Clean Energy and Development for South Africa: Scenarios

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Report 2 of 3

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Abbreviations and acronyms used

CCGT	Combined Cycle Gas Turbine
CO_2	Carbon dioxide
CO	Carbon monoxide
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
EE	Energy Efficiency (used in naming conventions)
ERC	Energy Research Centre
FBC	Fluidised Bed Combustion
FCO	Foreign Commonwealth Office
FGD	Flue Gas Desulphurisation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IEP	Integrated Energy Plan
IEP2	Second Integrated Energy Plan
IGCC	Integrated Gasified Combined Cycle
IPP	Independent Power Producer
LEAP	Long-range Energy Alternatives Planning
LTMS	Long-Term Mitigation Scenarios
MARKAL	Market Allocation model
NER	National Energy Regulator
NOx	Oxides of nitrogen
NRE	Non-Renewable Energy
OCGT	Open Cycle Gas Turbine
PBMR	Pebble-Bed Modular Reactor
PF	Pulverised Fuel
PPP	Purchasing Power Parity
PWR	Pressure Water Reactor
PV	Photo Voltaic
RDP	Reconstruction and Development Program
RE	Renewable Energy
RES	Reference Energy System
SO_2	Sulphur Dioxide
StatsSA	Statistics South Africa
SWH	Solar Water Heater
Toe	Tons of Oil Equivalent
TPES	Total Primary Energy Supply
UCT	University of Cape Town

Energy Units

Power

MegaWatt (MW)	Unit of power (rate of energy consumption)
	1MW = 1000 000Watts
GigaWatt (GW)	1GW = 1000MW

Energy

KiloWatt hour (kWh)	Unit of energy consumption (used in domestic electricity billing)
GigaWatt hour (GWh)	1GWh = 1000MWh = 1000 000kWh
TeraWatt hour (TWh)	1TWh = 1000GWh = 3.6 PJ
PetaJoule (PJ)	The Joule is the basic unit of energy
	1PJ = 10^{15} Joules

1. Introduction

This report is the second of three reports outlining sustainable development pathways for South Africa. It forms part of the reporting for the project entitled “Clean Energy and Development for South Africa” funded by the British Foreign Commonwealth office.

The study has three main objectives, firstly to update both the national LEAP and MARKAL models and the data developed and captured during the first integrated energy planning process. Secondly to project future scenarios for the South African energy system and develop “roadmaps” for sustainable development using sustainability indicators and thirdly to develop additional capacity for energy modelling in South Africa and in particular within the Department of Minerals and Energy (DME).

The objective of this document is to lay out the scenarios considered. It attempts to clearly define and record all the assumptions used to develop the scenarios. As the model is to be made available to the DME for use by its energy modelers and planners on completion of the project, the document serves as a guide to the scenarios in the model for the energy officers who will be using it. All model results and sustainability indicators developed are reported in the third report.

Sustainable development has several objectives, it aims to improve the environmental impact of energy use as well as the social impact of energy use. The scenarios are designed to offer insight into the effect that following different policy pathways will have on the goals of sustainable development.

The scenarios represent deviations from the base case in order to determine the effect specific policies or actions will have on the final energy demand and related emissions and costs of the system. The scenarios modelled in this study are improvements in energy efficiency, fuel switching, following a renewable energy strategy, implementing an environment tax, and pursuing particular pathways for generation technologies such as increased use of renewable energy or nuclear technologies.

In the addition to scenarios the study includes a base case sensitivity analysis with a lower GDP growth rate and another with technology learning applied to electricity generating technologies. Initially the aim was to include the effect exchange rate would have on technology choices that rely on large foreign input, such as future power stations. It has been estimated that a large percent of investment into generation capacity will not be spent locally unless effort is made to increase the human capacity required. A gradual increase in the exchange rate in the base case was applied to the investment costs of power stations. On examining the results it was decided to keep the exchange rate fixed in the base case, as it was felt that results were unrealistic. For demonstration purposes the results of the base case with the increased investment cost of generation technologies due to the assumed increase in exchange rate are included in the third report.

The report has three sections; the first outlines current government policies that are included or adopted in the scenarios, the second section describes the scenarios including all assumptions made to include them in the model. The third and final section describes the sustainability indicators used in the analysis. A summary of penetration rates and efficiency improvements adopted in the scenarios can be found in Appendix A.

2. Government policies included in the scenarios

The energy efficiency and renewable energy scenarios include policies which government is intending to implement or has begun to implement such as the energy efficiency strategy and the energy white paper for renewable energy (which the Department of Minerals and Energy have begun to implement) and the biofuels industry strategy (which is still a draft document). This section provides a brief overview of each.

2.1. The draft biofuels industrial strategy – November 2006

The biofuels strategy “aims to achieve a biofuels average market penetration of 4.5% of liquid road transport fuels (petrol and diesel) by 2013”. This target is based on an assumed level of local production of biofuels “using surplus agricultural capacity” that will not negatively affecting food production or food security. Currently biodiesel is manufactured from imported feedstock. The target includes a subsidy for farmers in the form of a fuel levy exemption.

The targets for blending of biofuel with petrol and diesel are as follows.

- E8, 8 % ethanol in petrol,
- B2, 2 % biodiesel in diesel.

2.2. The energy efficiency strategy for the Republic of South Africa – March 2005

The energy efficiency strategy sets targets for improvements in energy efficiency in the industrial and mining sector, commercial sector, residential sector and transport sector.

The targets are to be achieved through programmes implemented in three phases. Phase 1 begins in March 2005 and ends in February 2008. Phase 2 continues between March 2008 and February 2011, and Phase 3 runs from March 2011 until February 2015.

The targets are voluntary and are achieved through standards, awareness campaigns and audits, energy management systems, appliance labelling and investment in research and technology development. The targets were set based on saving which could be achieved at 2.8 percent yearly increase in GDP and a population growth of 1.3% per annum. Although the population growth and GDP growth used in this study are different, the targets, which are given as a percentage reduction in demand by sector in the strategy document, have been kept the same. The target does not include fuel switching.

Targets for the sectors are summarised below in Table 1 as well as the programmes which will be introduced to achieve them. Government has begun to implement the strategy, with the development of standards for commercial buildings and the signing of voluntary agreements with industries such as SASOL. The voluntary agreements are aimed at encouraging industry to improve its energy efficiency. In the voluntary agreements industries agree to improve their energy efficiency 15% by 2015.

Table 1: Targets and strategies contained for improving energy efficiency

Sector	Target	Phase	Implementation of programmes and savings
Industry	15%	Phase 1	
		Phase 2	Awareness campaigns
		Phase 3	Standards, Awareness campaigns
Commercial	15%	Phase 1	
		Phase 2	Awareness campaigns (Labels)
		Phase 3	Standards, Audits, Awareness campaigns (labels)
Residential	10%	Phase 1	
		Phase 2	Awareness campaigns
		Phase 3	Standards
Transport	9%	Phase 1	Driver awareness campaigns
		Phase 2	Promotion of diesel vehicles Auditing of vehicle fleets
		Phase 3	

2.3. The Energy White Paper on renewable energy – Renewable energy target - 2003

The medium term target of government is to have a 10 000GWh renewable energy contribution to final energy consumption by 2013. The renewable target does not include renewable capacity that existed before 2000 and it also does not include the use of biomass in the residential sector. Biomass use by the residential sector is excluded as it is not considered to be sustainable and often, when used in poor households, impacts negatively on the health of those using it.

The estimated existing renewable contribution to final energy consumption in 2000 was 115 TWh/ annum coming mainly from fuelwood and waste in the pulp and paper and food and beverage sectors. There has been no formal assessment of the impact of the policy to date, this is due to take place in 2008 at which point the white paper may be revised.

There is much discussion around the correct interpretation of the target. Some interpret it as a 10 000GWh per year contribution, and others as a cumulative 10 000GWh contribution by the end of the period. The document itself is unclear and for the purposes of this study we interpret it as a contribution of 10 000GWh per year.

3. Modelling scenario options

The scenarios are included as case studies within the model. The scenarios apply assumed penetration rates for standards and energy efficiency measures to technologies. For example, assumptions are made as to the amount of industries or commercial buildings in which audits could be carried out each year, or percentage of new buildings that are likely to improve their thermal efficiency if standards are implemented.

The scenarios considered are energy efficiency in the commercial, industrial, transport and residential sector, a tax on carbon dioxide and a targeted penetration of nuclear and renewable technologies.

