnerships on SWH	RES	HTWTR					0	Mtoe	2010	10	0
4		SWH production fully functional	RES	HTWTR					1	Mtoe	2015	35	0
5		Decide on SWH subsidy funding structure	RES	HTWTR					1	Mtoe	2010	2	0
6		SWH subsidy scheme established and running	RES	HTWTR					1	Mtoe	2010	40	0
7		Implementation of ceilings in households	RES	WARM	EEF	COAL	67	Point	1	Mtoe	2000	40	35
8		Electrify households	RES	WARM	FSH	COAL	-0.1	Mtoe/unit	1	Mtoe	2000	50	35
8	a				FSH	OIL	-0.4	Mtoe/unit					
8	b				FSH	BMS	-7.6	Mtoe/unit					
8	c				FSH	S/W	8.5	Mtoe/unit					
9		Subsidize electricity consumption in poor households	RES	WARM					1	Mtoe	2000	50	0
10		Campaigns on improved utilization methods coal braziers							1	Mtoe	0	0	0
11		Introduce renewable feed-in tariffs	ENE	ELE					1	Mtoe	2009	2	0
12		Develop local RE expertise and facilitate investment	ENE	ELE					1	Mtoe	2010	7	0
13		Develop RET's manufacturing capacity locally	ENE	ELE					1	Mtoe	2015	35	0
14		Review legislation to encourage participation in RE	ENE	ELE					1	Mtoe	2000	12	0
15		Establish Public-private partnership to pilot RE	ENE	ELE					1	Mtoe	2010	10	0
16		Review electricity pricing	ENE	ELE					1	Mtoe	2000	11	0
17		Introduce competition in electricity generation	ENE	ELE					1	Mtoe	2011	4	0
18		Cleaner Electricity Generation	ENE	ELE	FSH	COAL	-28.2	Mtoe/unit	1	Mtoe	2013	22	30
18	a				FSH	S/W	11.7	Mtoe/unit					
18	b				FSH	NUCL	16.5	Mtoe/unit					
19		Public-private partnerships on CCs R&D and implementation	ENE	COAL					1	Mtoe	20	15	20
20		Develop technical capacity for local CCS implementation	ENE	COAL					1	Mtoe	2012	13	20
21		Pilot CCS locally	ENE	COAL					1	Mtoe	2020	10	20
22		Implement CCS for synfuels	ENE	COAL	CO2	COAL	11	tC/unit	1	Mtoe	2030	15	25
23		Building management system	COM	COOL					1	Mtoe	2015	10	30
24		Cooling efficiency awareness drives for the commercial sector	COM	COOL					1	Mtoe	2005	25	20
25		Subsidy for major cooling installations with efficiency focus	COM	COOL	ACCEL		5	years/unit	1	Mtoe	2014	9	20
26		Installation of efficient cooling systems	COM	COOL	EEF	COAL	30	Point	1	Mtoe	201	27	20
27		Develop thermal efficiency standards for settlements and commercial structures	COM	WARM	ACCEL		5	years/unit	1	Mtoe	2010	15	30

