Long Term Mitigation Scenarios

Strategic Options for South Africa

Department of Environment Affairs and Tourism
South Africa

Prepared by
Scenario Building Team

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The suite of reports that make up the Long Term Mitigation Scenario study includes the following:

A Long Term Mitigation Scenarios for South Africa
B Technical Summary
C Technical Report
C.1 Technical Appendix
D Process Report

The study was supported by the following inputs:
LTMS Input Report 1: Energy emissions
LTMS Input Report 2: Non-energy emissions: Agriculture, Forestry and Waste
LTMS Input Report 3: Non-energy emissions: Industrial Processes
LTMS Input Report 4: Economy-wide modelling
LTMS Input Report 5: Impacts, vulnerability and adaptation in key South African sectors

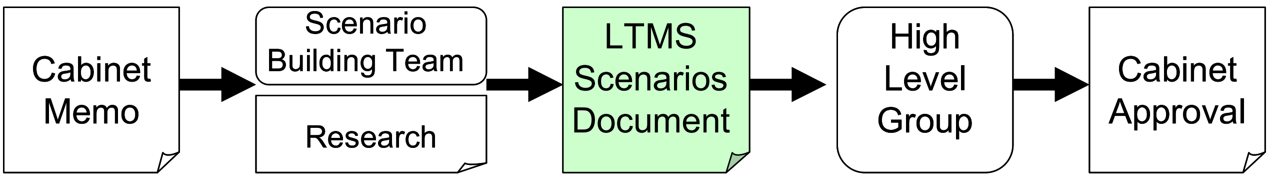
LONG TERM MITIGATION SCENARIOS
Strategic options for South Africa

The LTMS: motivation, process and results

In March 2006, the South African Cabinet commissioned a process to examine the potential for mitigation[1] of our country's greenhouse gas emissions. The process was to be informed by the best available information. The aim was to produce Long Term Mitigation Scenarios (LTMS) that would provide a sound scientific analysis from which Cabinet could draw up a long-term climate policy. Such a policy would give South African negotiators under the United Nations Framework Convention for Climate Change (UNFCCC) clear and mandated positions for their negotiations. It would also ensure that South African stakeholders understood and committed to a range of realistic strategies for future climate action.

LTMS Process
A) Scenario Document ***(this document)***
B) Technical Summary
Technical Report and Appendix
Technical Inputs:
- Energy emissions
- Non-energy emissions
- Macro-economic analysis
- Climate impacts

The first phase of this study has now been completed. A Scenario Building Team, comprised of strategic thinkers from government, business and civil society[2] working with four research teams, has produced this Scenario Document, backed up by a Technical Summary, which is in turn underpinned by detailed technical research. The document is to be presented to leaders in each sector for further discussion and refinement. A final version will be presented to Cabinet in early 2008.



This document attempts to answer two fundamental questions:
Why should South Africa be concerned with the mitigation of greenhouse gases?
and
What options for mitigation are available, how much can each option reduce emissions, and at what cost?

Starting from a base year of 2003 and continuing to a 2050 horizon, the Scenario Building Team explores two possible scenarios, assessing them against the full range of possible international climate change contexts. As will be seen, the assessment suggests that only one of these scenarios is actually robust. The Scenario Building Team then proceeds to explore, within the robust scenario, four strategic options for reducing greenhouse gas emissions.

[1] Mitigation is the reduction of greenhouse gases, the most important of which is carbon dioxide (CO_2).
[2] A full list of members of the Scenario Building Team is included in the Process Report.

The challenge of Climate Change

- The scientific evidence for a rise in global temperature over the past century is unequivocal.
- Climate change is almost certainly[3] driven by increased greenhouse gas concentrations caused by human activities.
- Climate change is already having predominantly negative impacts on people and ecosystems. Further temperature rises will have increasingly detrimental effects.
- To keep temperature increase within a range between 2.0 and 2.4ºC, global emissions have to peak by 2015 and then decline.[4]
- The economic case for action is compelling. The costs of emission reduction are high, but the costs of inaction will be far higher, because climate impacts require large-scale adaptation.
- This is not just an environmental issue. It goes to the very heart of the world's future economic viability, including achieving and sustaining the Millennium Development Goals.

For South Africa, the implications are important:

- South Africans, and particularly our poor communities, are especially vulnerable to many of the projected future climate impacts.[5] These impacts will most likely be catastrophic if climate change is not checked and drastically reduced.
- It is therefore in the interests of all South Africans that global emissions decrease to a degree that avoids dangerous climate change.
- South Africa is already committed to playing its part in this effort to mitigate emissions. The country is proactively engaging in the multilateral climate negotiations, which will likely agree on the future of the climate regime by 2009.
- Developing countries are currently not constrained under the Kyoto Protocol. However in the upcoming international negotiations there is increasing pressure on the larger developing country emitters to demonstrate their plans for achieving emissions reductions.
- It is accordingly incumbent on South Africa not only to urgently develop such a plan, but also to prepare the path for its implementation, at an appropriate time in the future, and to achieve the emissions reductions targets agreed upon. This LTMS document aims to help decision-makers begin this process.

The economic challenges are huge because of the sheer scale of the mitigation solutions required. However the alternatives to taking action on mitigation are even more expensive. The Stern Review[6] has reported that the costs of adaptation[7] for the world should no mitigation occur ('the costs of inaction'), will be in the order of 5 to 20 times the cost of the mitigation actions required. Hence if the world, including South Africa, does not mitigate, it will be overtaken by climate impacts and their much larger damage costs.

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[3] According to the IPCC's Fourth Assessment Report, "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations". 'Very likely' means that the assessed likelihood, using expert judgement, is greater than 90%.

[4] See the IPCC Fourth Assessment Report, Working Group III, Summary for Policymakers, Table SPM.5.

[5] An updated study on climate change impacts and adaptation in South Africa is reported separately.

[6] The Stern Review (2006) on the economics of climate change (see www.hm-treasury.gov.uk, go to Independent Reviews, and Stern Review).

[7] Adaptation is the act of responding to the impacts of climate change.

Three areas need to be brought together into a coherent vision to formulate and implement a plan of action that is economically risk-averse and internationally aligned to the world effort on climate change. These are:

- Technology: Wider deployment of existing climate-friendly technology is necessary, together with commercialisation of emerging technologies and spending at scale on research and development of new technology.
- Investment: The sources, mechanisms, and extent of investment in a low-carbon society need to be found and actively pursued.
- Policy: The country will need clear guidance through policy frameworks that send sustained and legally-enforced messages to the markets.

South Africa in the context of climate change

The focus of this document is mitigation: if South Africa takes the decision to mitigate, then this document addresses how to determine the options, the emissions reductions achieved by these options, and the attendant costs of each option.[8] How, then, is South Africa to grow and develop in order to reduce poverty, while at the same time retooling its economy in order to reduce its greenhouse gas emissions?

Emissions

In 2004, the world produced about 49 000 Mt CO_2-equiv[9], mainly from energy generation and deforestation. In comparison, South Africa produced about 440 Mt, or about 1% of the global figure.

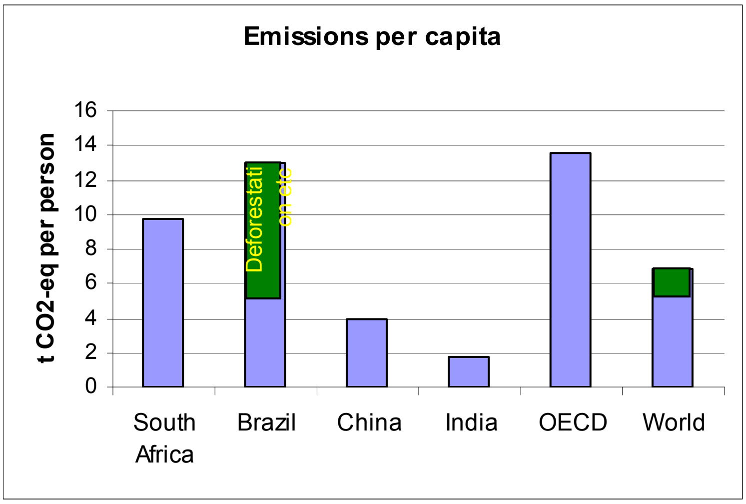
South Africa's emissions are large relative to its population and economy. Our coal-based energy economy has enjoyed relatively low energy prices historically, which have favoured energy-intensive industries.

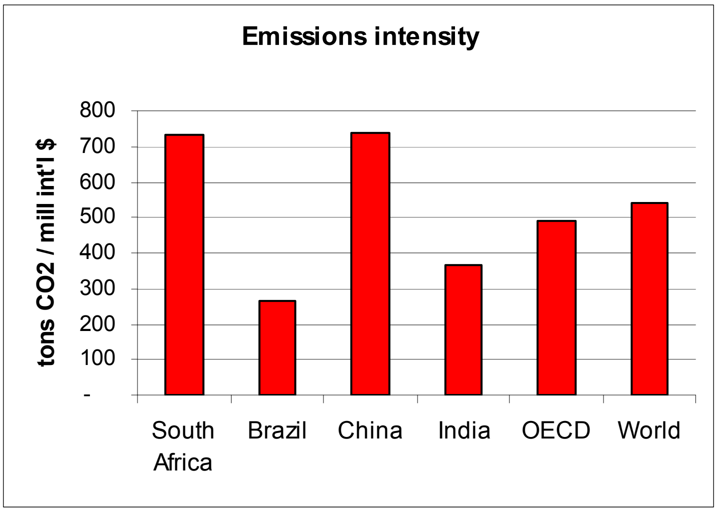
Comparison of South Africa's annual and cumulative emissions [10]

	Annual GHG emissions, 2000		*Cumulative CO_2 emissions, 1950-2000*	
	Mt CO_2-equiv	*%*	*Mt CO_2*	*%*
	Six gases, energy & LULUCF	*As share of global total*	*CO_2 only, energy & LULUCF*	*As share of global total*
South Africa	415	1.0%	10,250	0.9%
Brazil	2,213	5.4%	68,389	6.1%
China	4,920	11.9%	110,675	9.9%
India	1,814	4.4%	17,581	1.6%
OECD	15,423	37.4%	467,564	42.0%
World	41,240	100.0%	1,113,122	100.0%

As the left hand figure below shows, South Africa's emissions intensity (i.e. emissions per GDP) is high compared to most developed (OECD) countries and developing countries. Our emissions per capita are higher than China and India, which are also coal-based energy economies, and higher than Brazil – until we add Brazil's emissions due to changes in land use, notably deforestation.[11]

[8] Our state of knowledge currently does not enable us to model the comparative "costs of inaction" in South Africa.
[9] Greenhouse gas emissions are measured by Megatons (Mt) of CO_2-equivalent. Emissions from the other greenhouse gases (GHGs) are converted to CO_2-equivalents by Global Warming Potentials – 21 tons of CO_2 equivalent to 1 ton of methane, 310 per ton of nitrous oxide. Units of million tons (Megatons, Mt) are preferred, although inventories tend to report in Gigagrams (Gg). 1 Mt = 1000 Gg.
[10] Note on table: Gases for annual emissions include CO_2 (energy), CO_2 (land use change), CH_4, N_20, PFCs, HFCs, SF_6.
[11] In climate negotiations, these sources of emissions are referred to as 'LULUCF' – land use, land use change and forestry.