3.1. Energy efficiency

South Africa has been slow in taking up energy efficient practices. The barriers to improving energy efficiency are frequently published but can be summarised as follows;

- Information barriers: Low level of awareness of the benefits and savings and the available technology options

- Institutional barriers: Lack of government promotion and regulation. Alternative priorities within the company.
- Financial and market barriers
- Technical barriers: Lack of technology, equipment and technological innovation as well as the human resources necessary for improving energy efficiency.

Energy efficiency improvements in the industrial, commercial, residential and transport sectors are included in the scenarios. Energy saved through the use of solar water heaters for water heating in the commercial and residential sectors are included under energy efficiency even though they rely on renewable energy and the energy that they "generate" adds to the renewable energy target. This is due to the decreased demand for other fuels when they are used.

Energy efficiency savings are forced in to obtain the highest savings possible by 2015. It should be noted that in most cases, significant penetration rates are needed to achieve the targets laid out in the energy efficiency strategy in the modelling.

3.1.1. Energy efficiency in the Commercial sector

In the commercial sector, a number of energy efficient technologies are available to replace older demand technologies or reduce their energy consumption. These technologies include energy efficient HVAC systems, heat pumps, variable speed drives, efficient motors and efficient boilers. In the scenario these technologies are introduced in 2008, i.e in the first year that government is expecting to implement awareness campaigns under the energy strategy. The exception is efficient lighting options such as CFL's which are introduced prior to 2008. This is done because attempts to improve lighting efficiency through the use of CFL's and electronic ballasts have already begun through demand side management campaigns.

There is large scope to improve the energy efficiency of commercial buildings in South Africa, for example the Nedbank building in Cape Town has managed to achieve a reduction in energy intensity of 65% below that of other similar buildings through design.

The standards, retrofits and other management actions implemented to improve the energy efficiency of the commercial sector impact on either the useful energy intensity of demand or the energy efficiency of the technology meeting the demand. Building thermal design, or design measures that reduce lighting demand will have an impact on energy intensity and will reduce the useful energy demand to be met by HVAC systems, heating systems and lighting. These improvements to useful energy intensity by lighting and thermal design standards are restricted to new buildings in the scenario. Retrofits to the lighting systems or HVAC systems in existing buildings and are included as an improvement in energy efficiency.

New technologies are given an investment bound which restricts the investment in new capacity of the technology each year. This is done so that their use is gradually increased during the planning period. In this way a more realistic policy impact is modelled.

Assumptions are made around the payback period for energy efficiency measures and the marginal cost of the electricity saved. From these assumptions, we calculate an investment cost for the efficiency measure.

Another important aspect of commercial efficiency is the thermal performance of buildings. Assumptions are made about the potential improvement in efficiency of new buildings should building standards be introduced. Certain measures can also be applied to older buildings as retrofits.

HVAC Systems

HVAC retrofits to more efficient HVAC systems and the improvement of the energy efficiency of HVAC systems is allowed in both existing and new buildings. The savings are assumed to result from audits and other awareness campaigns. The efficiency of HVAC systems can be improved through the use of variable speed drives (VSD's) on fans, retrofitting HVAC systems and using alternative HVAC systems such as heat pumps or central air conditioning units that have a higher coefficient of performance (COP).

It is assumed that variable speed drives can improve the efficiency of HVAC systems by 15% and that this efficiency improvement is applicable to 12.5% of building floor space.

HVAC retrofits to HVAC systems in old buildings are allowed in one third of all buildings and can improve energy efficiency by an average of 35%. Generally these improvements are easy to implement and are assumed to have a payback period of five years.

Efficient HVAC systems in new buildings are allowed in one third of buildings in 2015, and the efficiency of the system can improve by an average 42.5%. A payback period of 5 years is assumed for these measures.

Heat pumps and central air conditioners are allowed to meet a greater portion of demand after 2008. The portion of demand that they can meet is increased 5% between 2008 and 2015 and a further 6% by 2030. This assumes that all new buildings will have the option of using either a heat pump or central air conditioner to met their cooling needs.

Thermal design

It is assumed that building standards aimed at improving the thermal design of buildings could reduce the useful energy demand for cooling by an average 40%. The standards and thus improvement in useful energy demand apply to new buildings only.

It is assumed that the 40% savings in demand for cooling can be achieved in 50% of new buildings each year and a further 30% savings can be achieved in 40% of buildings. The savings are introduced into new buildings from 2008 onwards.

Efficient lighting

Retrofits and a move towards CFL’s improve the energy efficiency of lighting in existing buildings. Standards reduce the useful energy demand for lighting in new buildings. Eskom DSM campaigns targeting lighting have been very successful and are achieving significant savings. These campaigns include the subsidy of the sale of electronic ballasts which have effectively eliminated the sale of magnetic ballasts. When electronic ballasts replace magnetic ballasts, there is a saving of 20%.

It is assumed that lighting demand in existing buildings can be improved in two ways. Either magnetic ballasts are replaced with electronic ballasts achieving a savings of 20%, or the entire lighting system will be retrofitted achieving a saving of 40%. Again this is a conservative saving, retrofitted commercial buildings such as Plein Street in Cape Town recorded savings as high as 60%.

In existing buildings savings of 20% through the replacing of magnetic with electronic ballasts are allowed in 50% of buildings, a further 40% saving through the complete retrofit is allowed in 20% of buildings by 2015. The assumed payback periods for the lighting retrofit is 4 years, ballasts are replaced with electronic ballasts as they fail at no additional cost.

CFL’s are allowed to replace 3.3% of demand for incandescent lighting in 2015 and 6% of demand for incandescent lighting by 2030.

In new buildings it is assumed that improved design will reduce demand by 60% in 40% of buildings and 30% in a further 40% of buildings.

Water heating

Water heating efficiency is improved through the increased use of solar water heaters and heat pumps to meet demand. Both technologies can meet up to 10% of demand in new buildings in 2015 and 20% of demand in 2030.

Other appliances

The energy required by new electrical appliances or equipment such as computers and fridges is assumed to reduce over time. These improvements in energy efficiency rely on design improvements to technologies. Other savings are the result of behaviour changes and rely on successful awareness campaigns or training. It is assumed that 25% of appliance demand can increase 15% in efficiency and a further 25% can achieve a 30% increase in efficiency. These measures are assumed to have a one year payback.

3.1.2. Energy efficiency in the Industrial sector

The industrial sector is a sector which promises great opportunities for improving energy efficiency. In this sector improvements in energy efficiency are likely through improved lighting efficiency, compressed air efficiency, motor efficiency, thermal efficiency, steam system efficiency and HVAC efficiency. These are standard measures and are all easily implemented.

For each end use demand in industry such as boiler fuels, compressed air, etc, an assumption is made about how much energy can be saved through efficiency measures. These assumptions are based on currently available technology and studies on industrial efficiency potential (Howells et al 2003).

Efficiency measures in the industrial sector are introduced in 2008 and continue to improve until 2030. They are assumed to be driven by awareness campaigns, auditing of industrial facilities, and the implementation of standards within the sector.

Savings for all processes reliant on electrical energy are presented below, in all cases the savings suggested are the average savings that could be achieved across all types of industries in the industrial subsectors.

Thermal savings

These savings are realised through savings in the steam system as well as improved efficiency in other areas. Savings in the steam system can be achieved through steam trap maintenance, improved boiler efficiency, isolating steam from unused lines, repairing steam leaks, optimising condensate return, minimising vented steam and a number of other measures. The focus here is on improving the efficiency of the steam system and boiler and not on improving the efficiency of the end use process. It is estimated a 20% improvement in steam system efficiency could be achieved. An average payback period of 1.4 years is assumed for the basket of measures.

Compressed air savings

Compressed air savings can be realised at the compressors as well as the ducting system. Fixing leaks in compressed air pipes and closing pipes that are not needed and reducing elbows, all result in savings that can be achieved in the piping system with minimal capital expense. Sequencing compressors to meet demand so that they run at full load or using more compressors of smaller size, as well as using cool intake air and waste heat recovery are all ways in which savings can be made at the compressors at a low cost. Typically these savings have a payback period of less than a year. We estimate the payback period for compressed air savings to be 11 months and that a saving of 20% is achievable.