28		Implementation of thermal insulation in commercial structures	COM	WARM	EEF	COAL	60	Point	1	Mtoe	2010	40	30
29		LPG prices regulated to avoid manipulation	RES	COOK	ACCEL		3	years/unit	1	Mtoe	2011	4	30
30		Public awareness on safe handling and operation of LPG gas bottles	RES	COOK	ACCEL		2	years/unit	1	Mtoe	2000	20	30
31		Public-private fund for development of Small LPG distributors	RES	COOK	ACCEL		4	years/unit	1	Mtoe	2012	8	30
32		Public-private partnership established for LPG transport distributors	RES	WARM	ACCEL		3	years/unit	1	Mtoe	2013	12	30
33		Cleaner cooking using gas	RES	COOK	FSH	COAL	-0.1	Mtoe/unit	1	Mtoe	2001	49	30
33	a				FSH	GAS	0.15	Mtoe/unit					
33	b				FSH	ELE	-0.05	Mtoe/unit					
34		Promote use of CFL lighting	RES	LIGHT	ACCEL		2	years/unit	1	Mtoe	2007	9	15
35		Country-wide roll-out of CFL lighting	RES	LIGHT	ACCEL		3	years/unit	1	Mtoe	2008	7	15
36		Public awareness on safety and safe disposal of CFL light bulbs	RES	LIGHT					1	Mtoe	2007	13	15
37		Markets to phase-out inefficient Incandescent light bulbs	RES	LIGHT	ACCEL		5	years/unit	1	Mtoe	2020	10	15
38		Energy efficient lighting in residential sector	RES	LIGHT	EEF	COAL	75	Point	1	Mtoe	2005	50	15
39		Energy efficient lighting in commercial sector	COM	LIGHT	EEF	COAL	80	Point	1	Mtoe	2005	45	15
40		Dedicate lanes for public transport	TR_P	BUS	ACCEL		4	years/unit	1	Mtoe	2005	45	30
41		Up market public transport system to attract car owners	TR_P	BUS	ACCEL		3	years/unit	1	Mtoe	2012	8	30
42		Improve public transport infrastructure	TR_P	LARGE	DRV		-0.15	Mtoe/unit	1	Mtoe	2010	25	30
43		30 per cent bus modal shift	TR_P	TRAIN	DRV		0.18	Mtoe/unit	1	Mtoe	2010	25	30
44		20% railway modal shift	TR_P	BUS	DRV		0.27	Mtoe/unit	1	Mtoe	2010	25	30
45		Greener bus fleet	TR_P	BUS	FSH	OIL	-0.1	Mtoe/unit	1	Mtoe	2014	9	30
45	a				FSH	GAS	0.1	Mtoe/unit					
46		High levies on heavy vehicle imports	TR_P	LARGE	ACCEL		5	years/unit	1	Mtoe	2011	7	30
47		Move towards smaller vehicles	TR_P	LARGE	DRV		-0.029	Mtoe/unit	1	Mtoe	2012	2018	25
48		Move towards diesel cars	TR_P	LARGE	DRV		-0.063	Mtoe/unit	1	Mtoe	2010	25	20
49		Improvements in road efficiency	TR_P	LARGE	DRV		-0.09	Mtoe/unit	1	Mtoe	2008	12	20
50		Subsidies to stimulate green car sales	TR_P	LARGE	ACCEL		3	years/unit	1	Mtoe	2016	12	20
51		Pollution levy on fossil based on fossil based fuels	TR_P	LARGE	ACCEL		5	years/unit	1	Mtoe	2013	7	25
52		Develop capacity to produce green cars	TR_P	LARGE	ACCEL		3	years/unit	1	Mtoe	2014	11	20
53		Public-private partnership on green car research	TR_P	LARGE	ACCEL		3	years/unit	1	Mtoe	2010	2020	20
54		Implementation of hybrid-electric vehicles	TR_P	TR_P	DRV		-0.12	Mtoe/unit	1	Mtoe	2007	13	20
55		Implementation of electric cars	TR_P	TR_P	DRV		-0.06	Mtoe/unit	1	Mtoe	2018	22	20
56		Favourable pricing structure for transport via pipelines	TR_F	TRAIN					1	Mtoe	2017	8	20
57		Greener local freight transport	TR_F	SMALL	FSH	OIL	-1.1	Mtoe/unit	1	Mtoe	2020	10	20
57	a				FSH	ELE	1.1	Mtoe/unit					
58		Improved supply chain management and ICT for Fright	TR_F	LARGE	DRV		-0.15	Mtoe/unit	1	Mtoe	2012	8	20
59		Supply Chain Management and ICT for Large Freight	TR_F	SMALL	DRV		-0.55	Mtoe/unit	1	Mtoe	2012	8	20
60		Private-public partnerships in gas to liquids plants	ENE	OIL	ACCEL		2	years/unit	1	Mtoe	2009	16	30
61		Local capacity to operate and maintain CTL plants	ENE	OIL	ACCEL		2	years/unit	1	Mtoe	2003	17	25
62		Ensure Gas supply	ENE	OIL	ACCEL		2	years/unit	1	Mtoe	2003	42	25

