South Africa Low Carbon Scenario Report

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Summary

South Africa is the most industrialized country in Africa, with a population of about 47 million people by 2007. Its economy is highly dependent on energy production and use, making it one of the largest emitters of greenhouse gases in the world. Coal provides 75% of the fossil fuel demand and accounts for 91% of electricity generation. After the ratification UNFCCC and Kyoto Protocol respectively in August 1997 and July 2002 the South Africa government embarked upon numerous projects that relate to a broad understanding of issues around climate change, including projects that have been intended as measures to reduce GHGs and adapt to climate change.

The bulk of GHG emissions in South Africa come from the energy sector, whereby the sector contributed 78% of South Africa's total greenhouse gas emissions in 1994, and more than 90% of carbon dioxide emissions. An energy-intensive economy and high dependence on coal for primary energy is a major reason for this pattern. Being a non-Annex 1 country with no binding target to reduce GHG emissions, South Africa has generally taken the approach of sustainable development to create a platform for developing into a low carbon society. Three main areas are seen as being critical toward achieving such objectives, namely energy efficiency, renewable energy and cleaner fossil fuels.

Achieving a low carbon emission profile in South Africa is essentially in the context of the power sector, the largest source of greenhouse gases in the country. At the end of 2000, there were 50 power stations in the country, of which 20 were coal-fired, accounting for 90% of the total licensed capacity of 43 142 MW. For future sustainable energy supply, South Africa is looking to more Southern African regional resources, as opposed to purely domestic resources, especially within the Southern African Development Community (SADC), which has considerable hydropower and natural gas potential. This is in line with the objective of government policy for electricity supply is that of the 1998 White Paper on Energy Policy, namely to 'ensure security of supply through diversity'.

The government has also expressed intention to examine all available energy technologies, and plan for future electricity capacity needs based on planning to select the least-cost option. Major options for electricity supply increase include de-mothballing of coal-fired power stations, new pulverised fuel plants, fluidised bed combustion, open cycle gas turbines (for peak generation), and combined cycle gas turbines. Other options considered include nuclear power from the Pebble-Bed Modular Reaction (PBMR) and various renewable energy technologies, notably wind, solar thermal electricity, biomass and landfill gas.

A number of studies have been undertaken in modeling of future electricity supply in South Africa, on the basis of the 'base plan', which aims at minimising costs, assuming moderate growth in electricity demand and moderate penetration of demand side management. One such modelling study uses a base plan for 2001-2025, with the following electricity supply scenarios:

- The return to service of four mothballed coal-fired power stations or units within stations, mainly for peaking and mid-merit operation (total 3 556 MW). This would start from 2007, when demand forecasts are expected to exceed supply.
- Building two new pulverised coal plants starting from 2013 for base-load (14 080 MW).
- Gas-fired plants, simple from 2011 and one combined cycle from 2014 (1 950 MW). However, there are alternative uses for gas – chemicals and liquid fuels at Sasol; heat; reducing agent for iron. CCGT has been explored for converting Cape Town's Athlone power station, but is relatively expensive (Kenny & Howells 2001).
- Pumped storage facilities from 2011 (3 674 MW).
- Demand side interventions (residential and industrial/ commercial; load management and end-use energy efficiency; interruptible load) distributed over the period (equivalent to 4 807 MW).

The base case is dominated by coal which continues to supply most of the electricity capacity, even though some coal power plants come to the end of their life around 2025. On a low GHG

emission scenario, major other sources of new capacity in the base case are gas (open cycle and combined cycle). Smaller low GHG emission contributions come from existing hydro and bagasse, electricity imports, existing and new pumped storage.

The low carbon "policy" emission scenario is characterised by the following attributes;

- Base-load coal stations, with flue-gas desulphurisation (FGD);
- 'Cleaner coal' technologies, in particular the Fluidised Bed Combustion (FBC) technology;
- Nuclear technology in the form of the Pebble-Bed Modular Reactor;
- imported hydro-electricity from Mozambique, Zambia or the DRC; and
- imported gas, and
- renewable energy technologies (wind, solar thermal, biomass, domestic small hydro).

The two scenarios results in the following emissions reductions for the various policy cases;

Scenario	*Emission reductions (Mt CO_2)*			
	2000	*2010*	*2020*	*2030*
Base	350	438	543	645
Gas	0	0	-12	-12
Hydro-electricity	0	1	-13	-19
PBMR nuclear	0	0	-23	-32
Renewables	0	-6	-11	-18

The table below shows the total investment costs as well as the installed capacity that results in each policy case. It is observed that domestic investments in capacity in hydro case are lower, and to a lesser extent this is also true for gas. The largest investments requirement is needed for the PBMR case, where installed capacity in that case is the same as for the base case. The additional investment needed for the renewables case lies between the base and PBMR cases.