Efficient lighting

Lighting efficiency can be improved by switching to more efficient lamps and fixtures, this includes replacing magnetic ballasts with electronic ballasts and improved lighting design. Experience through DSM lighting programmes in South Africa has shown that between 30 and 60% savings in lighting in factories are achievable. Additional savings can be achieved by making use of daylight through sky lighting, or using sensors to switch lights off in areas where they are not needed continuously. It is estimated that an average 40% savings could be achieved and that the average payback period is 3.6 years.

Efficient motors

Motor savings can be achieved through the correct sizing of motors and the use of high efficiency motors. A payback period of 6 years is estimated for these measures along with a saving of 5%.

Variable speed drives

Variable speed drives, also called variable frequency drives achieve savings by regulating the speed of the motor. Variable speed drives can achieve savings of between 5 and 10% depending on the application. The largest savings are generally realised for fans and pumps where the input power varies with the cube of the pump or fan speed. The assumed payback period for variable speed drives is 7 years

Industrial measures are allowed a penetration rate of between 2% and 7% each year, ie 2-7% of demand is assumed to improve in efficiency each year. This penetration rate is based on anticipated success of audits and awareness campaigns, but it should be noted that without significant effort on the part of government it is likely that this penetration rate will be achieved (Howells et al, 2003).

3.1.3. Energy efficiency in the residential sector

In the residential sector, savings are achieved by allowing households to switch to more efficient appliances and fuels. The target for final energy demand reduction by 2015 in the residential sector is 10%. In order to reach this target, fairly significant changes need to take place in the early part of the time period. The following measures are the most important measures taken in the residential case to achieve the savings.

Basa Njengo Magogo

An improved method of using Coal Braziers known as the "Basa Njengo Magogo" method shows an increase in efficiency of 37.5%. This method of cooking which is simple and requires no additional or alternative appliances is part of a DME programme to reduce local air pollutants in low-income areas. The combustion of fuel is more efficient in the "Basa Njengo Magogo" method of cooking as the fire is lit from the top of the Briazier and burns slowly down, in the traditional method of cooking the fire is lit at the bottom of the stove. Major advantages include reduced particulate emission, ease of ignition and reduction of coal required by 17%. This coal saving equates to 1kg per use and, at a cost of approximately R1 per kilogram of coal, this translates to a saving of R30 per month (Le Roux et al 2005).

In the base case (or growth without constraint), it is assumed that the Basa Njenga Magogo method is used in up to 3% of households in 2015 and 7% in 2030. In the reference case it is assumed that in Urban Low-income Electrified and Non-electrified households up to 20% of coal braziers shift to the Basa Njenga Magogo method by 2015 and 40% by 2030 for space heating and cooking. These upper bounds on penetration rates are based on assumptions about the effectiveness of government programs to reach households and convince them to shift to the new method.

Solar Water Heaters

Solar water heaters (SWHs) are gaining popularity with cities such as Cape Town considering policies to make Solar water heaters on new homes a by-law. In the residential reference case, we allow high penetration rates of Solar water heaters, Table 1 shows the assumed penetration rates of solar water heaters into new houses. A much lower rate is assumed for old houses.

Table 2: penetration rate of SWHs in the different household types

New houses	2008	2015	2030
Rural rich electrified	20%	25%	60%
Rural poor electrified	20%	25%	60%
Rural poor unelectrified	1%	5%	10%
Urban rich electrified	40%	50%	75%
Urban poor electrified	50%	55%	80%
Urban poor electrified	2%	7%	15%

Geyser blankets

Geyser blankets are another efficient water heating technology to be implemented in this scenario. We assume a high penetration rate of approximately 65% of electric geysers are insulated with a geyser blanket (or similarly effective insulation) by 2015 (Howells et al 2003). Geyser blankets achieve a 14.3% improvement in efficiency.

Thermal efficiency of houses

Thermal performance of buildings can be improved through addition of insulation, ceilings and general thermal efficiency building standards. In many low income households ceilings are omitted as a cost-saving mechanism however it greatly affects the thermal comfort and space heating requirements of the building. In this scenario we assume a high penetration of thermal efficiency in new buildings and a smaller penetration rate for old buildings where limited retrofit is possible and more costly. In new houses it is assumed that all new houses will have improved insulation. Of those, 50% will have significant winter heating requirement and the improved insulation will result in a 30% reduction in space heating requirements (Howells et al, 2003).

Ethanol gel

Ethanol gel fuel is a new replacement to paraffin for use in low-income houses for cooking and lighting. Advantages are mainly in safety (if knocked over, gel fuel stoves will not cause wide-spread fires as paraffin stoves do) and in reduced particulate emissions. The efficiency of these stoves is under investigation and while the calorific value of ethanol gel was thought to be similar to paraffin (23 MJ/kg for gel versus 25 MJ/kg for paraffin), recent studies have shown that the energy intensity of ethanol gel fuel is closer to 16 MJ/kg (Lloyd, 2007). Another drawback is that during tests, a large amount of water vapour collects at the bottom of the pot during cooking. This reduces the efficiency of the stove and lengthens the time required for cooking. The cost of the gel fuel could also prove prohibitive since five litres of gel fuel costs approximately R160 whereas the same amount of paraffin costs R50 (Makgetla, 2006). Nevertheless, users of the gel fuel stoves have commented that the clean burning fuel is more pleasant to use and easier to store and transfer than paraffin. And while costs are high, they claim that an amount of gel fuel that could last up to a month would only last a week if it were paraffin (Makgetla, 2006). It is interesting to note that the efficiencies of gel fuel stoves and paraffin stoves are not very different (0.41 versus 0.4) yet the calorific value of the fuels and resultant energy costs are very different.

Given the algorithms used by the model, gel fuel stoves would prove to be very unfavourable in a least-cost optimising scenario. In reality, it seems that gel fuel may have advantages over paraffin that the model cannot take into account: the safety aspect mentioned above and reduced evaporation rate. In the base case there is little to no penetration of gel fuel into the residential fuel mix, however in the reference case, the bounds on gel fuel are opened up, and the model is free to choose the least-cost option to meet demand.

Lighting

Lighting in the residential sector is another area in which significant savings are possible. Eskom has already initiated a massive roll-out of CFLs in the Western Cape to aid with the recent power shortages. In the base case, a very low penetration rate of CFLs is assumed: 5.3% in urban areas and 1.9% in rural areas. In the reference case this is increased dramatically to 40% by 2015 in urban areas and up to 35% in rural areas. The upper bound on penetration continues to increase to 60% and 50% by 2030 in urban and rural areas respectively. These rates remain constant to 2050.

For other water heating, cooking and space heating technologies, the upper and lower bounds are widened in the reference case, so as to give the model the freedom to choose most efficient fuel and technologies to meet demand.

3.1.4. Energy Efficiency in transport

The overall target for final energy demand reduction in the transport sector by 2015 is 9%. In order to reach this goal a number of stringent policies or measures are introduced. The transport sector energy efficiency case is modelled with less freedom than the other efficiency cases. It is not believed that customers will choose more efficient vehicles without the introduction of policy or that the purchase or use of transport modes amongst the higher income groups is done with consideration to the cost.

In the base case, all new private passenger vehicles and light commercial vehicles increase in efficiency by 0.4% per annum. In the scenario this efficiency improvement is increased to 0.9% per annum, based on savings which have been achieved in the United Kingdom (An and Sauer 2004). In addition to this, vehicle occupancy is assumed to increase from 2.1 passengers per vehicle-km to 2.2 passengers per vehicle-km.

The taxi recapitalization plan is also included in this scenario. In the base case we have assumed a moderate increase in the number of diesel taxis introduced to the taxi fleet, and a significant impact is only made after 2015. The diesel taxis that form part of the programme are larger Midi bus vehicles that seat 19-35 passengers compared with the mini buses that seat 18 passengers or less and are designed for longer distances. In the scenario, the target is introduced sooner so that by 2015, 4.7% of taxis are diesel. This is increased further to 7.4% by 2030.

The number of private diesel cars also increases in comparison to the base case where an increase is only noticed after 2015. It increases further to 15% in 2030. The number of diesel passenger vehicles has increased dramatically over the past few years. While the base case does demonstrate this with an increase from 2.8% in 2001 to 5% in 2030 of private passenger-kilometres, this efficient transport scenario allows the model greater penetration of diesel vehicles. In this scenario diesel cars make up 15-30% of private passenger-kilometres by 2030.

Hybrid vehicles are included as an option for improved vehicle efficiency. Hybrid vehicles can make up 2% of passenger km by 2030. SUV use decreases compared to the base case where it is assumed to increase up to 4%. In the scenario the use of SUV's is capped at 2% of private passenger-kilometres.