63		Regulations on labelling of CO2 related information on industrial products	IND	MING	ACCEL		2	years/unit	1	Mtoe	2013	2	30
64		Energy Efficiency Petrochemicals	IND	PETRO	EEF	ELE	25	Point	1	Mtoe	2005	30	30
65		Energy Efficiency Agric	IND	AGR	EEF	ELE	25	Point	1	Mtoe	2005	30	30
66		Energy Efficiency Food	IND	FOOD	EEF	ELE	25	Point	1	Mtoe	2005	30	30
67		Energy Efficiency Cement	IND	CEMNT	EEF	ELE	25	Point	1	Mtoe	2005	30	30
68		Energy Efficiency Steel	IND	STEEL	EEF	ELE	25	Point	1	Mtoe	2005	30	30
69		Energy efficiency Non Ferrous	IND	FERR	EEF	ELE	25	Point	1	Mtoe	2005	30	30
70		Energy Efficiency Other Manufacturing	IND	OTHER	EEF	ELE	25	Point	1	Mtoe	2005	30	30
71		Energy Efficiency Pulp & Paper	IND	PAPER	EEF	ELE	25	Point	1	Mtoe	2005	30	30
72		Energy Efficiency Mining	IND	MING	EEF	ELE	25	Point	1	Mtoe	2005	30	30
73		Thermal efficiency Petrochemicals	IND	PETRO	EEF	COAL	30	Point	1	Mtoe	2000	35	30
74		Thermal efficiency Steel	IND	STEEL	EEF	COAL	30	Point	1	Mtoe	2000	35	30
75		Thermal efficiency Other Manufacture	IND	OTHER	EEF	COAL	30	Point	1	Mtoe	2000	35	30
76		Thermal efficiency Pulp and Paper	IND	PAPER	EEF	COAL	30	Point	1	Mtoe	2000	35	30
77		Thermal efficiency in Coal power stations	ENE	ELE	EEF	COAL	0.05	Point	1	Mtoe	2020	20	30

Table A5.2: Summary of ZA50B mitigation options and their implementation

			Sector	Service	Factor	Energy	Effect		Max Q.		Comm.	Term	Life
		LCS mitigation option						**unit**		**unit**	**[Yr.]**	**[Yr.]**	**[Yr.]**
1		Implementation of SWH	RES	HTWTR	FSH	COAL	-0.8	Mtoe/unit	1	Mtoe	2000	50	35
1	a				FSH	OIL	-0.2	Mtoe/unit					
1	b				FSH	S/W	1.1	Mtoe/unit					
1	c				FSH	ELE	-0.1	Mtoe/unit					
2		Develop capacity for SWH production	RES	HTWTR					1	Mtoe	2010	15	35
3		SWH production fully functional	RES	HTWTR					1	Mtoe	2015	35	20
4		Decide on SWH subsidy funding structure	RES	HTWTR					1	Mtoe	2010	2	20
5		SWH subsidy scheme established and running	RES	HTWTR					1	Mtoe	2010	40	20
6		Implementation of ceilings in households	RES	WARM	EEF	COAL	67	Point	1	Mtoe	2000	40	35
7		Subsidize electricity consumption in poor households	RES	WARM					1	Mtoe	2000	50	20
8		Campaigns on improved utilization methods coal braziers	RES	WARM					1	Mtoe	2005	10	20
9		Introduce renewable feed-in tariffs	ENE	ELE					1	Mtoe	2009	2	20
10		Develop local RE expertise and facilitate investment	ENE	ELE					1	Mtoe	2010	7	20
11		Develop RET's manufacturing capacity locally	ENE	ELE					1	Mtoe	2015	35	20
12		Review legislation to encourage participation in RE	ENE	ELE					1	Mtoe	2000	12	20
13		Establish Public-private partnership to pilot RE	ENE	ELE					1	Mtoe	2010	10	20
14		Review electricity pricing	ENE	ELE					1	Mtoe	2000	11	20
15		Introduce competition in electricity generation	ENE	ELE					1	Mtoe	2011	4	20
16		Public-private partnerships on CCs R&D and implementation	ENE	COAL					1	Mtoe	2020	15	20
17		Develop technical capacity for local CCS implementation	ENE	COAL					1	Mtoe	2012	13	20
18		Pilot CCS locally	ENE	COAL					1	Mtoe	2020	10	20
19		Implement CCS for synfuels	ENE	COAL	CO2	COAL	-11	tC/unit	1	Mtoe	2030	15	25
20		Building management system	COM	COOL					1	Mtoe	2015	10	30

