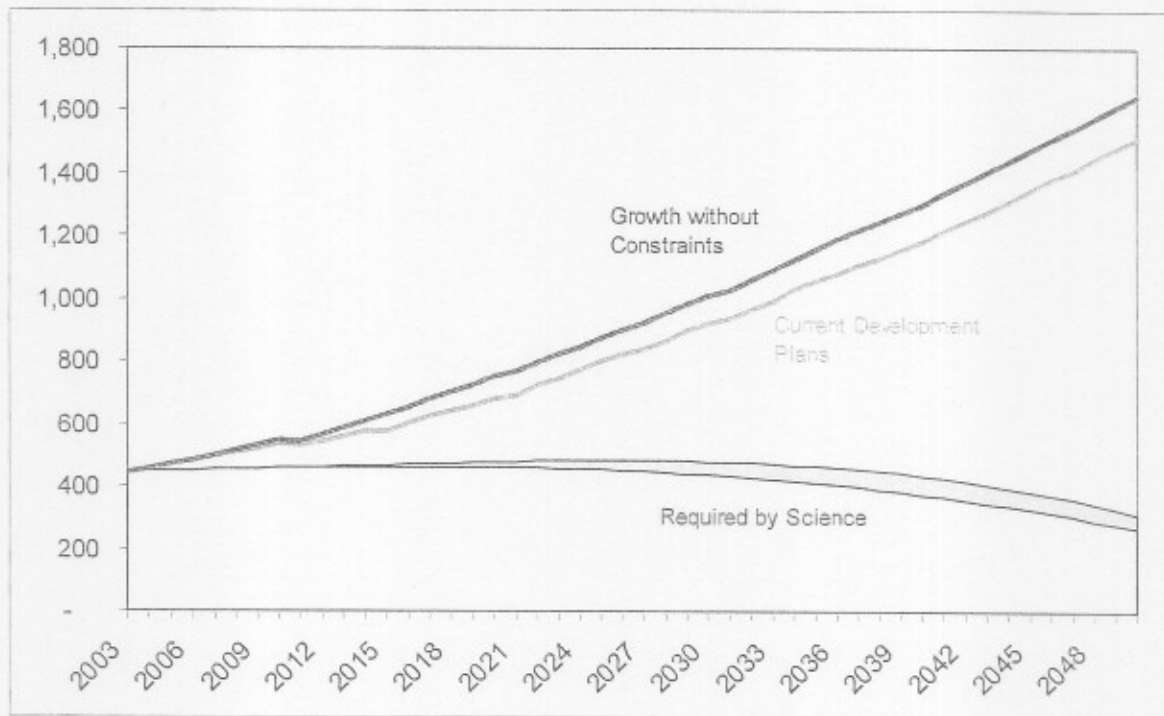


Comparing the Scenarios' emission trajectories, introducing current efforts

The two Scenario stories look dynamically different by 2050 both in everyday life and also in terms of the respective emission trajectories. The graph below shows the **Growth without Constraints** trajectory compared with the line representing the target range for **Required by Science**.

A further trajectory, called **Current Development Plans** is added: this assumes that existing government policy is implemented. For example, energy efficiency interventions achieve a final energy demand reduction of 12% by 2015.¹³ The target of 10 000 GWh renewable energy contribution to final energy consumption by 2013 is also included. Current efforts do reduce emissions below GWC initially. When simply extended to 2050, however, the diagram illustrates that the trajectory under the **Growth without Constraints** story would not be radically changed: it would still continue climbing, and would still see emissions reach a point above 1500 Mt.



What can we learnt from this? Firstly it can be seen that the current Government policies do not significantly lower the **Growth without Constraints** trajectory in the long-term, whilst the appreciable level of effort is apparent.

Secondly, and more significantly, the emissions trajectories of our two Scenarios reveal a *large gap*. While one Scenario's emissions grow exponentially, the other peaks quite soon around 470 Mt CO₂-eq in 2020, and then declines. The gap in 2050 represents

¹³ 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 from the White Paper on Renewable Energy (DME 2003).

some 1300 megatons of mitigation effort. What is significant is that this gap is three times larger than South Africa's total emissions in 2003.