In addition, the use of public transport is allowed to increase. In the base case public transport is 51.2% of demand, in the scenario case public transport is allowed to grow by 5% above this.

The use of rail for freight is also increased. The base case assumes that 28.3% of tonne-km are transported by rail in 2015 and 32.3% in 2030. In this scenario, the use of rail for freight is allowed to increase to 44.6% in 2015 and 45.15% in 2030.

In this scenario the biofuels blends are increased to determine the effect this has on the cost and fuel mix of the country. The blend fractions are increased to 8% ethanol with petrol and 2% biodiesel with diesel in 2013. Thereafter the percentage of ethanol in petrol is taken up to an assumed maximum of 20% and biodiesel to a maximum of 5% in 2030. 20% ethanol is the maximum fuel blend for petrol cars before major modifications are required and the volume of ethanol required to achieve this blend could be produced in South Africa without impacting on food supply based on agricultural trends and land availabilities. It should be noted however that if we also produce biofuels for sale to other foreign countries, this may no longer be true.

Bioethanol is produced locally from maize in the scenario, biodiesel is produced from imported sunflower seeds, or other imported feedstock. The cost of feedstock as well as plant capacity is included in the scenario.

3.2. Tax on CO_2

In a carbon restricted environment, in which countries agree to reduce their carbon emissions, carbon dioxide levels may be reduced by placing a tax on carbon dioxide emissions, thus giving a monetary value to "clean" energy processes. In this scenario, we introduce a tax of R100 and R150/ton CO_2. The tax is applied to CO_2 emitted by the transformation sector only i.e. it on CO_2 emitted from power stations and refineries.

3.3. Renewable energy

In this scenario we apply a minimum penetration of renewable technologies for electricity generation. The technologies are introduced in 2008 (other than additional cogen capacity) and are forced to provide 36PJ (10 000GWh) by 2014 and is increased to 247PJ (15% of electricity demand) by 2030. Included in the renewable options to meet demand are hydro, wind, solar, biomass and landfill gas technologies. Imported hydro is restricted in this scenario to 15% of supply.

3.4. Nuclear

In this scenario the contribution of nuclear technologies to the supply of electricity is increased. The technologies considered are the pebble bed modular reactor and new pressurised water reactor similar to the one at Koeberg. Starting in 2015, nuclear energy is forced to supply 15% of electricity demand (247PJ) by 2030 in this scenario.

3.5. Sensitivity analyses

Due to the reliance on assumptions when projecting demand and costs and the possible variance of each, sensitivity analyses are conducted. In this case we are comparing the base case results to a base case with altered assumptions.

Three sensitivity analyses are performed; the first assumes a lower GDP growth and therefore has lower demand growth and lower final demand at the end of the period. The second includes technology learning on all generation technologies. The third a change in the rand dollar exchange rate over the period. The aim is to test the robustness of results to changes in assumptions, and to identify assumptions that are most influential on results and should be given priority in future studies.

3.5.1. GDP Growth

In this analysis a GDP growth is used with is lower than that of the base case. This is more in line with current GDP growth trends in South Africa. The growth rate, which reaches 6% in the base case, relies on the success of government policies. It was decided to test the base case model results against those with a lower growth rate.

The growth rate used in the analysis is shown in Figure 1 below. It increases to a maximum 4.4 % in 2018. The sectoral contribution to GDP growth is kept the same as that of the base case as do all other assumptions about penetration rates and availability of technologies.

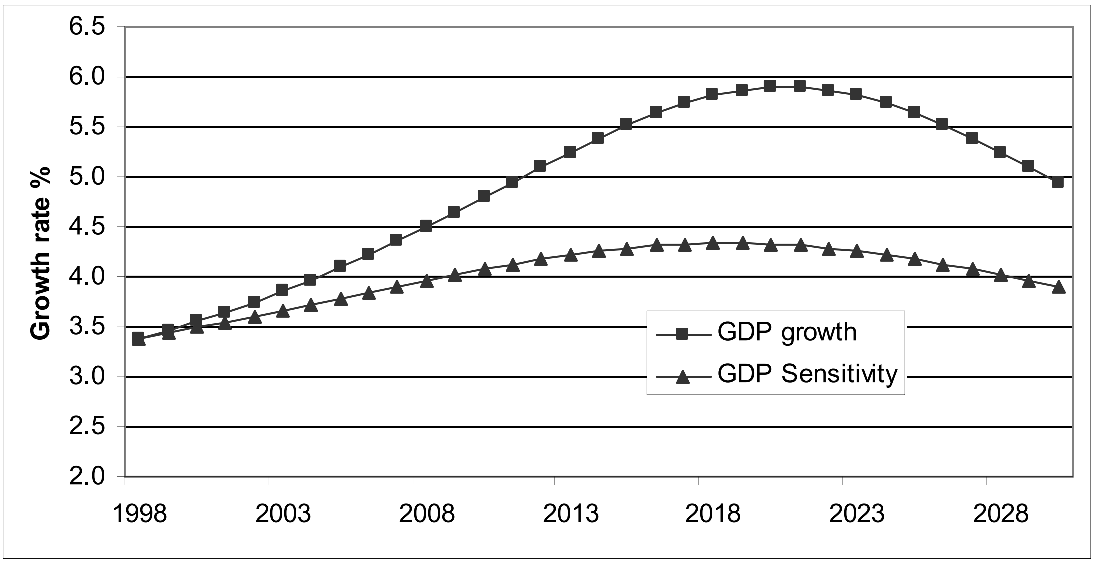


Figure 1: GDP growth rate of the base and lower GDP growth scenario

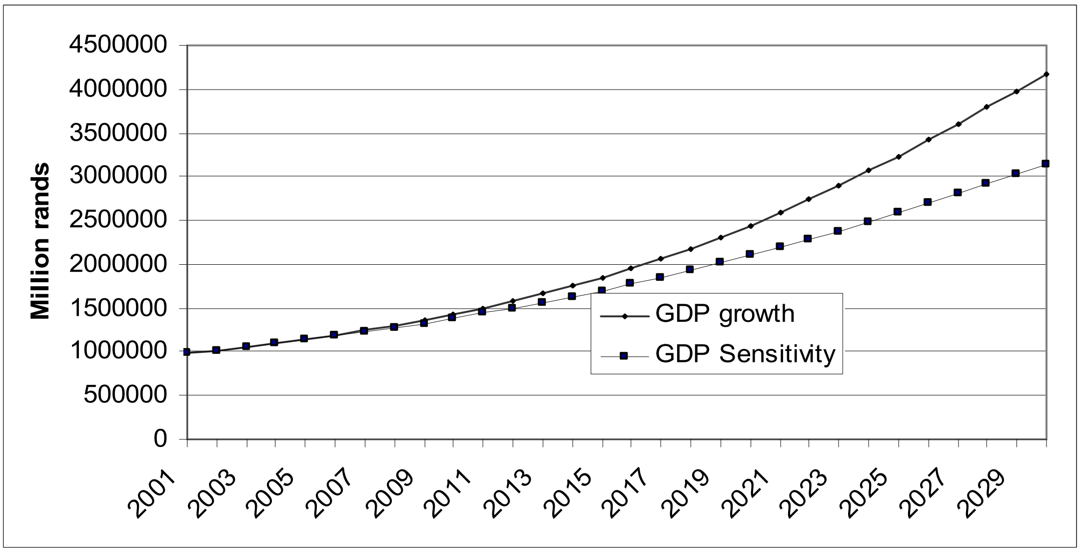


Figure 2: sensitivity GDP vs that of the base case

3.5.2. Exchange Rate

The strength or weakness of the South African Rand compared to international currencies can influence model outputs. It was therefore decided to test the model output of the base case against one in which a changing exchange rate is applied to the investment costs of power stations. Exchange rate variations were not applied to variable operation and maintenance costs, or fixed operation and maintenance costs.

It has been suggested that a 2% decrease in exchange rate per year is likely (Personal communication Kalie Pauw, UCT Economics Department, October 2006). This translates to the rand dollar exchange rate given in Table 3 below.

Table 3: Projected rand-dollar exchange rate over the study period

2003	R7.50
2005	R7.80
2010	R8.62
2015	R9.51
2020	R10.50
2025	R11.59
2030	R12.80

3.6. Technology Learning

Technology learning is applied to electricity generating technologies only. It changes the costs of the technology options over the period and therefore affects the results of the optimisation within the electricity transformation sector and other end uses that rely on electricity as the marginal cost of producing electricity will change.