Note on graphs : 'Per capita' means annual emissions of a country or region divided by its population. 'Emissions intensity' divides emissions by economic output ($ of GDP), with GDP measured in international dollars on a power purchasing parity basis.

South Africa is therefore in a difficult position in relation to some proposed climate regimes. Some countries argue – on the basis of equity – for allocation of emission allowances on a per capita basis. South Africa already exceeds the global average. Other proposals for developing countries are based on emissions intensity. Again, given our high relative emissions intensity, this is not likely to be a favourable approach for South Africa. The Brazilian Proposal takes a different approach to equity, allocating emissions based on historical responsibility for temperature change.

The multilateral negotiations

South Africa has ratified the United Nations Framework Convention on Climate Change and its Kyoto Protocol, and plays a proactive role in the climate negotiations. Thus far, South Africa has been exempt from taking mandatory action to reduce our high level of relative emissions. In the United Nations Framework Convention on Climate Change (UNFCCC) the principle of equity and "common but differentiated responsibility" was agreed, by which the developed nations would take the lead in mitigating greenhouse gases. South Africa has a loose commitment to mitigate under the Convention, but no legally binding, quantified target.

Under the Kyoto Protocol, carbon constraints, or caps, were placed on industrialised countries only. In the first commitment period (2008 to 2012), South Africa, along with other larger developing countries such as Brazil, China and India, may continue to grow without any cap on emissions. However, once the developed nations take the lead with more ambitious emissions reductions, they will expect at least some developing countries to take a fair share of our common (albeit still differentiated) responsibility. What happens to the climate regime beyond 2012 is currently the subject of negotiations, with agreement expected in 2009. It is therefore urgent for South Africa to translate LTMS into policy and negotiation positions.

Pressing for total exemption from any mitigation effort is not an option for South Africa. This is because the full extent of the impacts South Africa will progressively experience over the 21st century will depend on how much the international community constrains their emissions. The more effective the agreement, the more South Africa will be protected from serious or even catastrophic climate impacts. To be protected, South Africa will have to rely on the commitment of others to match the challenge of the science. It will have to match the international community's commitment with a commitment of its own.

Hence the question is: In the negotiations ahead, what position should South Africa take? This choice can only be based on a full knowledge of how different mitigation options (wedges) reduce emissions and how much might they cost, What actions should South Africa take, and should they be packaged so that emissions peak fairly early – and at what level might the peak be? When should emissions begin to decline, and how fast?

The Scenario Building Team of the LTMS has explored these questions. The key results are presented in the sections that follow.

The LTMS Scenarios and Strategies were achieved rigorously, both in the processes followed and the data used. A bank of data was produced by modelling, and agreed with the Scenario Building Team. This is presented in the LTMS Technical Report (a Summary of which is attached). Cost and emissions levels for a number of mitigation actions were calculated. Assumptions that underpin all scenarios include population growth, GDP projections, prices of oil and other fuels, as well as exchange rates. The data was also fed into economic models, giving additional results on how mitigation actions would affect GDP, job creation and wealth distribution.

SCENARIO 1
What if South Africa did not mitigate its emissions before 2050?
The "Growth without Constraints" story

What would our economy and greenhouse gas emissions look like if by 2050 (and beyond) South Africa were to develop without any consideration of greenhouse gas emission? What would be the scenario if there were no climate impacts highly damaging to the economy, if there was no significant oil constraint, if we made our choices to energise our economy purely on least-cost grounds and without internalising external costs? This scenario is labelled the Growth without Constraints Scenario. All other scenarios and strategic options are assessed against it – it is our reference case.[12]

Assumptions about economic growth that underpin this scenario were consistent with the growth targets of the Accelerated and Shared Growth Initiative for SA (ASGISA), ranging between 3% and 6% GDP growth per year. These and other assumptions were fed into the model, which selected the least-cost sources of energy to fuel the economy over the period 2003 to 2050. Current trends in land use, agriculture and waste sectors were assumed to continue.

Here are the characteristics of the Growth without Constraints Scenario:

- **Overall emissions**
  SA's emissions in the base year 2003 stand at 440 megatons of CO_2-eq. By 2050 our emissions have quadrupled to around 1600 Mt per year.

- **Demand side: Energy efficiency**
  Overall fuel consumption grows more than five-fold, mainly in the industry and transport sectors (see the Technical Report for details). There is no incentive for (and therefore no uptake of) energy efficiency, despite the potential net savings over time, demonstrating the typical market pattern of not taking up no-cost strategies.

- **Supply side: Coal**
  New coal-fired electricity generating plants use supercritical steam technology (23 GW, or 7 new plants, by 2050) or integrated gasification combined cycle (IGCC)[13] (68 GW, or 21 new plants, by 2050). IGCC becomes attractive as it is only slightly more expensive but significantly more efficient than supercritical coal technology. Since no carbon constraints are imposed, no electricity plants have carbon capture and storage (CCS).
- **Supply side: Nuclear**
  A total of 9 new conventional nuclear plants are built, mostly between 2023 and 2040, adding 15 GW of new capacity. Twelve modules of PBMR (Pebble Bed Modular Reactors) are built for domestic use.

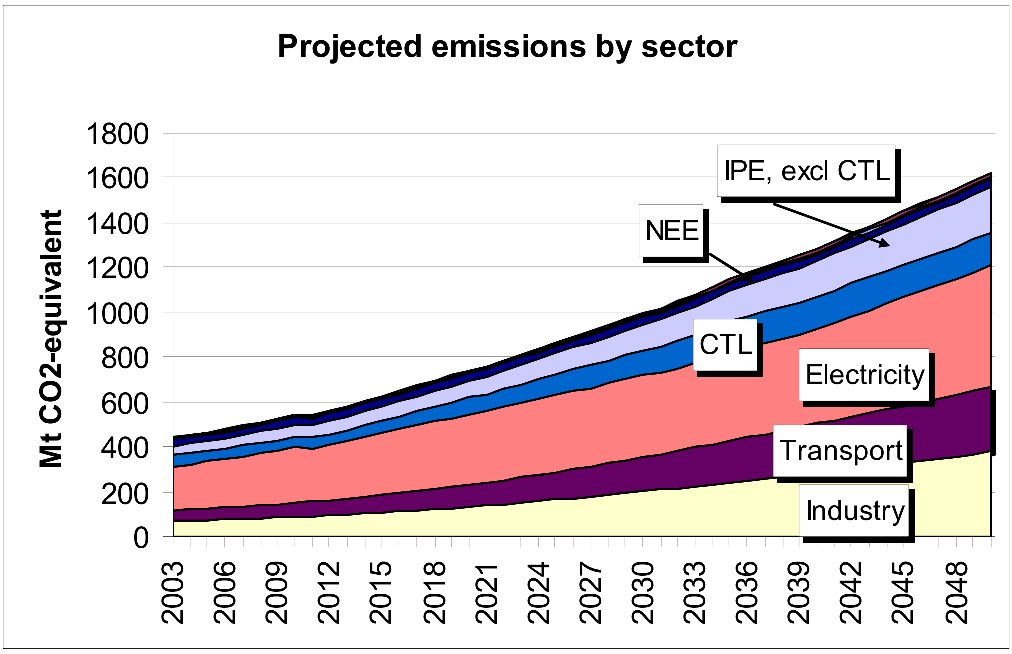
- **Supply side: Renewables**
  Very few renewables enter the electricity mix in this Scenario. No electricity is generated from solar, thermal, or wind, with the only significant addition being 70 MW of landfill gas.

[12] The reference case was modelled in great detail. Figures quoted are arrived at through this modelling process.
[13] IGCC plants first gasify coal, before it is combusted.

- **Liquid fuel**
  Liquid fuel supply is dominated by oil and synfuel (coal-to-liquids, CTL) refineries. Five new oil refineries add 1.5 million barrels per day by 2050. Five additional CTL plants are built over the period, each with a capacity of 80 000 barrels-eq per day, i.e. each half a Secunda. The costs of bringing forward water supply options are a potential constraint, with the costs of securing a reliable supply potentially prohibitive under current economic conditions. In this Scenario, CTL plants are built without carbon capture and storage (CCS).

- **Human behaviour**
  Patterns of human consumption of energy and goods do not change markedly in the period, compared to 2003 patterns.

Emissions continue to be dominated by energy sources. Electricity generation accounts for 45% of greenhouse gas emissions in 2003, declining to 33% in 2050. The declining share of electricity is due to emissions growth from liquid fuels, with five new coal-to-liquid plants. Industrial process emissions (non-energy) increase more than four times, with the largest share in this category coming from synfuels. Emissions in the other non-energy sectors – notably waste, agriculture and forestry – increase much less rapidly than for the energy sector. The diagram that follows summarises the emissions and respective shares of each major sector:



Notes on graph: CTL is coal to liquids; IPE are industrial process emissions, not including CTL; NEE are non-energy emissions not already counted in the previous two.
The emissions from commercial, residential and agricultural energy use are are too small to see on this scale.