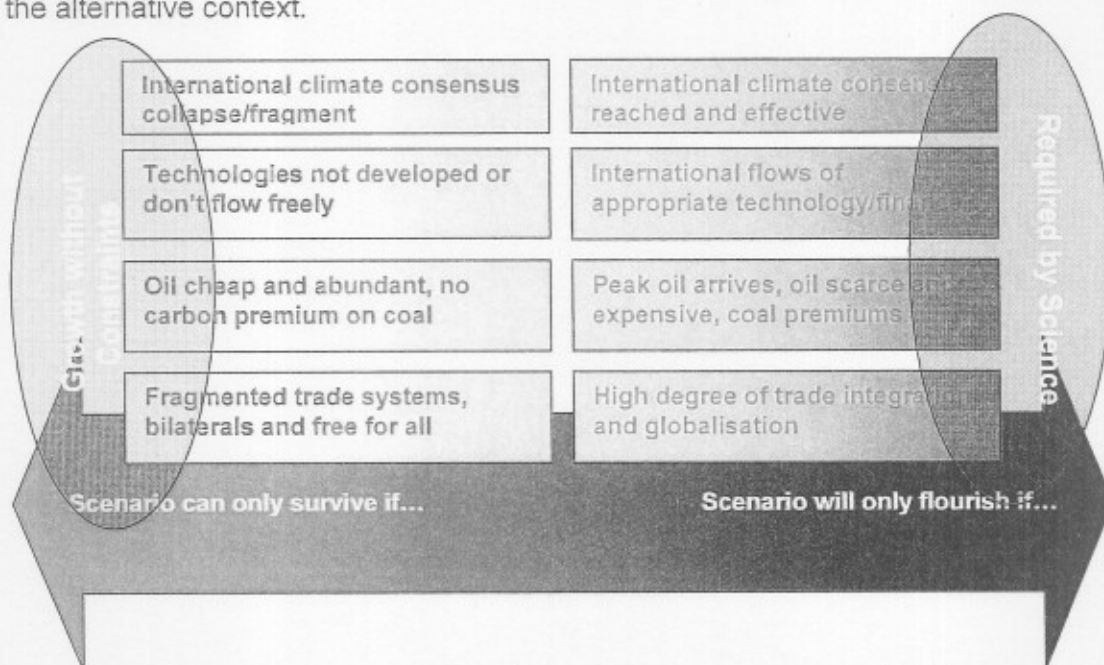
Assessing the two Scenarios for plausibility and robustness

The two Scenarios are now assessed for plausibility and robustness with the overall question: how the Scenarios relate to a possible future "real world in 2050".

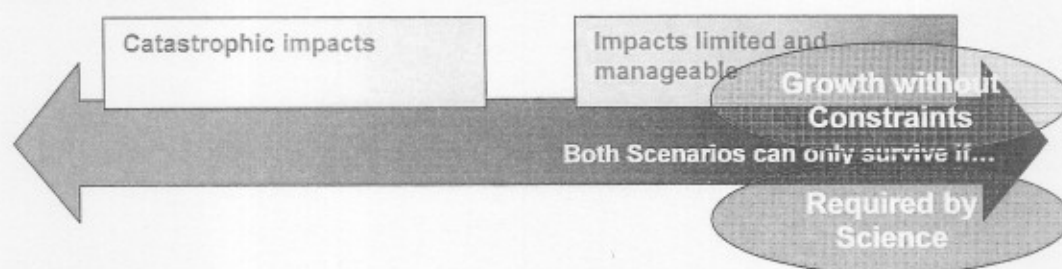
Stakeholders interested in how we developed these external contexts can look at the Process Report for details.

Thus far the Scenarios are described without any judgement. Both will be difficult to achieve and both assume many barriers are overcome. But how do the two stories perform, respectively, against the external worlds they are likely to encounter between now and 2050? Which Scenario is more robust, and more plausible, against the various possible backdrops?

A simple diagram shows how a series of alternative contexts in 2050 affect the two Scenarios. Each Scenario is placed where it will flourish, and correspondingly it will fail in the alternative context.



The diagram reveals that our **Growth without Constraints** scenario really only flourishes 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. **Required by Science** 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. Add to this the impacts assessment and a plausibility issue arises:



Both Scenarios can only survive in the long run if climate impacts are kept to manageable limits, and as the Growth without Constraints scenario is in fact a contributor to the catastrophic impacts it cannot survive with, it becomes implausible in this context. The Scenario Building Team was unanimous in suggesting the conclusion that the Growth without Constraints was neither robust nor plausible in a world that had come to grips with climate change.

Given that Required by Science is the more robust Scenario, what would have to be done to reach for the goals it describes?