21		Cooling efficiency awareness drives for the commercial sector	COM	COOL					1	Mtoe	2005	25	20
22		Subsidy for major cooling installations with efficiency focus	COM	COOL	ACCEL		5	years/unit	1	Mtoe	2014	9	20
23		Installation of efficient cooling systems	COM	COOL	EEF	COAL	30	Point	1	Mtoe	2008	27	20
24		Develop thermal efficiency standards for settlements and commercial structures	COM	WARM	ACCEL		5	years/unit	1	Mtoe	2010	15	30
25		Implementation of thermal insulation in commercial structures	COM	WARM	EEF	COAL	60	Point	1	Mtoe	2010	40	30
26		Promote use of CFL lighting	RES	LIGHT	ACCEL		2	years/unit	1	Mtoe	2007	9	15
27		Country-wide roll-out of CFL lighting	RES	LIGHT	ACCEL		3	years/unit	1	Mtoe	2008	7	15
28		Public awareness on safety and safe disposal of CFL light bulbs	RES	LIGHT					1	Mtoe	2007	13	15
29		Markets to phase-out inefficient Incandescent light bulbs	RES	LIGHT	ACCEL		5	years/unit	1	Mtoe	2020	10	15
30		Energy efficient lighting in residential sector	RES	LIGHT	EEF	ELE	90	Point	1	Mtoe	2005	45	15
31		Energy efficient lighting in commercial sector	COM	LIGHT	EEF	COAL	80	Point	1	Mtoe	2005	45	15
32		Dedicate lanes for public transport	TR_P	BUS	ACCEL		4	years/unit	1	Mtoe	2005	45	30
33		Up market public transport system to attract car owners	TR_P	BUS	ACCEL		3	years/unit	1	Mtoe	2012	8	30
34		Improve public transport infrastructure	TR_P	LARGE	DRV		-0.15	Mtoe/unit	1	Mtoe	2010	25	30
35		30 per cent bus modal shift	TR_P	TRAIN	DRV		-0.18	Mtoe/unit	1	Mtoe	2010	25	30
36		20% railway modal shift	TR_P	BUS	DRV		-0.27	Mtoe/unit	1	Mtoe	2010	25	30
37		Greener bus fleet	TR_P	BUS	FSH	OIL	-0.1	Mtoe/unit	1	Mtoe	2014	9	30
37	a				FSH	GAS	0.1	Mtoe/unit					
38		Greener local freight transport	TR_F	SMALL	FSH	OIL	-1.1	Mtoe/unit	1	Mtoe	2020	10	20
38	a				FSH	ELE	1.1	Mtoe/unit					
39		Regulations on labelling of CO2 related information on industrial products	IND	MING	ACCEL		2	years/unit	1	Mtoe	2013	2	30
40		Energy Efficiency Petrochemicals	IND	PETRO	EEF	ELE	30	Point	1	Mtoe	2005	30	30
41		Energy Efficiency Agric	IND	AGR	EEF	ELE	30	Point	1	Mtoe	2005	30	30
42		Energy Efficiency Food	IND	FOOD	EEF	ELE	30	Point	1	Mtoe	2005	30	30
43		Energy Efficiency Cement	IND	CEMNT	EEF	ELE	30	Point	1	Mtoe	2005	30	30
44		Energy Efficiency Steel	IND	STEEL	EEF	ELE	30	Point	1	Mtoe	2005	30	30
45		Energy efficiency Non Ferrous	IND	FERR	EEF	ELE	30	Point	1	Mtoe	2005	30	30
46		Energy Efficiency Other Manufacturing	IND	OTHER	EEF	ELE	30	Point	1	Mtoe	2005	30	30
47		Energy Efficiency Pulp & Paper	IND	PAPER	EEF	ELE	30	Point	1	Mtoe	2005	30	30
48		Energy Efficiency Mining	IND	MING	EEF	ELE	30	Point	1	Mtoe	2005	30	30
49		Thermal efficiency Petrochemicals	IND	PETRO	EEF	COAL	30	Point	1	Mtoe	2000	35	30
50		Thermal efficiency Steel	IND	STEEL	EEF	COAL	30	Point	1	Mtoe	2000	35	30
51		Thermal efficiency Other Manufacture	IND	OTHER	EEF	COAL	30	Point	1	Mtoe	2000	35	30
52		Thermal efficiency Pulp and Paper	IND	PAPER	EEF	COAL	30	Point	1	Mtoe	2000	35	30
53		Thermal efficiency in Coal power stations	ENE	ELE	EEF	COAL	8	Point	1	Mtoe	2020	20	30
54		Create walkways and bicycle lanes	TR_P	LARGE	ACCEL		4	years/unit	1	Mtoe	2015	20	30
55		Awareness on Rules & Procedures for Bicycle lanes and walkways	TR_P	LARGE	ACCEL		3	years/unit	1	Mtoe	2014	2	20
56		Public-private partnership in cost effective bicycle production	TR_P	LARGE	ACCEL		5	years/unit	1	Mtoe	2014	8	25
57		Subsidies for public bicycle dissemination	TR_P	LARGE					1	Mtoe	2014	11	30
58		Upgrade traffic control lights to accommodate pedestrians and cyclers	TR_P	LARGE	ACCEL		4	years/unit	1	Mtoe	2014	11	20
59		Legislation to limit private cars in cities	TR_P	LARGE	ACCEL		5	years/unit	1	Mtoe	2014	16	20