The Growth without Constraints Scenario presents an economy and society based very much on the patterns and dynamics that dominate South Africa today. Mining has declined and the composition of GDP moved even further into tertiary sectors. The scenario assumes that all resource constraints (e.g. local water availability) have been overcome. It further assumes that industrial policy continues with its current, energy-intensive focus. No negative feedbacks of a changing climate are considered in this Scenario. In the absence of these constraints, the economy by 2050 is still performing well, and by all accounts South Africa is seen as a successful country having achieved its goals. Its emissions, however, have quadrupled.

Comparing the Scenarios' emission trajectories, and introducing current efforts

The Growth without Constraints Scenario has shown emissions quadrupling. What would happen if existing Government policy was implemented?. This is shown in another trajectory, called Current Development Plans, which includes the Government's Energy Efficiency Strategy to achieve a final energy demand reduction of 12% by 2015.[14] Also included is the current target of 10 000 GWh renewable energy contribution to final energy consumption by 2013.

The trajectory (shown in the next graph) shows that Current Development Plans do reduce emissions below Growth without Constraints initially. But when extended to 2050, however, the trajectory is not radically different from the Growth without Constraints Scenario - it still continues climbing. Emissions reach a level above 1500 Mt per year in 2050.

What can be learnt from this? Whilst an appreciable level of effort is apparent, it means that current Government policies do not lower the emission trajectory significantly below the Growth without Constraints Scenario.

[14] This is in line with the Energy Efficiency Strategy of the Republic of South Africa (DME 2005), which sets a higher target of 15% for some major sectors, notably industry, mining and commerce. The renewable target is taken from the White Paper on Renewable Energy (DME 2003).

SCENARIO 2
What if full-scale Mitigation was undertaken by South Africa?
The "Required by Science" story

If South Africa had all the resources and technology at its disposal to contribute to the global mitigation effort that is required to stabilise the climate, what could it achieve by 2050? What would the implications be if South Africa began to chart this course from 2007 onwards?

A note on modelling this scenario
The Required by Science scenario could not be modelled in the same way as the Growth without Constraints reference Scenario. The reason is primarily because this scenario depends on technologies and measures whose parameters are largely unknown, and therefore it cannot be assessed within a modelling framework based on known technologies with well-understood parameters, including cost. The LTMS process did not attempt to quantify the emission reductions or costs of behavioural changes, and so could not analyse the costs and other characteristics of this scenario. This scenario is therefore the classic "story of the future" with its components imagined rather than arrived at through the rigour of modelling.

In this scenario, called the Required by Science Scenario, South Africa joins the world community in taking action to stabilise GHG concentrations, and negotiates a target as its fair contribution to this shared vision.

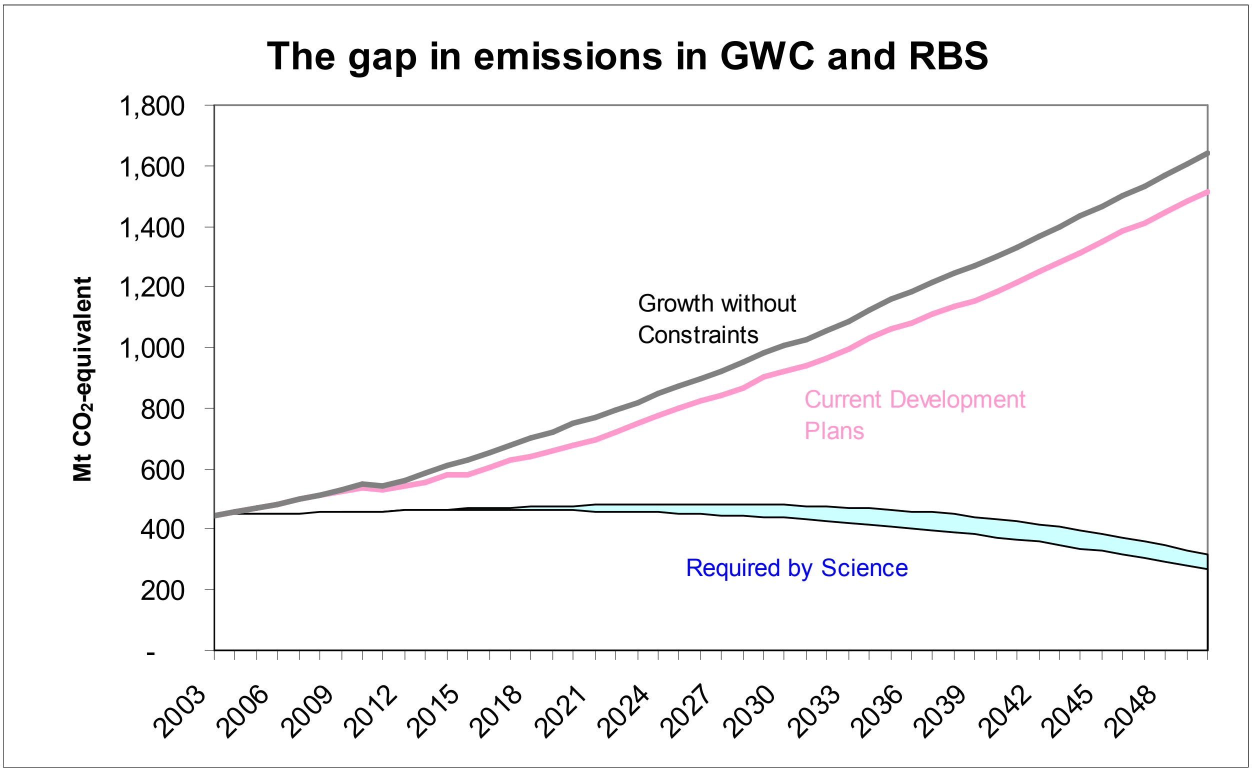
The IPCC[15] tells us that to stabilise GHG concentrat-ions, global reductions of between -60% to -80% from 1990 levels must be achieved by 2100.[16] The burden of sharing this target between nations is the subject of the international negotiations.

In the Required by Scenario, the burden taken up by South Africa is not exact, but is seen rather as a target band of between -30% to -40% from 2003 levels by 2050. A burden-sharing discount has been assumed i.e. that SA bears less than its proportional share of the global burden of reduction because it is a developing country.

The lower end of the target (-40%) can be thought of as a global or collective bottom line. The upper end of the target range suggests some differentiation in responsibility, depending on countries' different capabilities and different national circumstances. The target range can be made even wider, although this is not explored in the Required by Science Scenario.

By 2050 the Growth without Constraints Scenario and the Required by Science Scenario look dramatically different from each other, both in their picture of everyday life and in their respective emission trajectories.

[15] The Inter-Governmental Panel on Climate Change, the leading scientific body on climate change.
[16] At the time that the Scenario Building Team agreed this level for 2050, the IPCC's Fourth Assessment had not yet been published. The latest science suggests that, if anything, even greater reductions will be needed for the required stabilisation levels to avoid serious impacts.



As can be seen, there is a large gap between the emissions trajectories of the Growth without Constraints Scenario and the Required by Science Scenario. Growth without Constraints emissions grow exponentially, while Required by Science peaks quite early, in 2020, at around 470 Mt CO_2-eq, and then declines. The gap in 2050 represents some 1300 Mt per year of mitigation effort – the gap itself is three times larger than South Africa's total emissions in 2003.

The results show that even if a large burden-sharing discount is negotiated, the extent of the emissions reduction challenge does not shift significantly. The degree of the burden-sharing discount will be based on a number of factors:

- South Africa's status as a developing country and our imperative to reduce poverty.
- The coal-based nature of South Africa's energy economy and the degree of effort and cost to make the changes required.
- The extent to which the technological and financial resource transfers agreed in the Convention are realised.

It is assumed in this Scenario that South Africa does not have to take the same mitigation actions as the developed countries but, along with other major emitters in the developing world, it takes responsibility and quantifiable mitigation action commensurate with its level of development and national circumstances.

For South Africa, emissions would still rise at first, but they would have to peak at an appropriate level, and sufficiently early, to guarantee the required decline to the target range of this scenario. This implies large emissions reductions achieved through a coordinated mitigation programme at the national level with appropriate international assistance. In short, a high degree of planning is required in this scenario.

In turn the Required by Science Scenario assumes that climate security is guaranteed through joint international action. Developed countries reduce emissions by -80% from 1990 levels by 2050, enabling South Africa to limit its emissions to -30% to -40% of 2003 levels. South Africa suffers less dramatic climate change impacts, and experiences reduced costs for adaptation and lower direct damage costs.

The Required by Science Scenario sees a South Africa in 2050 vastly different to the one we know today. New technologies dominate the electricity generation and transport sectors, and the renewable and nuclear technologies encountered in the Growth without Constraints Scenario are taken up much earlier, and at a much larger scale. It is assumed that large-scale investment in new technologies across the globe will have substantially reduced the unit costs of technologies, for example renewables. New technologies, notably hydrogen-based transport, will by then be the norm, with hydrogen being manufactured through non-carbon means. Although the largest emissions reductions are achieved in the energy and fuel sectors, a good proportion of emissions reduction come about through widespread changes in human behaviour patterns that underpin GHG emission. Much of this is achieved through awareness, as most citizens will be acutely concerned about emissions and adopting low emission lifestyles.

In the sections that follow, more detail is provided on the likely characteristics of this scenario. To a large degree the Required by Science Scenario imagines a post-carbon world very different from ours, one that is therefore difficult to describe in detail. What we do know, however, is that achieving this emissions target range will be an immense task.

Assessing the scenarios for plausibility and robustness

How do the Growth without Constraints Scenario and the Required by Science Scenario relate to a future "real world in 2050"? Which scenario is more robust, and more plausible, in this future real world?

The table below shows under which conditions the two Scenarios can survive and be robust. The conditions for each scenario to flourish are given, and correspondingly the conditions for it to fail in the alternative context.

Growth without Constraints Scenario is only robust if:	Required by Science Scenario is only robust if:
▪ International climate consensus collapse/fragment ▪ Technologies not developed or don't flow freely ▪ Oil cheap and abundant, no carbon premium on coal ▪ Fragmented trade systems, bilaterals and free for all	▪ International climate consensus reached and effective ▪ International flows of appropriate technology/finance ▪ Peak oil arrives, oil scarce and expensive, coal premiums ▪ High degree of trade integration and globalisation

Growth without Constraints Scenario is really only likely if the world fails in its efforts around climate change, if oil remains cheap, and if South Africa can survive isolated from a carbon conscious world. The Required by Science Scenario flourishes on a broader spectrum, but does best where the world reaches agreement and where climate-friendly technologies come into the market and flow freely. It is only viable with international technology and financial support.