To reach for goal of the Required by Science objective we need to find strategies over time which will in effect reduce annual emissions by 1300 Mt CO₂-eq by 2050. The question that arises is: What mitigation actions can 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 on the basis of exploring groups of mitigation action options, or wedges, considering the emissions reduction results, and impacts on the economy. These are then assembled as packages of actions. These packages suggest strategic options, and should inform strategic planning. Four such Strategic Options are packaged. Given that most emissions are attributable to the energy sector, most work was done to achieve reductions in this sector. But mitigation can be achieved across many sectors, through both through technology and behaviour change. LTMS can model known technology that can be costed, but not future technologies and human behaviour changes. These latter two elements are contained in the final Strategic Option set out, but in the first three LTMS explores "wedges" of emissions reductions in a wide range of sectors. The relative size of the emissions reduction that are achieved illustrate (see diagram below) where the low-hanging fruit (biggest mitigation actions) are. These largest wedges are illustrated in the first three Strategic Options.

A word on methodology:

- The SBT first considered individual mitigation actions, seen 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 that they reveal a distinct pathway.
- These modelled pathways form the data-based Mitigation Strategies.

Strategic Options for reaching the "Required by Science" objective

The following packages of information suggest Strategic Options which could form part of the plan suggested in the Required by Science Scenario. Each of the first three packages considers costs, emissions results and economy-wide impacts.

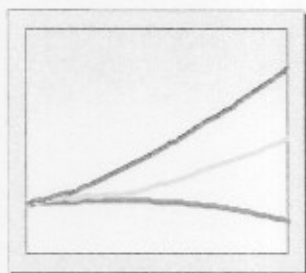
The packages of information emerged through a process of progressively modelling actions, which would largely take place through state action. What emerged was the following: a first set of actions modelled came in at no net cost to the economy against the Growth without Constraints base case, suggesting that as a strategy it was a clear

imperative. But the **Start Now** strategy closed under half of the gap between GWC and RBS (44% in 2050). This prompted an extension, within the bounds of reasonableness and feasibility, of the actions. The results of this (now much more ambitious package) closed two-thirds (64%) of the "gap" between the scenarios.

Three packages are explored first. The Strategic Options are not presented in order of implementation or importance, and it is suggested that all need immediate and significant effort.

Start Now	Suggests actions that are save money over time.
Scale Up	Suggests further extension of the actions in Start Now, but adds more wedges with positive cost
Use the market	Suggests tax and incentive packages
Reach for the Goal	Suggests a final suite of options, emphasising future technologies and behavioural change

Strategic Option 1: "Start Now"



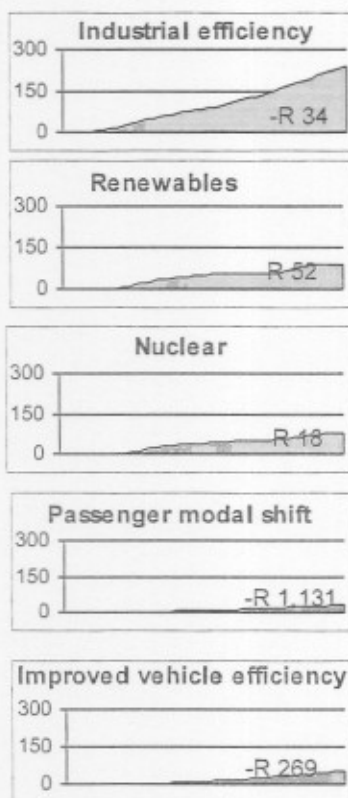
In the first of the strategic options, mitigation actions are suggested that are implemented through state action. The actions suggested should be taken for good economic reasons and other sustainable development co-benefits, quite independent of climate change. As a package this option saves money over time, even if pushed right along to 2050 (the orange line in the small graph at left).

Net-negative cost wedges are obvious candidates for **Start Now**. By "net negative cost wedges" we mean 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 sector would have to act to realise the wedges of emissions reduction. Hence each government department would have to consider the policy drivers and other actions which would drive the emissions reduction action described in that wedge. Sector players would have to be involved in making each sector perform to plan. Most government departments are involved in this process.