Technology learning assumes that the costs of generating technologies will change over time. It assumes a decrease in the cost of a technology as production improves with increased output. Technology learning is included as a sensitivity analysis as it has been found that technology learning assumptions can have large effects in the output of planning models (IEA & OECD 2000; Repetto & Austin 1997; Fisher & Grubb 1997; Energy Innovations 1997; IEA & OECD 2006). The effect of technology learning is greater when the planning horizon is lengthened.

Technology learning or the decrease in the cost of technologies over time is a result of two drivers, the first assumes that the more you do something the better you will become at it, the second assumes that the more you produce of something the cheaper you can produce it, i.e. economies of scale. These assumptions hold true for energy technologies (IEA & OECD 2000).

The relationship between the cost of a technology at two points in time and the capacity at the same two points in time is expressed with the following three equations:

$$C_t = C_0 (\frac{q_t}{q_0})^{-b} \qquad \text{(Eq. 1)}$$

Where *C* is the unit cost of the technology, *q* represents cumulative output, the exponent *b* defines the relationship between the capacity ratio and the cost ratio.

The progress ratio (PR) and learning ratio (LR) are calculated from equation 2 and 3.

$$PR = 2^{-b} \qquad \text{(Eq. 2)}$$

$$LR = (1-PR) \qquad \text{(Eq. 3)}$$

Assumptions around the growth of capacity and global potentials are drawn from a range of literature. For fossil fuel plants, the International Energy Agencies (IEA) World Energy Outlook projects fossil based generation expansion to 2030, data for renewable technologies is drawn from the IPCC's 3rd assessment report and World Bank reports (IPCC, 2001, World Bank, 1999).

The assumptions used to include technology learning in the analysis are recorded in Table 4 below.

Table 4: Parameters and assumptions for technology learning

Sources:(IEA, 2003; Greenblatt, 2006 ; IEA, 2006; Pacala, 2004; IEA, 2003; World Bank, 1999)

Energy technology	*Range of learning rates in the literature*	*Maximum level this technology can reach globally, GW*	*Learning rate adopted in %, this study*	*Current installed capacity, (GW)*	*Year*	*Increase in installed capacity in past five years (%/yr)*
Wind	5 - 40%	2,000	19%	59	2005	30%
Solar photovoltaic	17 – 68%	500	25%	1.1	2000	30%
Solar thermal, parabolic trough	5 – 32%	500	15%	0.65	2005	10%
Solar thermal, power tower	5 – 20%	500	20%	0.135	2005	10%
Small hydro	5%		5%	32	2000	3%
Supercritical coal	3 – 7%	3,072	4%	138	2003	7%*
Integrated gasification combined cycle				1	2003	
Fluidised bed combustion				17	2003	
Natural gas combined cycle	4 – 7%	3,773	5%	351	2003	5%*

*Note: * . there is increased level of uncertainty in these numbers*

A different approach is applied to the pebble bed modular reactor. This is due to two factors, firstly there is no previous experience with a local technology of this type that we can draw from and secondly the global market for the technology is unknown. Technology learning for the PBMR begins in 2014 after the commissioning of the first pilot plant. NIRP 2 includes technology learning for multimodule PBMR's. The assumption in NIRP2 is that by the 3rd multi module 70% of the cost reduction will be realised. In this study it is assumed that 32 modules will be built between 2014 and 2026, resulting in the technology learning cost reductions shown in Figure 3.

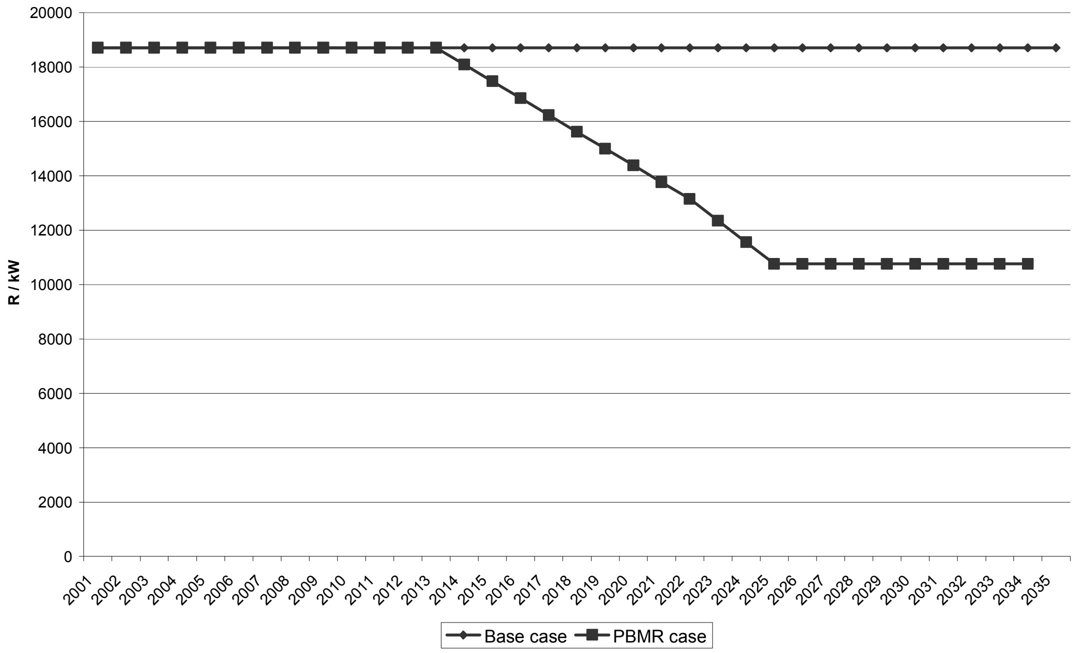
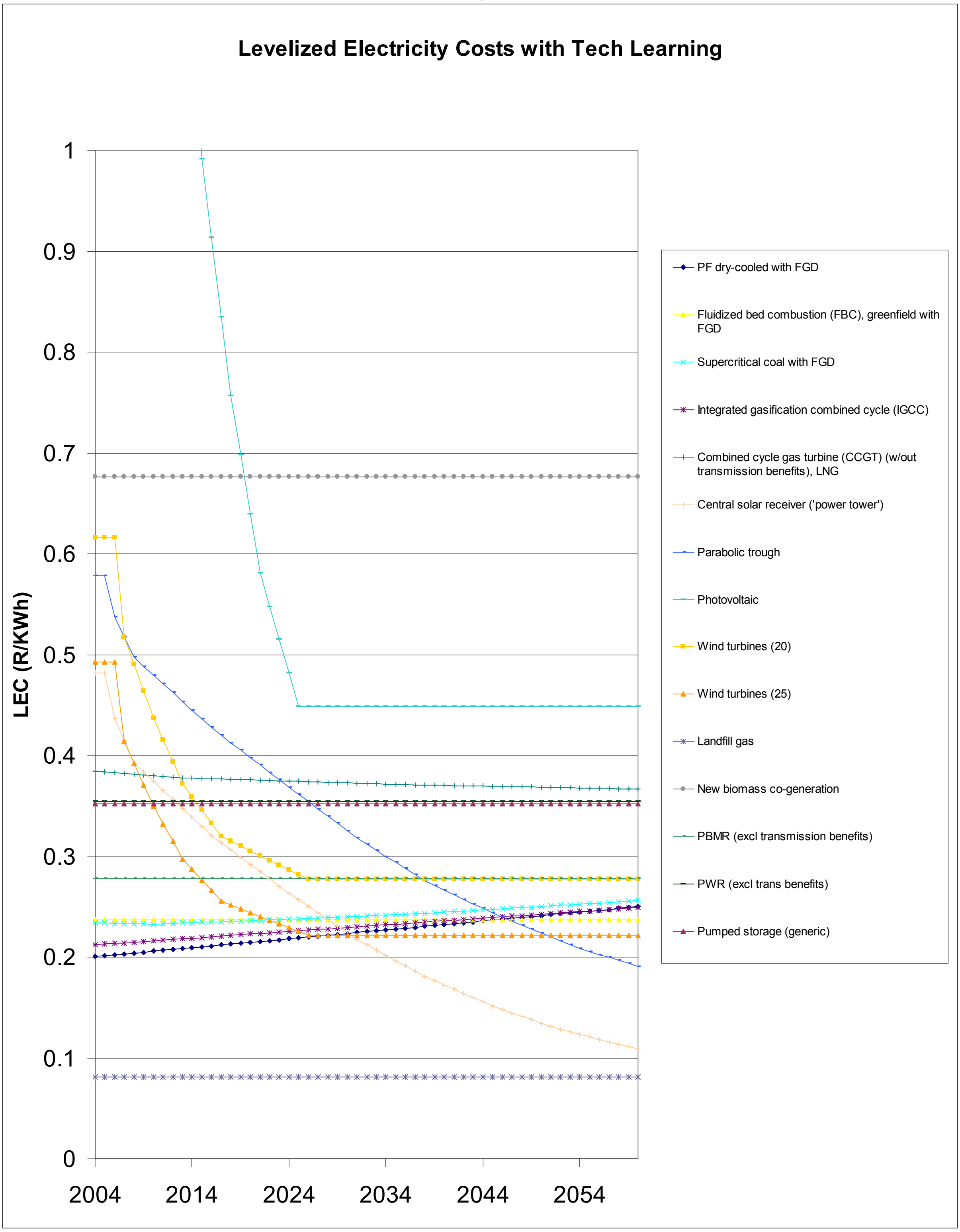