Both scenarios can only survive in the long run if climate impacts are kept to manageable limits. But as the Growth without Constraints Scenario is in fact a contributor to catastrophic impacts, it becomes implausible. The Scenario Building Team concluded unanimously that Growth without Constraints is neither robust nor plausible in a world that has come to grips with climate change.

This leaves Required by Science as the more robust and compelling scenario, and leads to the question: What has to be done to reach its goals, which are to reduce annual emissions by 1300 Mt CO_2-eq per year by 2050? What mitigation actions should South Africa take to reach this objective? What options are available? And what would the effect on our economy be of such actions?

LTMS proceeded by exploring groups of mitigation action options ('wedges') and considering their emissions reduction results and impacts on the economy. These were then assembled as packages of actions to inform strategic planning. Four such Strategic Options were packaged, and these are presented below.

Given that most emissions are attributable to the energy sector, most of the work was focussed on achieving reductions in this sector. However mitigation can be achieved across many sectors, not only through technology, but also through behaviour change. The first three LTMS Strategic Options explore wedges of emissions reductions in a wide range of sectors. They model currently known technology that can be costed. The relative size of the emissions reductions that are achieved illustrate where the biggest and most affordable mitigation actions can be carried out. These largest wedges are illustrated in the first three Strategic Options. Future technologies and human behaviour changes cannot be modelled by LTMS, but these elements are included in the fourth and final Strategic Option.

The methodology of arriving at Strategic Options

- The Scenario Building Team first considered individual mitigation actions, as wedges of emission reductions.
- The wedges were modelled, reported, refined and extended forward in time.
- Combining various wedges produced packages of action large enough to reveal distinct pathways.
- These modelled pathways formed the data-based Strategic Options.

Strategic Options for reaching the "Required by Science" objective

Four Strategic Options are now presented, which, when implemented together, would allow South Africa to achieve the Required by Science Scenario. The four Strategic Options are not presented in order of implementation or importance, and all of them would need immediate and significant effort.

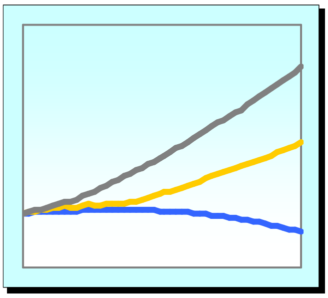
Each of the first three packages considers costs, emissions results, and economy-wide impacts. They emerged through a process of progressively modelling actions which would largely take place through state action. The first set of actions modelled, called the Start Now strategy, added no net cost to the economy against the Growth without Constraints base case. This suggested a clear imperative for pursuing this strategy.

However it was found that the Start Now strategy closed less than half of the gap between the Growth without Constraints and the Required by Science scenarios (44% in 2050). This prompted an extension, within the bounds of reasonableness and feasibility, of the Start Now actions. The results of this much more ambitious package closed two-thirds (64%) of the gap between the two scenarios.

The actions suggested by the four strategies can be summarised as follows:

Start Now	Suggests actions that save money over time.
Scale Up	Suggests further extension of the actions in Start Now, but adding more wedges with positive cost.
Use the Market	Additional to or replacing the first two options, suggests tax and incentive packages.
Reach for the Goal	Suggests a suite of parallel options, emphasising future technologies and behavioural change.

Strategic Option 1: "Start Now"



This strategic option suggests mitigation actions that are implemented through state action. The actions suggested should be taken for good economic reasons and other sustainable development co-benefits, quite independent of climate change. This option saves money over time, even if implemented up to 2050 (the orange line in the graph at left).

All net-negative cost wedges are good candidates for **Start Now**. Net-negative cost wedges are mitigation actions that have upfront costs, but where the savings over time more than outweigh the initial costs. Energy efficiency is the classic example.

In each case, the relevant sector would have to act to realise the wedges of emissions reduction. Each government department would have to consider policy and other actions needed to drive the emissions reduction action described in that wedge. Different sectors with their corresponding government departments would have to be involved in implementing sectoral plans.

The **Start Now** option goes beyond implementing or extrapolating existing policy. The analysis shows that quite substantial positive cost wedges can be included in the strategy, as these are offset by large negative cost wedges. The largest net-negative wedges are to be found in industrial energy efficiency. In the transport sector, for example, the **Start Now** option assumes that greater efficiency of vehicles is promoted and vehicle size is limited. Technological change allows a shift to hybrid vehicles, while at the same time behavioural changes are reflected in passengers shifting from private to public modes of transport.

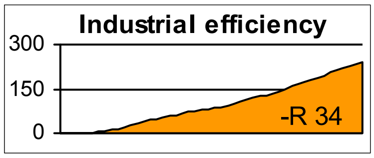
Energy supply sees a move away from coal-fired electricity, with renewables, nuclear and cleaner coal each providing 27% of electricity generated by 2050.

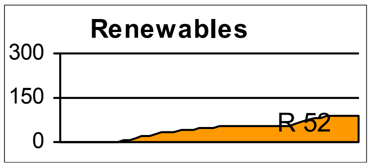
The biggest wedges for Start Now – in terms of emission reductions – are those shown in the diagrams on the left. The vertical axis of each wedge shows the emission reduction for any year from 2003 to 2050, while the area of each wedge represents the cumulative emission reductions over this period. The Rand figures on each diagram indicate the cost-effectiveness in R / t CO_2-eq. For **Start Now**, the biggest wedges are in efficiency in industry and transport (greater vehicle efficiency and shifts from private to public transport) as well as in more renewable sources and nuclear sources for electricity. More detail is given in the Technical Summary. Further wedges are illustrated in the Annexure to this document.[17]

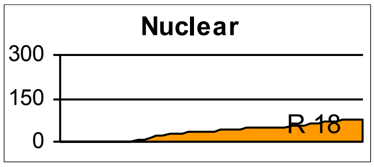
Emissions in **Start Now** are lower than in the Growth without Constraints Scenario – there is a *relative* reduction in emissions, with an average of about 230 Mt CO_2-eq avoided each year. However *absolute* emissions continue to rise, reaching around 1000 Mt by 2050, well over double the level of the base year (2003). Another way of thinking about this is to consider how much of the gap between the two scenarios is closed**.** **Start Now** reduces the gap by 43% in 2050.

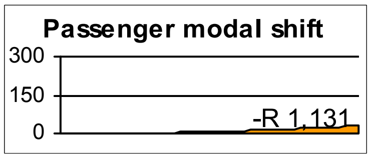
[17] The wedges in the Annexure are a fuller set than the major wedges shown in each Strategy Option. Variations on some wedges were also analysed – these are fully reported in the LTMS Technical Report.

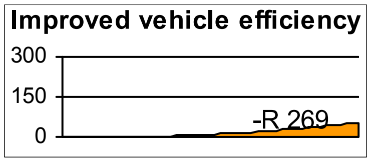
The overall cost of mitigation of the 'initial wedges' is a *saving* equivalent to 0.5% of the size of the economy, thus giving a net economic gain.[18] In the energy system, costs are reduced by 2.2% compared to Growth without Constraints.











The economy-wide impacts of **Start Now** can now be assessed. The impacts on GDP, on job creation and poverty reduction are revealed through economy-wide modelling. The modelling shows that **Start Now** has a relatively small impact on the economy, at least in the shorter period considered robust for economy-wide results (0.1% in 2015), and this is buoyed somewhat by the positive effects of increased energy efficiency. While the impact on jobs is negative, this again is small (-0.3%). Nevertheless even small job losses are of concern, and would need offsetting measures. The lowest figure is -2% for semi-skilled workers in 2010.

At the same time, household welfare rises 3% on average. The effects are not the same for all household types, since the greatest effect is to draw on household savings to finance new investment, which mostly comes from more affluent households. **Start Now** requires less saving, so high-income households benefit the most. One could call this an unintended consequence.

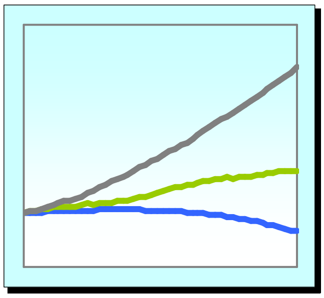
To enable **Start Now**, existing policy must be implemented, and aggressively. But under the **Start Now** strategy, South Africa would have to go further than existing policy, notably in diversifying its energy mix for both electricity and liquid fuels.

In short, **Start Now** is the obvious and economically imperative strategy option, even though it is institutionally challenging. But it is not sufficient to reach the Required by Science objectives by 2050, nor is it likely to be regarded as an adequate or fair contribution in the multinational negotiations. It runs the risk of creating an uncompetitive economy (as other economies and trade relations advance to climate-friendly technologies and trade rules), and leaving stranded assets in the economy. This is why it is called **Start Now**: the modelling shows it is a good start, with positive economy-wide results in the short term, and is good at least for the next decade. It would certainly be an appropriate strategy during a second commitment period under a Kyoto succession agreement. It would allow South Africa to demonstrate its commitment to making its development more sustainable – reducing emissions whilst not reducing GDP (some job losses are illustrated).

Start Now is thus a good Strategic Option for the first part of an overall mitigation plan.

[18] Mitigation costs are reported in various units. Unit mitigation costs (Rand per ton of CO_2-eq) reflect the difference in costs between the mitigation and reference case, averaged over the period and using a discount rate of 10%. The Technical Report shows results for discounting at 3% – the rate recommended by the IPCC for long-term mitigation analysis – and 15%, which is closer to a rate of return. To give a sense of the *total* mitigation cost, we compare the total increase (or decrease) in system costs to the size of the economy. In this context, the % GDP should not be understood as an impact on GDP, but is simply a way of comparing aggregate mitigation costs to the size of the economy.

Strategic Option 2: "Scale up"



The LTMS results for the **Start Now** Strategic Option showed that less than half the gap was closed in reaching for the **Required by Science** target. Thus an extension of the **Start Now** package of actions needed to be considered. The Scenario Building Team modelled two means of going further towards **Required by Science** – the first through state-led action (in Strategic Option 2: **Scale Up**) and the second through economic instruments (in Strategic Option 3: **Use the Market**).