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, since large negative cost wedges save money – the largest being industrial energy efficiency. In the transport sector for example, greater efficiency of vehicles is promoted and vehicle size is limited. Technological change sees a shift to hybrids and behavioural changes are reflected in passengers shifting from private to public mode. 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 – in terms of emission reductions – are shown in this diagram for **Start Now**. The height of the wedge shows the emission reduction in each year, while its area represents the cumulative emission reductions from 2003 to 2050. The Rand figure



on the wedges indicates the cost-effectiveness in R / t CO₂-eq. For **Start Now**, the biggest wedges are in efficiency in industry and transport (greater vehicle efficiency and shifts in modes) and renewables and nuclear for electricity. More detail is shown in the Technical Summary and further wedges illustrated in the Annexure to this document.¹⁴

Emissions in **Start Now** are lower than in the **Growth without Constraints** scenario, i.e. there is a *relative* reduction in emissions. An average of about 230 Mt CO₂-eq are avoided each year. Yet *absolute* emissions would continue to rise, reaching around 1000 Mt by 2050, well over double the levels in 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.

The overall **cost of mitigation** of the 'initial wedges' is a saving equivalent to 0.5% of the size of the economy, giving a net economic gain.¹⁵ In the energy system, costs are reduced by 2.2% compared to GWC.

The economy-wide impacts of **Start Now** can now be assessed. The impacts on GDP, on job creation and on poverty reduction are considered. The following results are revealed through economy-wide modelling.

Start Now shows relatively small impact on the economy, at least in the shorter period considered robust for economy-wide results (0.1% in 2015), buoyed somewhat by the positive effects of increased energy efficiency. While the impact on jobs is negative, this is again small (-0.3%). Even small job losses are of concern, and would need off-setting measures. The lowest figure seen is -2% for semi-skilled workers in 2010. At the same time, household welfare rises 3% on average. The effects are not even for different 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 in addition, under this strategy South Africa goes further than existing policy, notably in diversifying its energy mix for both electricity and liquid fuels.

¹⁴ The wedges in the Annexure are a fuller set than the major wedges shown in each Strategy. However, variations on some wedges were also analysed, which are fully reported in the LTMS Technical Report.

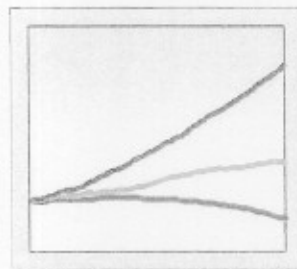
¹⁵ Mitigation costs are reported in various units. Unit mitigation costs (Rand per ton of CO₂-eq) reflect the difference in costs between the mitigation and reference case, averaged over the period and using a discount rate of 10%. The Technical Report shows results for discounting at 3% - recommended by the IPCC for long-term mitigation analysis - and 15%, 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 is not an impact on GDP, but a means of comparing the scale of large investment to the entire economy.

In short, **Start Now** is an obvious, intuitive and economically imperative strategy option, albeit still an institutionally challenging one. But there is a problem if it is all South Africa aims for by 2050. It is unlikely to be regarded as an adequate or fair contribution in the multinational negotiations. It runs the risk of creating an uncompetitive economy over time (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**: it is a good *start*, has positive economy wide results in the short term, and is good for the next decade or so. It could certainly be an appropriate strategy during a second commitment period under a Kyoto succession agreement. South Africa would demonstrate its commitment to making its development more sustainable and thus reducing emissions, whilst not reducing GDP (some job losses are illustrated).

This could be the first part of an overall plan.

Strategic Option 2: "Scale up"

Given that the LTMS results for the **Start Now** strategic option showed that less than half the gap is closed in reaching for the **Required by Science** target, a further extension of the **Start Now** package of actions was modelled. The Scenario Building Team considered two means of going further towards **Required by Science** – through State-led action (in Scaling Up) and through economic instruments (in Strategic Option 3: Using the Market)



The results suggest that South Africa could prepare for a scaling up of the actions contained in the first approach during the early years of **Start Now**. Given that this scaling up takes the cost of acting into positive cost territory, a careful analysis of the impacts of this cost on the economy is required. In **Scale Up** South Africa increases its level of ambition, and achieves it through regulatory decision. The effect of this on the emissions trajectory can be seen in the green line on the graph, and gets about halfway to the objective if taken through to 2050.

The cumulative strategies can be thought of as "Energy Efficiency plus". **Start Now** built some positive cost wedges on top of the negative cost ones. **Scale Up** now goes further, adding further positive cost actions – without significantly extending the negative cost ones. While **Start Now** saved money while mitigating, **Scale Up** results in a cost of R 39 per ton CO₂ – a positive cost at the lower end of the range of prices already seen in the carbon markets: it is potentially affordable.

The **Scale Up** strategy sees a transition to zero-carbon electricity by mid-century. Nuclear power and renewable energy wedges are each extended to 50% of electricity generated by 2050. In other words, Cleaner coal technologies, particularly IGCC, already enter the Growth without Constraints reference case, so the emission reductions of that wedge are modest. In this 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. Electric vehicles provide a new transport technology that reduces emissions, given the move to a zero-emissions grid.