60		PDF PL	TR_P	LARGE	DRV		-0.12	Mtoe/unit	1	Mtoe	2015	20	30
61		PDF CPV	TR_P	COM	DRV		-0.05	Mtoe/unit	1	Mtoe	2015	20	30
62		PDF Bus	TR_P	BUS	DRV		-0.02	Mtoe/unit	1	Mtoe	2015	20	30
63		Coal to Gas for Boilers Pulp & Paper	IND	IND	FSH	COAL	-0.65	Mtoe/unit	1	Mtoe	2015	30	30
63	a				FSH	GAS	0.65	Mtoe/unit					
64		Coal to Gas for Other Manuf	IND	OTHER	FSH	COAL	-0.25	Mtoe/unit	1	Mtoe	2015	30	30
64	a				FSH	GAS	0.25	Mtoe/unit					
65		Coal to Gas for Petrochemicals	IND	PETRO	FSH	COAL	-0.4	Mtoe/unit	1	Mtoe	2015	30	30
65	a				FSH	GAS	0.4	Mtoe/unit					
66		Develop electricity and gas consumption meters	RES	APP	ACCEL		2	years/unit	1	Mtoe	2012	38	20
67		Provide Financial support for diffusion of meters	RES	APP					1	Mtoe	2011	14	30
68		Awareness to consumers about environmental information	RES	APP					1	Mtoe	2011	6	25
69		Provide incentives for emission reductions based on visual measurements	RES	APP					1	Mtoe	2013	7	25
70		Develop standards for energy consumption calculations	RES	APP					1	Mtoe	2011	4	30
71		Efficiency improvement in design_Com	COM	COOL	EEF	ELE	40	Point	1	Mtoe	2000	50	25
72		Efficiency_Com_oil	COM	COOL	EEF	OIL	40	Point	1	Mtoe	2000	50	40
73		Efficiency_Com_Gas	COM	COOL	EEF	GAS	40	Point	1	Mtoe	2000	50	40
74		Efficient warming	COM	WARM	EEF	OIL	40	Point	1	Mtoe	2000	50	30
75		Efficient warm_gas	COM	WARM	EEF	GAS	40	Point	1	Mtoe	2000	50	40
76		Efficient warming_Com_Ele	COM	WARM	EEF	ELE	40	Point	1	Mtoe	2000	50	40
77		Low-Carbon Electricity Generation	ENE	ELE	FSH	COAL	-24.6	Mtoe/unit	1	Mtoe	2016	24	30
77	a				FSH	BMS	1.9	Mtoe/unit					
77	b				FSH	S/W	15.2	Mtoe/unit					
77	c				FSH	NUCL	7.6	Mtoe/unit					
77	d				FSH	HYDR	1.9	Mtoe/unit					
78		Road efficiency and Secondary fuels	TR_P	LARGE	DRV		-0.09	Mtoe/unit	1	Mtoe	2015	30	30
79		Road efficiency	TR_P	BUS	DRV		-0.015	Mtoe/unit	1	Mtoe	2015	30	20
80		Road Efficiency_Freight Small	TR_F	SMALL	DRV		-0.33	Mtoe/unit	1	Mtoe	2000	50	20
81		Road efficiency freight_large	TR_F	LARGE	DRV		-0.18	Mtoe/unit	1	Mtoe	2000	50	20
82		PDF_small freight	TR_F	SMALL	DRV		-0.44	Mtoe/unit	1	Mtoe	2015	35	30
83		PDF_Large Freight	TR_F	LARGE	DRV		0.12	Mtoe/unit	1	Mtoe	2015	35	30
84		Develop infrastructure for Hydrogen supply	TR_P	MINI	ACCEL		5	years/unit	1	Mtoe	2025	25	30
85		Public-private partnership on Hydrogen infrastructure	TR_P	MINI	ACCEL		5	years/unit	1	Mtoe	2020	30	20
86		Oil displacement_20%_passnger large	TR_P	LARGE	DRV		-0.12	Mtoe/unit	1	Mtoe	2025	25	20
87		Thermal efficiency Mining	IND	MING	EEF	COAL	30	Point	1	Mtoe	2005	40	20
88		Thermal efficiency Cement	IND	CEMNT	EEF	COAL	30	Point	1	Mtoe	2005	40	30
89		Thermal efficiency Agric	IND	AGR	EEF	OIL	30	Point	1	Mtoe	2005	40	30
90		Thermal efficiency biomass_other manufac	IND	OTHER	EEF	BMS	30	Point	1	Mtoe	2014	30	20
91		Cleaner space warming_50% bio to elec	RES	WARM	FSH	BMS	-3.8	Mtoe/unit	1	Mtoe	2015	35	20
91	a				FSH	ELE	3.8	Mtoe/unit					
92		CCS for coal based electricity	ENE	ELE	CO2	COAL	-12.54	tC/unit	1	Mtoe	2030	20	20
93		Electrify households	RES	WARM	FSH	COAL	-0.1	Mtoe/unit	1	Mtoe	2000	50	35
93	a				FSH	OIL	-0.4	Mtoe/unit					
93	b				FSH	BMS	-7.6	Mtoe/unit					
93	c				FSH	ELE	8.1	Mtoe/unit					
94		Awareness_app_20%reduction	RES	REFRI	DRV		-0.27	Mtoe/unit	1	Mtoe	2012	30	25
95		Awareness_30% reduction_tv	RES	ICT	DRV		-0.27	Mtoe/unit	1	Mtoe	2012	30	25
96		awareness_20%_refrig	RES	APP	DRV		-0.27	Mtoe/unit	1	Mtoe	2012	30	20
97		Infra for Hydrogen	TR_P	LARGE					1	Mtoe	2025	20	20