The results suggest that South Africa should prepare for a scaling up of the actions taken in the early years of **Start Now**. Because such a scaling up would take the cost of acting into net-positive cost territory, a careful analysis of the impacts of this cost on the economy is required. In **Scale Up**, South Africa achieves this higher level of ambition through regulatory decision. The effect of this on the emissions trajectory can be seen in the green line on the graph – the trajectory gets about halfway to the objective if taken through to 2050.

The two strategies taken together can be thought of as "Energy Efficiency Plus". **Start Now** built some positive cost wedges on top of the negative cost ones. **Scale Up** goes further, adding further positive cost actions without significantly extending the negative cost ones. Unlike **Start Now,** which saved money while mitigating, **Scale Up** results in a cost of R39 per ton CO_2. However this cost is potentially affordable, being at the lower end of the range of prices already seen in the carbon markets.

The **Scale Up** strategy sees a transition to zero-carbon electricity by mid-century, with nuclear power and renewable energy wedges each being extended to 50% of electricity generated by 2050. Cleaner coal technologies, particularly IGCC, already enter the Growth without Constraints reference case, so the emission reductions of that wedge are modest. In the **Scale Up** strategy, however, the technology of carbon capture and storage matures, and is scaled up by a factor of 10 bigger than the largest currently planned facilities. Biofuels are extended as far as limits of arable land, water, and concerns about biodiversity and food security allow. As the country moves towards a zero-emissions electricity grid, electric vehicles provide a new transport technology that reduces emissions.

Scale Up leads to total emission reductions of around 13 800 Mt CO_2-eq between 2003 and 2050. Emissions follow the **Start Now** profile fairly closely at first, and continue to rise; but in the last decade they level out (plateau). **Scale Up** still does not, however, result in an overall decline in emissions – the 2003 emissions level almost doubles by 2050. Thus it too is only a partial solution. Under **Scale Up**, the gap is closed by two-thirds (64%) in 2050. Emission reductions become significantly larger than in **Start Now** around 2030, and in 2050 **Scale Up** reduces some 290 Mt CO_2-eq per year more.

The overall mitigation costs are equivalent to 0.8% of GDP[19] well below the benchmark suggested by the Stern Review on the economics of climate change. The Stern Review suggested that 1% might be acceptable, and that the costs of inaction would likely be much higher, at 5% to 20% of GDP. These are global figures, and developing countries may deem 1% of GDP too high an opportunity cost.

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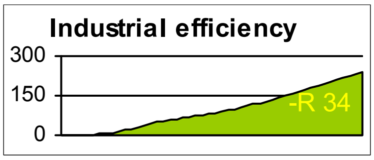
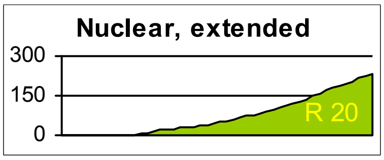
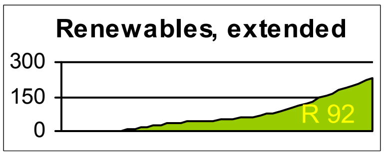
[19] Note that "% of GDP" in this analysis does *not* refer to the impact on the economy, but simply compares aggregate mitigation costs to the size of the economy.

Scale Up shows a positive impact on GDP initially, with a 1% increase in 2015. Employment broadly follows the GDP increase, with a 1% improvement in 2015. Low- and semi-skilled jobs increase, the latter peaking at 3% in 2015. However, there is a negative impact on household welfare: on average -1%, but slightly positive for low-income households (0.3%) and most negative for high-income households (-5.2%). Since greater investment is required in **Scale Up**, this again has to come from high-income households. The negative welfare effects under this scenario are generally small for other household groups, at least until 2015.

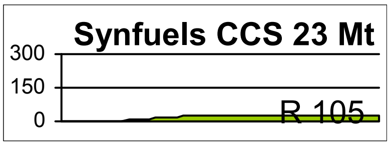


The big wedges in **Scale Up** again include industrial efficiency. Nuclear power and renewables for electricity give bigger emission reductions, but now at a higher cost per ton of CO_2 avoided. Renewable energy technologies show greater labour-intensity than other alternatives for generating electricity, and hence positive impacts on jobs (see the Technical Summary and Report).[20] New wedges are electric vehicles (which save emissions even if they operate in the same grid) and CO_2 capture and storage (CCS) for synfuels.

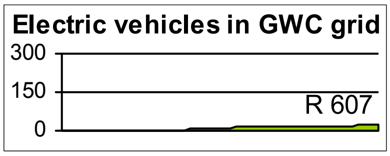




As regards national policy, **Scale Up** requires an ambitious plan for energy. Moving the energy economy, which currently relies on coal for three-quarters of primary energy, to zero-carbon electricity, is a massive undertaking. Under the **Scale Up** option, energy efficiency cannot be left to voluntary agreements, but must be guided by a policy framework and systems of penalties / incentives.

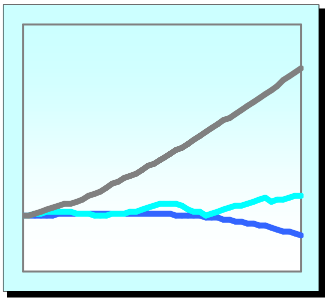


For the international negotiations, **Scale Up** is an 'ambitious-transitional' strategy. It is ambitious because it extends efforts well beyond existing plans. Yet it is transitional because the plateau arrives at a stage so late (2040-2050) as to be implausible in the negotiating context. This is why it could be examined in conjunction with other options, including the use of market-based instruments.



[20] Information on labour intensity or 'jobs per megawatt installed capacity' is obtained from a report by AGAMA (2003), which draws on Eskom for employment figures in various plants in 2003 and other energy statistics. For further details, see the Appendix to the Technical Report (section 13.2.2.2, p50), as well as the technical input paper on economy-wide modelling, p. 7.

Strategic option 3: "Use the Market"



The aim in this option is to get the market to work and promote the uptake of the accelerated technologies and social behaviour through incentives and taxes. At the tax levels considered in this option, **Use the Market** results in emissions reductions beyond those seen in **Scale Up** by using economic instruments – both taxes and incentives – to shift patterns of domestic investment. The key driver of **Use the Market** is a CO_2 tax – a price change which makes the use of fossil fuels much less attractive, and induces an indirect effect of greater investment in low-carbon technologies.

The Scenario Building Team considered various levels of CO_2 tax. The one included in **Use the Market** assumes that, over time, the price will rise from levels currently seen in carbon markets of R100 / t CO_2-eq. The rising tax level is designed to approximate a phase of slowing emissions growth, stabilising emissions and ultimately reducing absolute emissions through a high carbon tax of R750 in the last decade.[21]

Taxes generate revenues, and these can be used to provide incentives. For example, in **Use the Market**, much greater use of solar water heaters is incentivised. Instead of setting a target for renewables (as in the other two options), the cost gap is closed by 38c / kWh for renewable electricity.

The tax drives electricity supply to move away from coal to nuclear and renewables. No new coal plants are built and existing coal power supply declines rapidly from 2025, so that by 2040 only 4 GW of coal capacity is left. A total of 14 new conventional nuclear plants are built, adding 25 GW of new capacity by 2050. The renewables plants come in smaller units, but add a total of 118 GW by 2050 – 61 GW of solar trough, 42 GW of solar tower and 15 GW of wind. The price subsidy tilts the balance of alternatives towards renewables. By 2050 the total grid capacity is 151 GW, compared to 120 GW in the Growth without Constraints reference case.

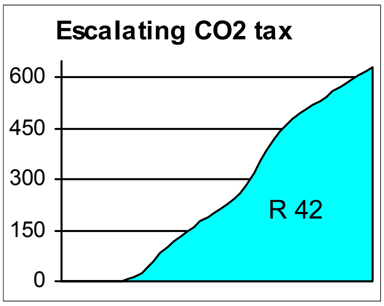
Under the **Use the Market** Strategic Option, with a CO_2 tax, no new CTL (coal-to-liquid) plant is built, but only new oil refineries – five of them. CTL plants would only be built if a significantly higher[22] oil price is assumed, and also if it is assumed that CCS was implemented at large scale or CTL became more carbon efficient by combining with other mitigation options such as biomass, other renewables, or nuclear.

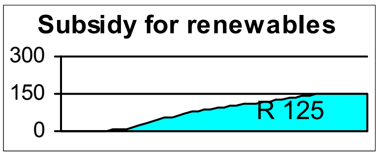
[21] The tax level starts at R100 / t CO2-eq in 2008 (current CDM prices) but rises to R250 in 2020 (prices already seen in the EU trading scheme); then flattens out as emissions growth in developing countries stabilises (2030 to 2040), before rising again to higher prices needed for absolute emission reductions in the long run (R750 from 2040 to 2050).
[22] The first sensitivity analysis on the oil price sees it rising from $55 / bbl in 2003 to $100 / bbl in 2030 and extrapolated at the same rate beyond. The second sensitivity rises to $155 / bbl in 2030. In the base case, the oil price is flat at the 2003 year level..

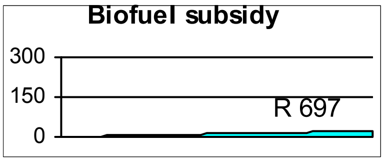
Use the Market reduces emissions by 17 500 Mt CO_2-eq between 2003 and 2050. Emissions in 2050 are 620 Mt CO_2-eq, closing the gap between Growth without Constraints and Required by Science by over three-quarters (76%).

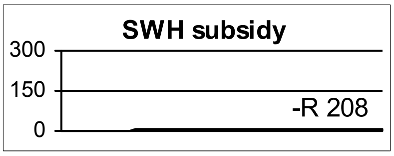
The major wedges in Use the Market are an escalating CO_2 tax, and incentives for renewables for electricity generation, biofuels and solar water heaters. Note that in the diagrams of wedges, the scale for the CO_2 tax is twice as big as for any other wedges shown – in 2050, it reduces emissions by more than 600 Mt CO_2-eq.

Use the Market includes taxes and incentives. Economic models see taxes as a distortion away from equilibrium. Hence the impact on GDP is negative (-2% in 2015). This finding is important, but taxes also generate revenues.