Scale Up leads to total emission reductions of around 13 800 Mt CO₂-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 or 'plateau'. **Scale Up** still does not, however, result in an overall decline in emissions – 2003 emissions almost double. Thus once again it 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, this Strategic Option reduces ca. 290 Mt CO₂-eq more.

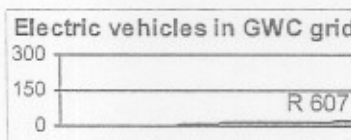
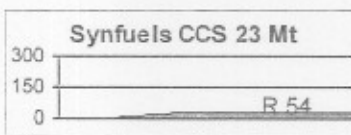
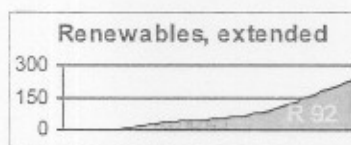
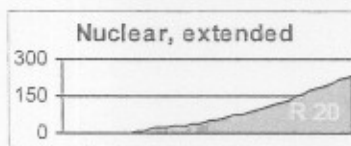
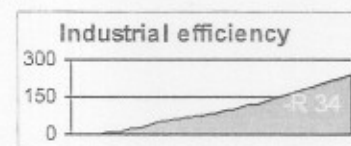
The overall **mitigation costs** are equivalent to 0.8% of GDP. This is well below the benchmark suggested by the Stern Review on the economics of climate change, which suggested that 1% might be acceptable, and that the costs of inaction were likely much higher at 5% - 20% of GDP. These are global figures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

Scale Up shows a positive impact on GDP initially, 1% in 2015. Employment broadly follows the GDP story, with a 1% improvement in 2015. Low- and semi-skilled jobs increase, with 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 (-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 up to 2015.

Big wedges in **Scale Up** again include industrial efficiency. Nuclear power and renewables for electricity give bigger emission reductions, but also at higher cost per ton of CO₂ 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 on economy-wide modeling).¹⁶ New wedges are electric vehicles (which save emissions even if they operate in the same grid) and carbon dioxide capture and storage (CCS) for synfuels.

For 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. In this option, energy efficiency cannot be left to voluntary agreements, but must be guided by a policy framework and systems of penalties / incentives.

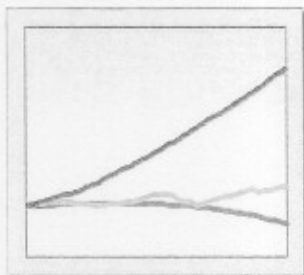
Scale Up is an ambitious-transitional strategy for the international negotiations. The actions taken are ambitious, extending efforts well beyond existing plans and what the



¹⁶ 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 detail, see the Appendix to the Technical Report (section 13.2.2.2, p50), as well as the technical input paper on economy-wide modeling, p. 7.

country should do anyway. Yet it is transitional since the plateau arrives at a stage so late (2040-2050) as to be implausible in the negotiating context. Other options need to be examined, including using market-based instruments.

Strategic option 3: "Use the Market"



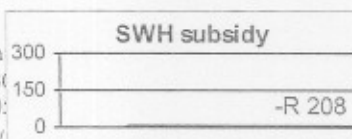
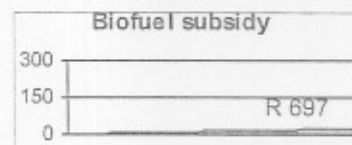
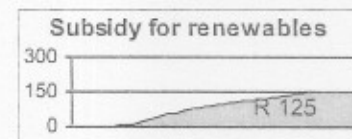
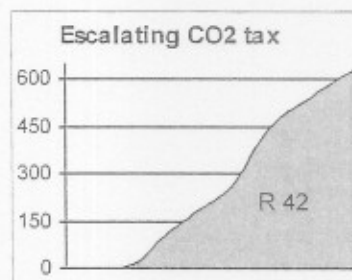
The aim in this option is to get the market to work and promote the uptake of the accelerated technologies and social behaviour through incentives and taxes. At the tax levels considered here, *Use the Market* results in emissions reductions beyond those seen in *Scale Up*. *Use the Market* thus includes a package that prepares South Africa to make use of economic instruments – both taxes and incentives – to shift patterns of domestic investment. The key driver of *Use the Market* is a CO₂ tax. This price change 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 CO₂ tax. The one included in *Use the Market* assumes that over time, the price will rise from levels currently seen in carbon markets of R 100 / t CO₂-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 R 750 in the last decade.¹⁷

Taxes generate revenues, and these can be used to provide incentives. In *Use the Market*, for example, 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 38 c / kWh for renewable electricity.