Figure 3: Technology learning applied to the PBMR

The impact that technology learning has on the levelised cost of plants operating at their maximum likely load factor between 2001 and 2030 is shown in Figure 4. For OCGT's a maximum likely load factor of 3% is assumed, for all baseload plants it is assumed that they will be run at their availability factor. It can be seen that there is a significant cost reduction in the cost of renewable technologies over the time period compared to that of the fossil fuel plants.

The levelised cost curves include fuel costs, which in the case of coal increase over the period. The increase in the cost of coal is seen in some of the coal plants where there is limited or no technology learning and the cost of the levelised cost increases.

Figure 4: Levelised cost of plants with technology learning



4. Energy sustainability indicators

Over the last few decades it has become apparent that, while energy is essential for economic and social development, the way in which it is produced, transported and used can contribute to local environmental degradation, such as air pollution, and global environmental issues such as climate change. Energy trade, particularly with regards to oil supply security, is closely linked with political and economic stability. These non-monetary costs associated with the energy sector are difficult to quantify, making it difficult to track progress towards sustainable development.

The use of sustainability indicators as developed by the Helio International Sustainability Energy Watch (SEW) and applied to South Africa by Sustainability Energy and Climate Change Partnership (SECCP) (Spalding-Fecher, 2002) are used in this study to quantify the sustainability of our current energy trends. A set of eight indicators was developed to cover four dimensions to development: Environment, society, economy and technology. The indicators are presented below;

- Environment
  1. Global impacts: energy sector carbon emissions per capita
  2. Local Impacts: level of most significant local energy pollutant
- Social
  3. Households with access to electricity: share of households with access
  4. Investment in clean energy as a proxy for job creation: RE and EE investment as share of total energy sector investment
- Economic
  5. Resilience to external trade impacts:
     - Exports: NRE exports as share of total export value
     - Imports: NRE imports as share of total primary energy supply
  6. Burden of energy investments on the public sector: public investment in NRE sector as share of GDP
- Technological
  7. Energy intensity: primary energy consumption per unit GDP
  8. Deployment of renewable energy: renewable energy supply as a share of total primary energy supply

For each of the indicators, a vector is calculated. A value of 1 indicates a measure of 'status quo' from historical national data or a global average. The goal is to achieve a value close to zero. In calculating these indicators, the underlying measure is normalized so that we can compare across indicators how close the country is to different sustainability goals. Each indicator is described in more detail below.

<u>Indicator 1: Energy sector carbon emissions per capita</u>

Due to an energy-intensive economy and a high reliance on coal, South Africa is one of the most carbon emissions-intensive countries in the world. The energy sector is responsible for most of the greenhouse gas emissions and in 1994 for more than 90% of the carbon dioxide emissions (RSA 2001).

With emissions data from IEA and population data from StatSA, Spalding-Fecher (2002) calculated that in 1999 carbon emissions per capita for South Africa was 2194 kgC/capita compared with a 1990 level of 2205 kgC/capita. This means that indicator values for South Africa are greater than 1 for both years: 2.35 for 1999 and 2.36 for 1990. This illustrates that South African carbon emissions from the energy sector are more than double the world average already, putting it much further from sustainability goals than other countries.

<u>Indicator 2: Level of most significant energy-related local pollutant</u>

In a developing country such as South Africa, the most critical energy-related local pollutants are not connected with large-scale electricity generation but rather on a household level because the types of fuels burnt for cooking, heating and lighting release dangerous pollutants in close proximity to people. Paraffin, coal and wood provide much of the energy for domestic use in low income households in South Africa. These energy carriers have a number of inherent risks such as indoor air pollution which can cause respiratory problems, illness and even death as well as non-pollutant risks such as increased risk of fire, burning and poisoning from paraffin.

In the South African study (Spalding-Fecher, 2002) a measure of total suspended particulate matter in a low-income area is used as a key indicator of energy sector environmental impacts. Since national air quality data is lacking, data from the Soweto Air Monitoring (SAM) project was used. This showed a decreased in winter concentrations of total particulates of 15% between 1992 and 1999. This puts the vector value for 1999 at 0.85 (Spalding-Fecher, 2002).

Indicator 3: Households with access to electricity

The South African aggressive electrification programme has been one of the most successful elements in the post-1994 government's Reconstruction and Development Program (ANC 1994) and in 1998 was included in the White Paper on Energy Policy (DME 1998). In its first phase, the National Energy Regulator (NER) aimed to connect 2.5 million households. By 1999, electrification rates had increased from about one third to about two thirds of all South African households. In 2001, the overall electrification rate in the country was 66% (NER 2001) and in 2002 a further 338 572 homes, 974 schools and 49 clinics were grid-electrified, as well as 5 321 Solar Homes Systems installed (Mlambo-Ngcuka 2003). The vector value for South Africa in 2001 is therefore 0.34.

Indicator 4: Investment in clean energy, as a proxy for job creation

It is important to track investment in 'clean energy' (usually referring to all renewable energy sources, excluding large dams and energy efficiency measures) as a share of total energy investment to measure the contribution the energy sector makes to employment generation. However, it is difficult to find reliable investment data since the projects are often diffuse, small-scale or private projects and there is not central or government data-collection service that can provide the information.

Spalding-Fecher estimated that total clean energy investment for 2000 was at R129 million. This equates to approximately 1.3% of total energy investments. Since the 1990 value (reference for unsustainability) is close to zero, the vector value for 2000 is 0.986. This, and indicator number 6 are the most difficult to assess in a developing country situation.

Indicator 5: Resilience to external trade impacts

This indicator is divided into energy imports and exports. While South Africa relies on imported petroleum for 60-65% of liquid fuel needs, it is a net exporter of energy, primarily in the form of coal exports. South Africa also exports refined petroleum products such as diesel, kerosene and petrol as well as electricity, of which almost 100% is based on non-renewable energy. Total non-renewable energy export was therefore R19.1billion or 8.4% of the total. The vector value is therefore 0.084 for 2000 (Spalding-Fecher 2002).

Economic vulnerability can also be measured by a country's reliance on non-renewable energy imports. As already mentioned, South Africa relies heavily on imported crude oil to meet liquid fuel demands and is thus vulnerable to changes in international prices and supply shocks. Historically, Sasol Synfuels has provided a significant portion of diesel and petrol for domestic consumption, however the rapid growth in transport energy demand has meant that Sasol provides and smaller portion of the demand. In the early 1990s Sasol provided more than 40% of domestic petrol and diesel but currently it is below 30%.

Indicator 6: Burden of energy investments on the public sector

The South African government has been heavily involved in the energy sector development. Electricity is dominated by data-owned utility, Eskom, while the state's Central Energy Fund (CEF) owns PetroSA which runs most of the local oil and gas exploration as well as the Mossgas gas-to-liquid refinery. Sasol was state owned but is now private while the nuclear industry is largely state-owned. Many of these parastatal companies have received loans and subsidies of billions of rands over the past few decades. The national government energy budget therefore represents only a small part of the government's involvement. It is difficult to quantify level of government investment in the energy sector. Some government enterprises have non-energy businesses, and much of the investment is not given as explicit investment but rather subsidies or tax-breaks.