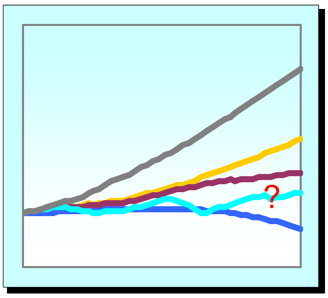
In Use the Market, jobs increase for lower-skilled workers (+3% semi-skilled, 0% for unskilled in 2015), but decrease for higher-skilled workers (-2% for skilled and -4% for highly skilled). This is due to the changes that are induced fairly rapidly by the tax. Welfare effects in Use the Market are negative overall, except for poorer households for whom it is neutral (0%).

Understanding the importance of revenue recycling is critical to a full understanding the economic impacts of Use the Market. At least at lower tax levels, spending revenue elsewhere could offset some of the negative impact on economic output. Given that the carbon tax is the biggest single wedge modelled, approaches that yield a triple dividend (growing the economy, creating jobs and improving income distribution) need further work.

While the carbon tax shows expected results on the supply side, the response on the demand side in the model is smaller than one would expect in reality. In particular, emissions from the industry and transport sector continue to rise throughout the period. Industry continues to use coal directly and only makes a limited switch to gas, and then only late, in the last decade. The use of petrol, diesel and jet fuel continues unabated in the transport sector, with the other options still too limited. For example, passenger cars can become electric, but electric trucks are not yet modelled.

These challenges are taken up in Strategic Option 4.

The Challenge of reaching "Required by Science"
Going beyond Strategic Options 1, 2 and 3



The Strategic Options considered so far are motivated by a long-term goal of reaching what is **Required by Science**. Yet it is clear that partial solutions to the climate challenge are pointless. They will involve great cost and will not solve any of the looming problems: failure to maintain competitive advantage, climate/political/trade risk, impacts and stranded assets. At the same time, even with an aggressive **Scale Up** of actions based on technologies we know and are able to cost (either driven by regulation or market), realistically the three Strategic Options suggested so far only get South Africa two-thirds of the way to the Required by Science goal. A parallel investigation of the "triangle of emissions" remaining from the middle to the end of the period may also provide new cost-effective solutions for the near term.

In addition, from about 2030 the levels of uncertainty are such that model results become less helpful. Beyond this point lie many questions for which answers are not apparent today. Sensitivity analysis was conducted on discount rates (reporting on three rates for each wedge in the Technical Report), lower economic growth assumptions and fuel prices (oil, gas, coal and uranium). The oil price has already increased significantly since the LTMS process started. Higher oil prices would make CTL more competitive and would also favour the adoption of alternative transport technologies, such as electric vehicles and hybrids.

While we expect that new technologies will emerge, we do not yet know what they will look like. Awareness of climate change may induce significant changes in people's patterns of consumption and behaviour – but to what extent? The fourth Strategic Option, **Reaching for the Goal**, lays the platform for getting these answers.

Let us summarise the combined effect of the first three Strategic Options over time. Both **Start Now** and **Scale Up** as strategies are reasonably close to the goal in the first half of the period, but diverge from Required by Science and from each other in the second half. Following these strategies until 2050 would foreclose the options of reaching the Required by Science goal. By around 2020 (this is not a prescriptive date, and is approximate) South African emissions should level out or plateau – and then decline at a later date. The third strategy, **Use the Market**, reduces emissions the most, but after 2035 falls short of the goal. So although **Scale Up** closes the gap between Required by Science and Growth without Constraints by roughly two-thirds (64%), and **Use the Market** gets us almost three-quarters (72%) of the way there, a 'triangle' of emission reductions remains unfulfilled. Hence a new set of options would have to be ready for implementation by this time. This Strategic Option would be pursued in parallel with the others. This is the **Reaching for the Goal** option.

Strategic option 4: "Reaching for the goal"

In the **Reaching for the Goal** option, exact costs cannot be modelled, nor can economy-wide impacts. The principal reason for this lies in the unknown technologies and behavioural changes that will have to mark this scale of emission reductions. Whilst it is acknowledged that the components of this strategic option cannot be modelled with any accuracy as was done with the other options, we can imagine what some of its salient characteristics might have to be, by 2050.

Four sets of actions are suggested, all requiring further study.

1: New Technology: investing in technologies for the future

The first set of actions refers to "new" technologies not yet modelled in LTMS. The Scenario Building Team chose a range of technologies not yet in the market, but which are at this stage "known", whether in the laboratory or already deployed in demonstration, and subjected them to the following test:

- Which show the most potential in achieving large emissions reductions?
- Which carry the lowest perceived technological risk?
- Which are likely to achieve extensive transfer internationally?
- Which appear to contribute most to the high emissions areas: electricity generation, transport, and industrial efficiency?

The study included a cursory pass at this problem, and a possible list of these technologies emerged. Stakeholders interested in how the Scenario Building Team developed the provisional technology list should look to the Process Report.

In **Reaching for the Goal**, technologies are seen as systems. Stand-alone technologies are integrated into larger systems, and taking a system view can increase savings. Technology interacts with human behaviour: An example would be a decentralised grid, in which citizens can generate their own electricity and pass surpluses back to the grid. Integrating distributed generation into the grid requires further research and development (R&D). Such efforts should build on the Department of Science and Technology's climate change R&D strategy.

These technologies require aggressive R&D effort, which should begin at the same time as the **Start Now** Strategy. Bringing these technologies *to the market*, *at scale*, *backed up by investment*, and driven by *appropriate policy*, is critical to **Reaching for the Goal**.

2: Resource identification: searching for lower-carbon resources

The second set of actions refers again to technology, but with the stress on resource availability. Here two technologies stand out: imported hydro energy from the Congo or East Africa, and natural gas from Kalahari and elsewhere. Significant gas found in the region would play a significant role in switching from coal. Security problems would have to be solved with imported hydro-electricity from our African neighbours. These two resource issues need further investigation, including the related political issues.

3: People-oriented measures: Incentivised behaviour change

One of the most compelling results of LTMS is that although most of the significant emissions reductions need to be within the energy sector, the technology-based actions, even when all carried out together, do not “close the gap”. Hence one must turn to the least studied of the possible options – social behaviour.

Changes in social behaviour, whether driven by policy, education, or awareness, may yet prove to have large scale and low cost mitigation effects. This may be so across a number of sectors.

- Human habitation, urban planning and the built environment are all areas where social change and new patterns, approaches and expectations will likely have significant mitigation effects.
- The distance between work, home and other life functions is also a factor.
- Modal shifts to public transport, moves away from individual car ownership towards the operation of shared vehicles, and other transport shifts deserve study. Business, commerce and consumption is currently heavily linked to transport of people. Much of this could potentially be replaced by, for example, internet-based interfaces.
- Food production and consumption, as well as the localisation of these activities, are also examples worthy of study.
- Population growth, but more importantly the growth of an urbanised population with high commodity expectations, could also be studied to see which changes may result in emissions reductions and how these might be driven.
- Tree planting and greening of towns is important.

4: Transition to a low-carbon economy: redefining our competitive advantage

Another compelling result from LTMS concerns the composition of the South African economy. The composition of the economy has played a major role in our high emissions, and any change in this and in our competitiveness, is worthy of further assessment. Perhaps the most difficult but most fundamental approach to mitigation would be to shift South Africa's economy away from its energy-intensive path. The LTMS results suggest that energy efficiency and a cleaner fuel mix are significant mitigation actions, but in the long run, the challenge is to consider the energy-intensity of our economy, structurally.

Considering this path would mean that instead of investing in energy-intensive sectors, which were at the heart of our economy over the twentieth century, South Africa would move towards a low-carbon economy. Industrial policy would then favour those sectors that use less energy per unit of economic output. Such a change would have to be integrated into the Department of Trade and Industry's National Industrial Policy Framework and Action Plan.

Over time, most economies shift from primary and secondary sectors to tertiary sectors. South Africa's GDP has already shifted significantly from mining through manufacturing to services. Associated with this shift is a decrease in energy intensity. Yet policy still tends to define competitive advantage around energy-intensive sectors. Climate change may require that we re-define what we mean by competitive advantage. This could have several dimensions.

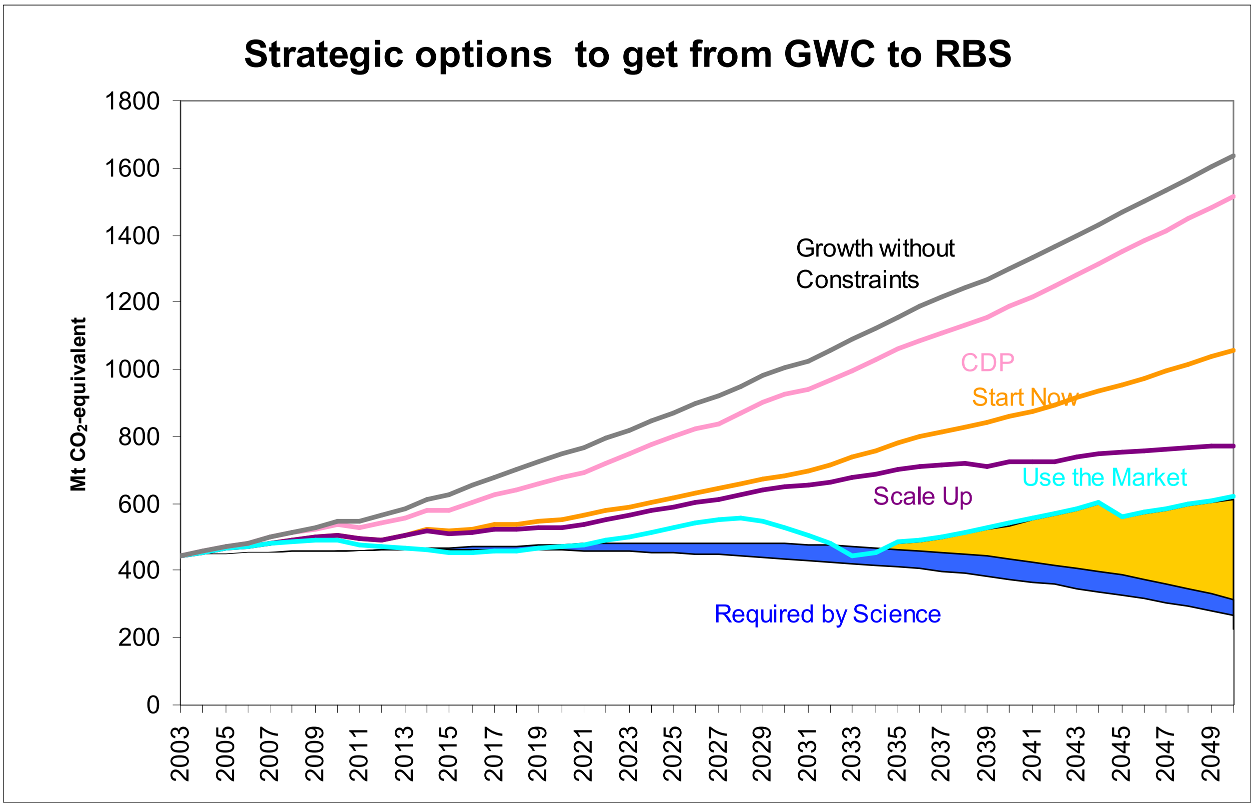
One dimension would be to focus on those parts of the economy which are not so sensitive to energy price rises. A transition to a low-carbon economy in South Africa might involve shifting incentives – removing incentives for attracting energy-intensive investments and using the resources freed up to promote lower-carbon industries.