The tax drives electricity supply to move away from coal to nuclear and renewables. No new coal is built and existing coal declines rapidly from 2025 and by 2040, only 4 GW of coal are 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 at that time – 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. The total grid is 151 GW, compared to 120 GW in the GWC reference case.

In this Strategy, with a CO₂ tax, no new CTL plant is built, but only new oil refineries – five of them. CTL would only be built if we assumed a significantly higher¹⁸ oil price, CCS was



¹⁷ The tax level starts at R 100 / t CO₂-eq in 2008 (current CDM prices) but rises to R 250 in 2034 (current trading scheme); then flattens out as emissions growth in developing countries stabilises (2034-2040); then rises to R 750 in 2040 (higher prices needed for absolute emission reductions in the long-run (R 750 from 2040 to 2050)).

¹⁸ The first (second) sensitivity on the oil price see it rising from \$ 55 / bbl in 2003 to \$ 100 / bbl in 2034 (2040) and extrapolated at the same rate beyond. In the base case, the oil price is flat at the 2003 year level.

Use the Market reduces emissions by 17 500 Mt CO₂-eq between 2003 and 2050. Emission in 2050 are 620 Mt CO₂-eq, closing the gap between GWC and RBS by over three-quarters (76%).

The major wedges in **Use the Market** are an escalating CO₂ tax and incentives for renewables for electricity generation, biofuels and solar water heaters. Note that in the diagrams of wedges, the scale for the CO₂ tax is twice as big as for any other wedges shown – in 2050, it reduces emissions by more than 600 Mt CO₂-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%).

Critical to a full understanding the economic impacts of **Use the Market** is revenue recycling. At least at lower tax levels, spending revenue elsewhere could off-set 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.

The tax shows the expected results on the supply side. However, 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 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 modeled. These challenges are taken up in Strategic Option 4.

Strategic option 4: “Reaching for the goal”

It is clear that “partial” solutions to the Climate challenge are pointless: they are achieved at great cost but do 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 that are based on technologies we know and are able to cost (either driven by regulation or market), one can only (at the limits of a realistic ability to physically achieve them) suggest a package of actions that gets South Africa two-thirds of the way to **Reaching for the Goal**. There remains a “triangle of emissions” some time from the middle of the period, as emissions continue up.

In addition, from 2030 the levels of uncertainty are such that model results become less helpful. Beyond roughly this point, 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 increased 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 look like. Awareness of climate change may induce significant changes in patterns of consumption and behaviour – but to what extent? Options do exist which lay the platform for getting these answers. This is the **Reaching for the Goal** strategy.

Both **Start Now** and **Scale Up** as strategies are reasonably close to the goal in the first half of the period from 2003 to 2050, but diverge from RBS and from each other in the second half. Following these strategies until 2050 would foreclose the options of reaching the RBS goal. By around 2020 (this is not a prescriptive date, and is approximate) South African emissions should level out or plateau – and decline at a later date. The third strategy, **Use the Market**, reduces emissions the most, but also does not reach the goal after 2035, leaving the 'triangle' of emission reductions unfilled. Hence a new set of options would have to be ready for implementation by this time.

In **Reaching for the Goal**, exact costs cannot be modelled, nor the economy wide impacts. **Scale Up** closes the gap between RBS and GWC roughly two-thirds (64%), **Use the Market** gets us almost three-quarters (72%) of the way there. But a 'golden triangle' of emissions above RBS remains. The principal reason for this lies in the unknown technologies and behavioural changes that will have to mark this scale of emission reductions. Hence the first part of the **Reaching for the Goal** strategy has to do with these "new technologies". Four sets of actions are suggested. These all require further study.

Whilst it is acknowledged that we cannot model with any accuracy the components of this Strategy, unlike the others, we can imagine what some of its salient characteristics might have to be, by 2050. The four sets of actions are presented as follows.

1: New Technology

The first set of actions refers to "new" technologies (not yet modelled in LTMS). LTMS subjected those technologies that are at this stage "known" but not in the market, whether in the laboratory or already deployed in demonstration, 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?

Stakeholders interested in how we developed the provisional technology list should look to the Process Report for details.

The study included a cursory pass at this problem, and already a possible list of these technologies has emerged.