Spalding-Fecher (2002) estimates the total public non-renewable energy investment as R4573 million. If GDP in 2000 is R874 billion (SARB 2001), the non-renewable public investments are

0.52% of GDP. With the reference for unsustainability at 10% of GDP and the sustainability goal at 0%, South Africa's vector for 2000 is at 0.052.

Indicator 7: Energy Intensity

South Africa's economy is highly energy-intensive with a heavy reliance on heavy industries such as mining, metals and chemicals. The low energy-costs in South Africa have perpetuated the energy intensive industries but has also provided a competitive advantage for South African industry.

Using values for commercial primary energy (ie excluding household use of biomass) per unit GDP at purchase power parity (PPP) exchange rates, Spalding-Fecher (2002) calculated South Africa's energy intensity for 1999 at 22.0MJ/US$ PPP. The values for 0 and 1 on this vector are based on global averages. The vector value for South Africa is much greater than 1 meaning that South Africa is much more energy intensive than the global average. The vector value for 1999 for South Africa is 2.19.

Indicator 8: Deployment of renewable energy

Historically in South Africa, renewable energy was seen as the 'poor cousin' to large, centralised fossil fuel and nuclear energy production. Renewable energy was largely biomass in rural areas with a few hydroelectric plants and cogeneration in sugar and paper industries. Nevertheless, the White Paper on Energy Policy (DME 1998) includes a range of policies to promote renewable energy both as distributed energy sources in rural areas and as large grid-connected generation facilities.

South Africa's share of renewable energy to total primary energy supply (TPES) in 1999 was 4.4% (Spalding-Fecher 2002). This includes commercial and household biomass use, domestic hydropower less than 100MW but excludes imported or large-scale hydro as these projects are not always considered renewable energy.

For this indicator, the value for 1 on the vector is the world average renewable energy supply as a share of TPES in 1995, which is 8.64% (Helio International 2000). The value for 0 on the vector (the sustainability goal) is 95%. This puts the South African vector value at 1.05.

One of the biggest problems with this estimate is that data for biomass use is very poor and since this is the largest portion of renewable energy used in South Africa, it plays an important role in the total deployment of renewable energy. Another factor to consider is that not all biomass use is sustainable. Harvesting of forests or bush in rural areas is often poorly monitored with little or no replanting, resulting in serious deforestation and related land degradation. Biomass from these sources should not be considered a renewable resource.

4.1. Indicator calculations

The generic formula for calculating the indicators is written:

$$I = \frac{X - Y}{Z}$$

where:

I = the value of the vector (in relative terms);

X = the value (in absolute terms) of the environmental, economic or social parameter for this indicator;

Y = the sustainability goal (in absolute terms) which corresponds to value 0 of the vector; and

Z = the value of the segment (in absolute terms) which goes from 0 to 1 on the vector.

Where:

Z = W-Y

And:

W = the reference value for unsustainability (in absolute terms) which corresponds to value 1 of the vector.

The two equations above demonstrate the importance of well defined vector values for Y (the sustainability objective) and W (the reference value for unsustainability). As the difference between Y and W becomes greater, the impact of difference in the variable in question becomes less significant.

Each indicator has an equation specific to its own upper and lower bounds or vector values however they all follow the generic formula given above.

4.2. South Africa's 'Snowflake'

A helpful way to view the results of sustainability indicators is in a 'snowflake'. Figure 5 below shows the 'snowflake' for South Africa in 2000. Each of the numbered axes refers to a different indicator with the centre of the 'snowflake' at the 0 vector (close to the sustainability goal) and concentric circles out from the centre referring to indicator values further away from the sustainability goal. In this way it is easier to see where we are succeeding in reaching goals of sustainability and which areas still need improvement.

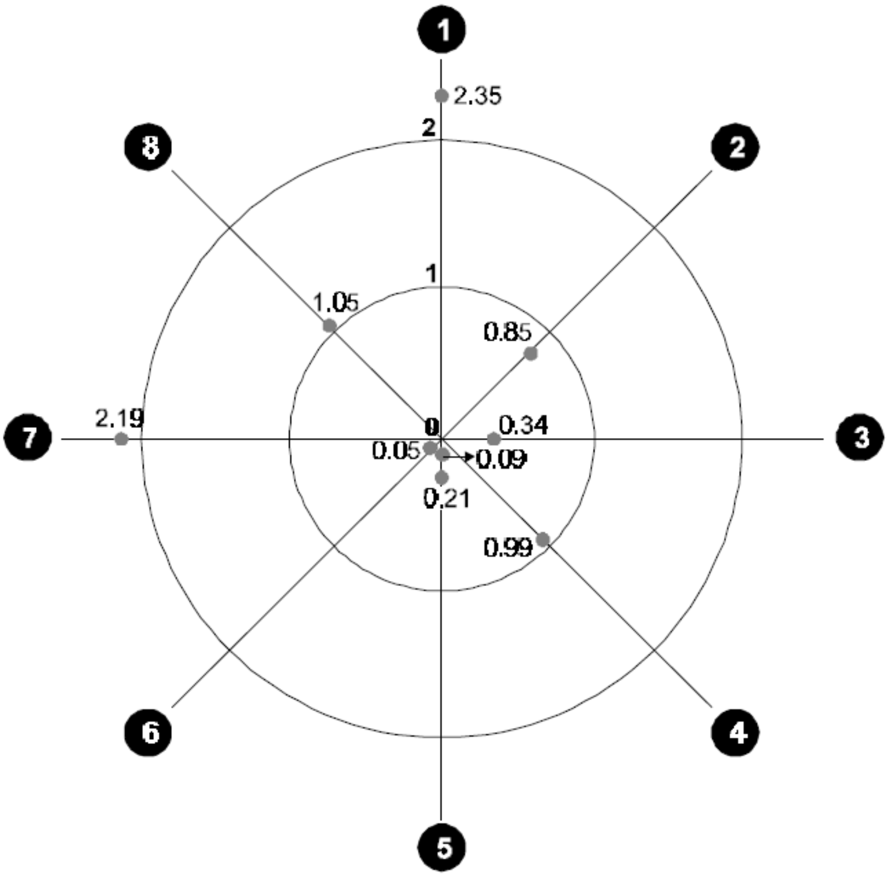


Figure 5: South Africa's sustainability indicator 'snowflake'

Source: Spalding-Fecher 2002

Note: For the two point on indicator 5, 0.09 is for exports and 0.21 is for imports.

South Africa is closest to the sustainability targets on indicators for access to electricity (0.34), resilience to external impacts (energy exports 0.09 and energy imports 0.21) and the burden of energy investments on the public sector (0.05). The first indicator reflects the success of the South

African government's rigorous electrification program. The low value for resilience to external impacts may be somewhat misleading because while South Africa has large resources of coal, it still relies very heavily on crude oil imports to supply transportation fuel and there is uncertainty about how the implementation of the Kyoto Protocol will affect the coal industry.

South Africa performs worst on the indicators for carbon emissions per capita (2.35) and energy intensity (2.19). As mentioned above, this is because of the energy-intensive industry and low-cost energy coupled with the high dependence on coal for primary energy.

5. Final Comments

This report is the second of three reports in the project entitled 'Clean Energy and Development for South Africa'. It has outlined the government policies included in the scenarios as well as assumptions for efficiency options, taxation of CO2 emissions, Renewable Energy targets and other sectoral specific measures. The report has also defined Sustainability Indicators and the mathematics in calculating them.

The first report gives background to the South African energy system and the base case of the model. This report provides information on the scenarios to be run and the following, and final, report describes the results from the modelling process.