A low-carbon economy will not emerge overnight. Energy-intensive industries will continue to exist, and a comprehensive strategy would have to include transition for these sectors and their labour forces. Policies to assist energy-intensive industry would include promoting higher value-added sectors, as well as ambitious energy efficiency targets (since the potential for energy savings are greater here).

More proactively, the transition would define new areas of advantage in climate-friendly technology. In much the same way as Brazil has become a world leader in biofuels, South Africa could deliberately seek to build new competitive advantage in climate-friendly technologies, such as solar thermal electricity or the pebble bed modular nuclear reactor (PBMR). The aim would be to become a market leader, with Government providing supporting measures.

Key findings

A key result of the LTMS process is how it reveals the large gap between where our emissions are heading and where they need to go. Even with various Strategic Options, a gap remains. **Start Now** would achieve around 43% of the goal; **Scale Up** gets us about two-thirds (64%) of the way from Growth without Constraints to Required by Science; and **Use the Market** closes the gap by three-quarters (76%). The remaining "triangle" of emissions challenges the exploration of new territory.



The key findings of the LTMS process, illustrated in the diagram, are:

1. Growing without carbon constraints may be good for South Africa's economic growth, but it will result in rapidly increasing emissions. A four-fold increase in emissions by 2050 is likely to be unacceptable to the international community. It is also a high-risk approach on other grounds, such as rising oil prices, carbon constraints in trade, and advancing impacts.

2. If all countries, including high emitters in the developing word, adopted a Growth without Constraints approach, climate change impacts in South Africa would be extensive.

3. A massive effort would be needed by South Africa to achieve emissions reduction sufficient to meet the Required by Science target. The gap between where South Africa's emissions are going and where they need to go is large (1300 Mt CO_2-eq, more than three times South Africa's annual emissions of 446 Mt in 2003).

4. Certain quantifiable strategic mitigation options are immediately implementable, even if they require significant effort. These include: energy efficiency, especially in industry;

electricity supply options; CCS; transport efficiency and shifts; people-oriented strategies; supported by awareness (see 'Next Steps' and the Annexure for details). These potential strategies show good emissions reduction results with costs to the economy ranging from affordable to significant. Significant mitigation action can have net public benefits, such as savings in energy bills and increased employment.

5. Within the quantifiable mitigation strategies, South Africa can choose both regulatory and economic instruments. Neither of these, however, completely closes the gap. With an escalating tax, economic instruments go the furthest in closing the gap – by almost three-quarters. But they are not intrinsically more effective than regulation.

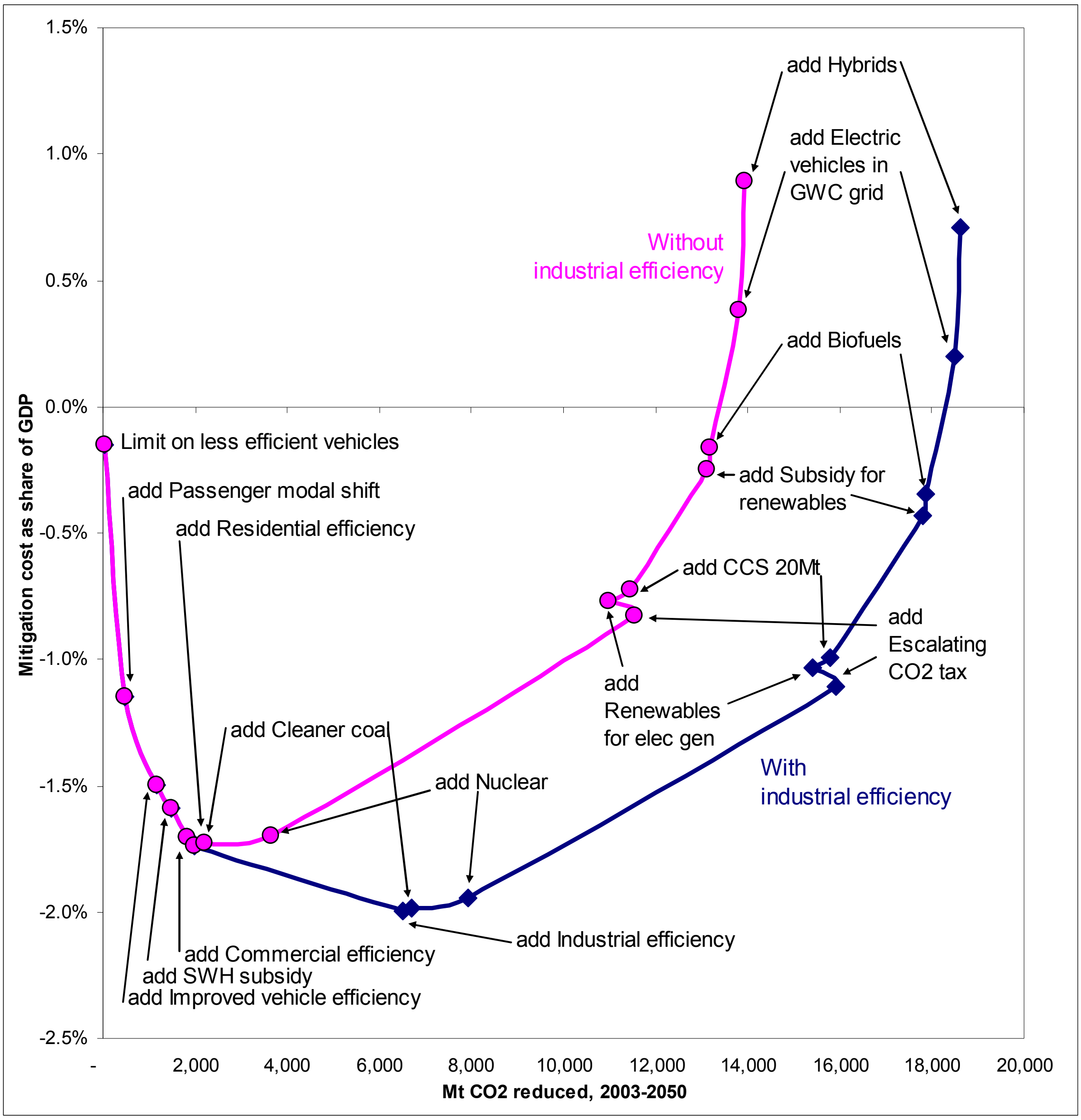
6. Preparing for a range of further, more uncertain and (for now) less understood actions – from future technology to changes in social behaviour – needs immediate exploration.

7. Key to success will be strong, committed and engaged South African leadership in government, business and civil society, coupled with international alignment and active support.

These findings have further implications in terms of cost and multilateral negotiations.

The cost implications of combined mitigation actions shown in the diagram is outlined in the Technical Summary (section 7.3). In essence, this compares the total mitigation costs over a 48-year period with the size of the economy. (As mentioned, "% of GDP" in this analysis does *not* refer to the impact on the economy, but simply compares aggregate mitigation costs to the size of the economy.)

Assuming the Stern threshold of 1% of GDP level were an acceptable overall cost to the South African economy, it is important to see where this level is crossed. This is calculated by adding different wedges incrementally, starting from the least-cost wedge. This is shown in the diagram below, with 'share of GDP' on the y-axis shown against the cumulative emission reductions on the x-axis.



As can be seen, combining a set of negative cost options – mostly energy efficiency in various sectors – makes the share of GDP more negative, so that the curve initially slopes downward. The diagram shows that a range of positive cost wedges, such as those for electricity generation or CCS, can be added with the combined costs still remaining below 0% of GDP.

The key findings also have implications for negotiations. LTMS concluded that the trajectory illustrated in the graph above for **Required by Science** is not realisable with currently known technologies. The question is how to get South Africa's emissions, after a period of unavoidable increase, to plateau and then to drop. Here two areas of "flexibility" appear. The first is: what is the "negotiating region" for the final goal set in the **Required by Science** trajectory? This could be anything between say -10% of current emissions and the full, undiscounted goal of -50%. The latter is not only what the latest science says is required, but is also currently under discussion in political circles, e.g. the G8+5 process. This "discount" means that other richer developed nations will have to reduce emissions more, hence allowing South Africa to do less.

The second area of flexibility is: when and how high do South Africa's emissions peak? It is clear that if the peak is too high, the decline is harder to achieve – likewise if the peak comes too late.

Arresting the emissions trajectory at the correct point at some time around the middle of the period becomes the subject of further planning. By implementing the **Start Now** and **Scale Up** or **Use the Market** options, South Africa will create the time to develop the strategies that will achieve the peak and decline of emissions.

The full implications for negotiators on the international front need to be further explored by the delegation. The LTMS process has analysed a range of quantifiable mitigation objectives, which provide information for South Africa to negotiate.

For domestic policy makers, business leaders and leaders in South African society, LTMS has revealed that action will be required across the board, and extensive further work is required. These are described in the final section below as Next Steps.