98		R&D on Hydrogen	TR_P	LARGE	ACCEL		3	years/unit	1	Mtoe	2025	20	20
99		Hydrogen_Fuel cells_15% oil reduc	ENE	OIL	DRV		-1.819	Mtoe/unit	1	Mtoe	2025	25	20
100		Biomass reduces oil dependency by 15%	ENE	OIL	FSH	OIL	-1.819	Mtoe/unit	1	Mtoe	2020	25	20
100	a				FSH	BMS	1.8192	Mtoe/unit					
101		LCS leadership	RES	WARM	ACCEL		5	years/unit	1	Mtoe	2011	30	20

Appendix F: Factor Analysis data

Table A5.1: LCS scenario ZA50A data

		2050 ZA50A					
		IND	RES	COM	TR-P	TR-F	Total
Change rate 2050/2000	D	0%	34%	19%	3%	155%	12%
	E/D	-12%	-40%	-35%	-49%	-131%	-24%
	C'/E	11%	-6%	7%	-7%	70%	11%
	C/C'	-56%	-71%	-78%	-9%	-131%	-65%
	Total	-57%	-84%	-87%	-61%	-38%	-66%
CO2 share	2000	63%	3%	29%	2%	4%	100%

Table A5.2: LCS scenario ZA50A data

		2050 ZA50B					
		IND	RES	COM	TR-P	TR-F	Total
Change rate 2050/2000	D	-12%	29%	7%	21%	102%	-1%
	E/D	-12%	-46%	-22%	-71%	-122%	-21%
	C'/E	2%	-12%	-14%	2%	34%	-2%
	C/C'	-41%	-61%	-63%	-17%	-55%	-48%
	Total	-63%	-89%	-92%	-64%	-42%	-71%
CO2 share	2000	63%	3%	29%	2%	4%	100%

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