A. APPENDIX: Scenario summary and new technology options:

Energy Generation

ACTION	*Base Case: Growth without constraint*	*Scenario options*
LIQUID FUEL SUPPLY		
Bio fuels – Bio diesel Ethanol	Blended biofuels with liquid fossil fuels: 4% of total petrol sales is ethanol by 2013 provided largely by Ethanol Africa (mainly from yellow maize). Biodiesel is blended to 1% with Fossil Diesel. Production begins in 2008	8% of total petrol sales is ethanol by 2013 provided largely by Ethanol Africa (mainly from yellow maize). Biodiesel is blended to 2%.
ELECTRICITY SUPPLY		
Landfill Gas	Upper bound of 74MW	All renewable options forced to 36PJ of electricity generation capacity by 2015, this is increased to 15 percent in 2030.
Concentrating Solar Power Tower 100 MW pilot	First Plant could be commissioned by 2014 Upper bound on output from CSP is capped at 643MJ An upper bound on new installed capacity is set at 1GW each year	
Concentrating Solar Parabolic trough 100 MW pilot	First Plant could be commissioned by 2014 Upper bound on output from CSP is capped at 643MJ An upper bound on new installed capacity is set at 1GW each year	
Wind	The first wind farm in Darling of 10MW comes online in 2007. Additional wind capacity can be introduced after 2013. Upper bound on wind turbine capacity at a capacity factor of 20 and 25 % set at 7.7GW each.	
Nuclear (conventional)	Upper bound on new PWR set at 8.72GW First new unit could be commissioned by 2015	Nuclear technologies forced to 15 percent of generating capacity in 2030 starting in 2015.
Nuclear PBMR	Upper bound set at 24 modules	
COAL (PF) (FGD)	Upper bound on capacity of conventional pulverised fuel coal plants set at 40GW. First new station could be commissioned in 2012. Upper bound on investment in new capacity set at 3600MW every one and a half years.	
COAL Super critical (FGD)	Upper bound on supercritical coal set at 40GW. All supercritical coal has FGD. First unit could be commissioned in 2015, Upper bound on new capacity set at 3600MW every one and a half years	
IGCC (uses coal)	First unit could be commissioned in 2015	
IMPORTED HYDRO Cahora Basa Dam (Mozambique)	Currently importing: Cahora Basa: Cost: 20 R/MWh/y Upper limit: 1138MW at 80% capacity factor Inga:	

ACTION	*Base Case: Growth without constraint*	*Scenario options*
Grand Inga (DRC) Mepanda Uncua	Cost: 91 R/MWh/y 40 000 MW (upper limit) Available after 2020 Imports from Mepanda Uncua Cost: 161 R/MWh/y 2011 with an upper bound of 7288 GWh/year (NER 2004a from Winkler et al 2006) NOTE: imported hydro electricity is restricted to 15% of electricity consumption	
IMPORTED COAL-FIRED ELC Botswana	Assume that the plant will be 3.6GW plant and SA will import 70% of the electricity generated. Importing begins in 2011 (Energy In Africa, 2006)	
CCGT 2000MW	New CCGT's are introduced in Coega (2012, 3.6GW) and New Castle (2008, 0.015GW), although the actual location is not important. Additional capacity is available after 2012 and is bound at 3.87GW.	

Energy Use

	Base Case: Growth without constraint	*Scenario options*
TRANSPORT		
High efficiency engines	Road Vehicle efficiency in new private passenger cars light commercial vehicles improves by 0.4% annually.	Private passenger cars & light commercial vehicles: Additional improvement of 0.5% per annum (2008 – 2030). Equal to 30% over the time period. (Michaelis 1994) (An and Sauer 2004)
Hybrid vehicles	0.1% of private passenger vehicles in the fleet are comprised of hybrid vehicles by 2030.	2% of private passenger vehicles in the fleet are comprised of hybrid vehicles by 2030.
Vehicle occupancy	Vehicle occupancy in passenger vehicles kept at 2.1 per passenger-km	Vehicle occupancy increased to 2.2 persons per passenger-km
Private diesel vehicles	From 2.8% in 2001 up to 5% of passenger vehicles in 2030 From 0% in 2001, diesel taxis increase to 1.2% of public passenger transport in 2030	Use of diesel passenger vehicles is allowed to increase to 15% in 2030 (Taylor 2006) Suggested in (DME 2004) From 0% in 2001, diesel taxis increase to between 10% and 15% of public passenger-km in 2030 (15% of taxis are diesel). Petrol taxis' share decreases to account for the increase in diesel taxis. (de Beer 2006)
Cap on SUV penetration		Diesel and petrol SUVs are capped at a total of 2% of private passenger-kilometres
Taxi Recapitalisation	Moderate increase in the number of diesel taxis	4.7% of taxis are diesel Midi bus vehicles by 2015. This is increased to 7.4% in 2030
Public transport		There is increased use of public transport from 51.8% to 57% in 2015
Bio fuels – Bio diesel Ethanol	In the base case biodiesel and bioethanol production is introduced in 2008 and increases to a mix of 4% bioethanoll with petrol and 1% biodiesel with diesel by 2013; these ratios are maintained to 2030.	An 8% mix of ethanol with petrol and 2% mix of biodiesel with diesel is introduced in 2013 and maintained to 2030.
RESIDENTIAL		
National electrification program	Assume that by 2030, 99% or urban and 90% of rural households will be electrified. This implies that 17% of rural low-income households and 3% of urban low-income households will still be non-electrified by 2030.	
Solar water heaters	Use of Solar water heaters to meet demand for water heating increases over the period, RHE: 9.1% by 2030 UHE: 0.8% by 2030	The penetration level of SWH allowed increases to: RHE: 10.5% in 2015, 25% in 2030 RLE: 0.7% in 2015, 1.8% in 2030 UHE: 10% in 2015, 27% in 2030, ULE: 2.7% in 2015, 11.2% in 2030
Geyser insulation	4% of demand for hot water is met with geysers with additional insulation in RHE households, 0.6% in RLE households. In UHE households this increases to 5.6%.	Up to 65% of electric geysers have additional insulation by 2015.

	Base Case: Growth without constraint	*Scenario options*
Insulation, passive solar design (combined) (Energy efficient house)	Moderate penetration rate	The shell of the house is improved by insulation, prioritising ceilings. Percentage of houses with additional insulation are: RLE and ULE 10% in 2030, ULN and RLN, 5% in 2030, These lower penetration rates are partly due to the slower population growth and the assumption that household income is increasing over the period and therefore there are fewer houses being built in the low income category.
CFLs	RHE: 25% of incandescents shift to CFLs by 2030 RLE: 20% shift to CFLs UHE: 30% shift to CFLs ULE: 30% shift to CFLs	RHE: 50% of incandescents shift to CFLs by 2030 RLE: 40% shift to CFLs UHE: 60% shift to CFLs ULE: 65% shift to CFLs It is unlikely that 100% of households will use CFLs, based on studies in the Netherlands, Germany, and Denmark. (Kofod 1996)
Wood Stove efficiency	Wood stove efficiencies improve from 25% to 40% in 2030.	Assume that 30% of all wood stoves have a further efficiency improvement of 20% (new design of stove). This translates to an overall increase in efficiency in 2030 of 6%. (ie efficiency in 2030 = 46%)
Coal Braziers- "Basa Njengo Magogo"	Coal braziers are used by urban low income households for both cooking and space heating. In ULE and ULN households 20% of coal braziers switch to the Basa Njengo Magago (BNM) method by 2030 for both cooking and space heating.	In ULE and ULN households, 40% of coal braziers switch to BNM method by 2030 for cooking and space heating.
Ethanol gel fuel	Ethanol gel is allowed to replace other fuels	Ethanol gel is allowed to replace other fuels
Other fuel switching options		Bounds are opened up 30% to allow other fuels to be used, on a least cost basis.
COMMERCIAL		
Lighting		Increased penetration of CFL's, Efficiency improvements new buildings: 60% improvement in 40% of buildings, and 30% improvement in an additional 40% of buildings Efficiency improvements in existing buildings through retrofits: Up to 40% in 20% of buildings and an additional 20% in all remaining buildings by 2015
HVAC, office equipment etc		Increased penetration of heat pumps and central air conditioners, 5% in 2015 and 11% in 2030. Increased use of VSD's on fans, up to 20% efficiency improvement applied to 12% of HVAC systems.
office equipment		It is assumed that electrical office equipment can increase in efficiency, half of all equipment is allowed to improve in efficiency by 40% and the other half by 15% over the period
Solar Water heating		Assume up to 20% of hot water needs in commercial sector is met by SWHs by 2015, this increases to 40% by 2030. This is based on a high penetration rate of SHW's in new commercial buildings.
Thermal efficiency of buildings		Thermal efficiency improves in new buildings only. A thermal efficiency improvement of 50% is introduced into 40% of buildings, and an efficiency improvement of 30% is introduced into an additional 40% of new buildings by 2015.

	Base Case: Growth without constraint	*Scenario options*
INDUSTRY		
Thermal savings		Thermal savings apply to all steam systems, and boilers. Steam system efficiency is improved by 20%
Compressed air savings		Savings in compressed air are restricted to 20% of final energy demand for compressed air.
Efficient lighting		Efficient lighting achieves a 40% saving
Efficient motors		Efficient motors achieve a 5% saving
Variable speed drives		Variable speed drives achieve savings of between 5 and 10% depending on the application

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