Next steps

Scenarios can help inform long-term policy choices and negotiating positions – particularly when underpinned by the rigorous analysis presented in the LTMS Technical Report. Regardless of the pathway chosen by South Africa, some "across-the-board realities" emerge, suggesting a list of next steps.

The LTMS process has presented two starkly different scenarios. The first step will be for a high level group of leaders to add their inputs to the LTMS study. The scenarios and strategic options, possibly in revised form, will then be presented to the South African Cabinet.

It is suggested that the next step will be to make a move towards a development path consistent with one of the two scenarios presented. If the **Required by Science** Scenario is to be followed, as suggested in this study, a number of steps must follow.

1. Energy Efficiency is a component of all the strategic options in the **Required by Science** scenario. Energy Efficiency can deliver large and smart mitigation. Indeed, all the suggested strategies can be thought of as "Energy Efficiency plus". Although economically obvious, voluntary agreements only work to a degree. Hence tough motivators will have to be introduced, some of which have already been suggested in the Energy Efficiency Strategy (DME 2005). Detailed design of such motivators requires urgent work and rapid implementation.

2. In electricity generation, the technology choice is fairly clear: there are two key domestic alternatives to coal. (Energy imports are another option but these come with key uncertainties – e.g. political stability for hydro-electricity from the DRC, and questions as to whether the Kalahari gas reserves are real.)

    - The challenges for nuclear power outlined in draft policy[23] include radioactive waste disposal, maintaining non-proliferation, and economic viability. If these can be resolved, the expansion of nuclear power is an obvious choice. The nuclear building programme will be financed, like other capital investment projects, through raising debt. For the pebble bed modular reactor (PBMR), government has committed to finance 51% of the capital requirements over the next three years.

[23] DME published a nuclear energy policy and strategy for public comment, July 2007.

- An equivalent scale of investment is needed in various renewable energy technologies. The challenge here is to scale up in the next years, so that implementation at larger scale is feasible and more affordable in future. The central problem is cost – and much depends on what technology learning happens in other countries (see the Technical Report). Renewable energy technologies face challenges due to intermittency of the source and dispatchability, which at larger shares may require additional investment in the system, e.g. storage. The Solar Power Tower shows most promise and may even have base-load potential.
- Cleaner coal appears to reduce emissions by relatively small amounts, unless accompanied by Carbon Capture and Storage (CCS).

3. Transport is the fastest growing emitting sector. It poses the most complex challenges, because it encompasses fuels, vehicle technology, infrastructure, as well as behavioural changes. Biofuels cannot solve the problem at any scale. An overall package needs to be designed, addressing a range of interventions in the sector. This package would have to look at the two large mitigation wedges as principal motivators: modal shifts in the way human and freight movement is achieved, and technology transfer away from petrol and diesel. Electric vehicles and hybrids provide efficiency gains over conventional engines, and hydrogen cars emit no GHGs at the point of use. The extent of mitigation will depend on the energy source from which the electricity, biofuel or hydrogen that power them is derived. Central and decentralised options need to be covered.

4. Carbon Capture and Storage (CCS) is important and requires some attention and support. It is clear that CCS is a large part of the solution for both CTL and coal-based electricity, and hence is included as a major component of our energy security strategy. CCS needs to address challenges and uncertainties, including technical, geological, economic, environmental impacts and the regulatory framework – but above all, it needs to prove whether it can scale up by a factor of 10 or 100.

5. These are the big mitigation interventions. But there are also many smaller activities that deliver cost-effective mitigation, such a manure management in agriculture (see the Annexure for an overview). Others are important to their sectors for their own reasons, e.g. fire control. A balanced portfolio should include wedges that have socio-economic/sustainable development benefits, notably in the residential sector. A number of government departments will have to address those activities which show most promise in their sectors.

6. Several strategic options require immediate support and further research:
   - Social behaviour change
   - Emerging technologies
   - Resource identification
   - Inducing a transition to a low-carbon economy

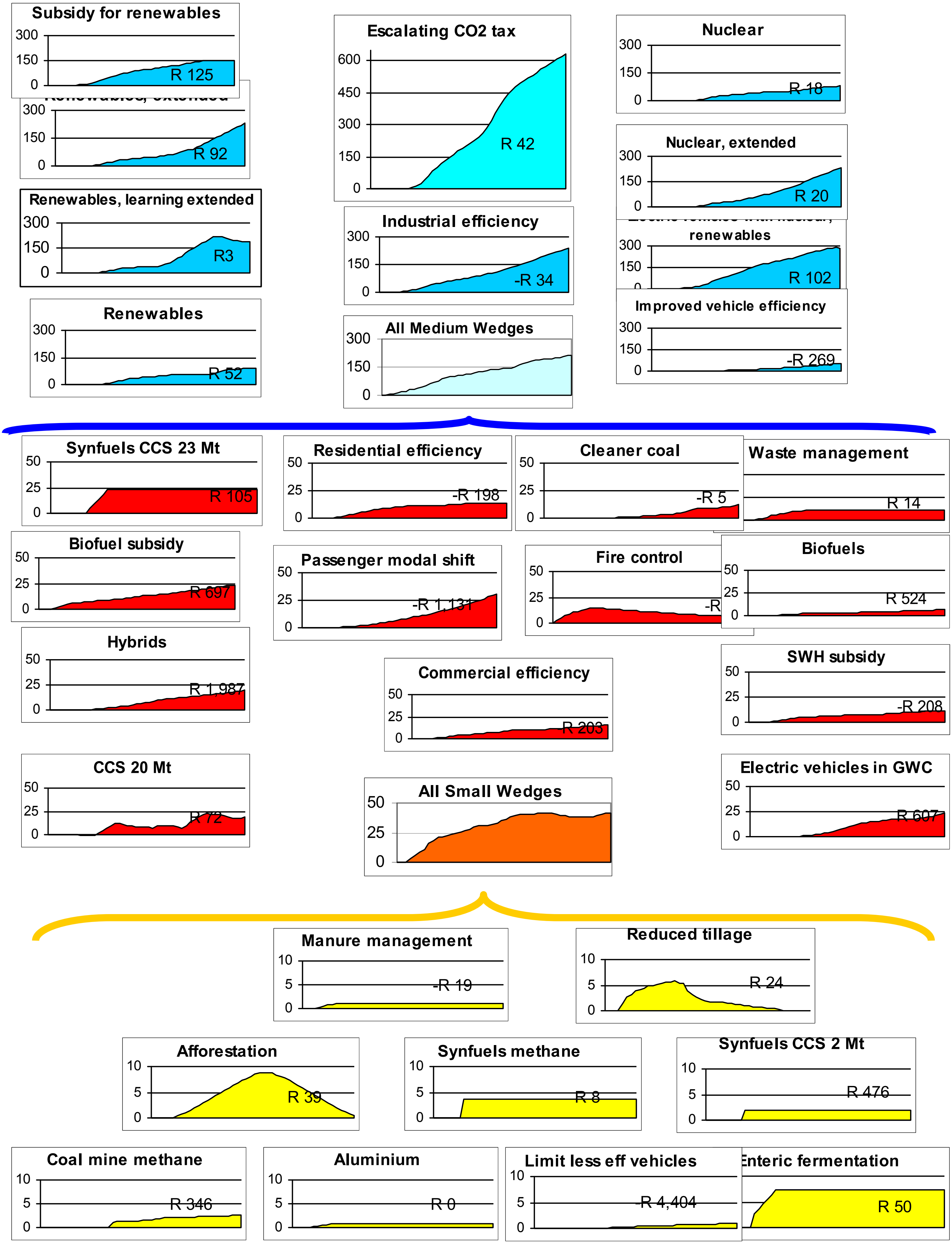
   Achieving changes in social policy and behavioural change would require focused public awareness raising.

7. The damage costs of climate change impacts under different concentration scenarios requires further research as the state of knowledge matures.

None of the technologies, policies and measures highlighted above is a 'silver bullet'. Investment will be needed in a portfolio of mitigation actions. These strategic choices about investment and technology will need to be guided by a long-term policy framework. Cost-effective solutions can best be found when policy guidance is 'loud, long and legal' and comprises a smart mixture of regulatory and economic instruments.

A further logical step would be to finalise, on the basis of the parameters presented in the LTMS, a long-term climate policy for the country. This would require a more formal policy process, on the basis of which government would choose a strategy. This strategy may be a combination or variant of the wedges presented here. The strategy could form the basis for a legislative and policy package which will give effect to such policy at a mandatory level. This domestic process of policy making will closely interact with the international negotiations over the next two years. Between 2007 and 2009 a strengthened climate regime for the period after 2012 will be negotiated under the UNFCCC and its Kyoto Protocol.

The climate challenge can be easily presented in desperately pessimistic terms, or its existence can simply be denied. The Scenario Building Team has done neither. It was determined to accept fully the current science as a basis to proactively engage in climate action. The scenarios and strategies presented here are positive and ambitious but realistic pathways which can meet the expected demands of the multinational negotiations.


Subsidy for renewables
300
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0
R 125
300
150
0
R 92
Renewables, learning extended
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150
0
R3
Renewables
300
150
0
R 52
Escalating CO2 tax
600
450
300
150
0
R 42
Industrial efficiency
300
150
0
-R 34
All Medium Wedges
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150
0
Nuclear
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150
0
R 18
Nuclear, extended
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150
0
R 20
renewables
300
150
R 102
Improved vehicle efficiency
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150
0
-R 269
Synfuels CCS 23 Mt
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25
0
R 105
Residential efficiency
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25
0
-R 198
Cleaner coal
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25
0
-R 5
Waste management
R 14
Biofuel subsidy
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0
R 697
Passenger modal shift
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25
0
-R 1,131
Fire control
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25
0
Biofuels
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25
0
R 524
Hybrids
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25
0
R 1,987
Commercial efficiency
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25
0
R 203
SWH subsidy
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25
0
-R 208
CCS 20 Mt
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25
0
R 72
All Small Wedges
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25
0
Electric vehicles in GWC
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25
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R 607
Manure management
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5
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-R 19
Reduced tillage
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5
0
R 24
Afforestation
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5
0
R 39
Synfuels methane
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5
0
R 8
Synfuels CCS 2 Mt
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5
0
R 476
Coal mine methane
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R 346
Aluminium
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0
R 0
Limit less eff vehicles
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5
0
-R 4,404
Enteric fermentation
R 50