	Total investment cost 2001 - 2025, discounted, R bn	*Installed capacity by 2025, GW*
Base case	134	57.7
Gas case	114	57.8
Hydro case	84	51.5
PBMR case	153	57.7
Renewable case	142	58.5

Becoming a low carbon society is quite a challenge for South Africa as its economy is highly dependent on fossil fuels, particularly coal. The sustainable development policies and measures (SD-PAMs), built on the national development objectives and priorities, is recommended to be instrumental in moving South Africa toward a low carbon society. This is achieved either by putting in place more stringent policies or by implementing new measures that align the development path to follow a sustainable course. For South Africa, the SD-PAMs approach would focus on development objectives of economic growth, job creation and access to key services, such as, to mention just a few, housing, water, transport and access to modern energy services. Such an approach would not only enhance reduction of GHG emissions, but would also acknowledge country's unique circumstances and development objectives.

1.0 Current trends and policies in South Africa[1]

South Africa is a developing country located in the southern end of Africa. It is the most industrialized country in Africa. In 2007 it had a population of about 47 million people, with a 2.1% annual growth rate, living on a land area of 1.2 million square kilometres. Its economy is highly hinged on energy production and use, with fossil fuels coal dominating more than 90% of the primary energy demand. Coal provides 75% of the fossil fuel demand and accounts for 91% of electricity generation.

The first ten years after the democratic elections of 1994 in South Africa saw tremendous changes in all sector policies of the country. This change was motivated by the change of government from an apartheid system to democratic governance. The main development objectives of South Africa was then pivoted around economic growth, job creation and access to key services (including housing, water, sanitation, transport, telecommunications, energy services and land reform) to the vast majority of its citizens. The new government under the African National Congress (ANC) party embarked on a new direction of governance by promoting social equity in the country and improvement on exports including capital goods. This led to several national policy reviews in all key economic areas, followed by White Papers and new legislation across all economic sectors, including the energy sector, which is the largest contributor of greenhouse gas emissions in South Africa.

Before 1994, energy policies in South Africa were orientated toward providing energy services based on 'separate development' of people according to their race. In general, government's policy on energy supply was largely concentrated on the electricity sector and the liquid fuel sectors as they were crucial to the economic and political interests of the country. Security was vital, and secrecy and control characterized most of the policies that prevailed.

After the political changes 1994, the government was determined to provide basic services to the poor and disadvantaged that formed the majority of the population. Modern energy was one of the main components of such services, especially high quality electricity supplies.

South Africa in the year of the democratic elections in 1994 set up a National Climate Change Committee (NCCC) that would be an advisory body to the Minister of Environmental Affairs and Tourism guide the government on issues of climate change, at both international and national level. In August 1997 the South Africa Government ratified the United Nations Framework Convention on Climate Change (UNFCCC), and later on in July 2002 signed the Kyoto Protocol. In order to fulfil its commitment to the UNFCCC, for a number of years now the South Africa government embarked upon numerous projects that relate to a broad understanding of issues around climate change, including projects that have been intended as measures to reduce GHGs and adapt to climate change.

1.1 South Africa's energy supply and emission profile

South Africa has large reserves of coal, which supplies over 70% of its primary energy, large reserves of uranium, and small reserves of crude oil and natural gas. South Africa is largely arid and has very limited potential for hydropower. Biomass is

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[1] This report draws from various publications made by the Energy research Centre (ERC), University of Cape Town, contributed to by the ERC staff, including the author of the report.

an important source of energy, both for poor households and the sugar refining and pulp and paper industries. Conditions for solar power are good, especially in the Northern Cape. Conditions for wind are fairly good, mainly in the coastal regions.

The bulk of GHG emissions in South Africa come from the energy sector, whereby the sector contributed 78% of South Africa's total greenhouse gas emissions in 1994, and more than 90% of carbon dioxide emissions. An energy-intensive economy and high dependence on coal for primary energy is a major reason for this pattern.

Compared to other major developing countries, South Africa's emissions intensity is relatively high, in that it emitted 0.96 kg CO_2 per dollar of GDP in 1999 compared to a non-OECD average of 0.66 (Table 1). Reliance on coal resources for electricity production is the main reason behind this emission profile, and other reasons include the production of synthetic liquid fuels, a high proportion of energy intensive industry and mining, and the inefficient use of energy.

South Africa's emissions per capita are high, at 8.23 tons of CO_2 (tCO_2) per capita, much higher than Africa's average of 0.94 tCO_2 and four times higher than the non-OECD value of 2.24 tCO_2.

Table 1: Energy sector carbon emissions intensity and per capita, 1999

	CO_2/cap	*CO_2/GDP*	*CO_2/GDP PPP*
	tonnes/capita	*Kg/1995 US$*	*kg/1995 PPP$*
South Africa	8.23	2.11	0.96
Africa	0.09	1.28	0.49
Non-OECD	2.24	1.79	0.66
OECD	10.96	0.46	0.52
World	3.88	0.71	0.58
Key: PPP = purchasing power parity, GDP = Gross domestic product			

Source: IEA, 2001a

1.2. Energy and sustainable development for a Low Carbon Society

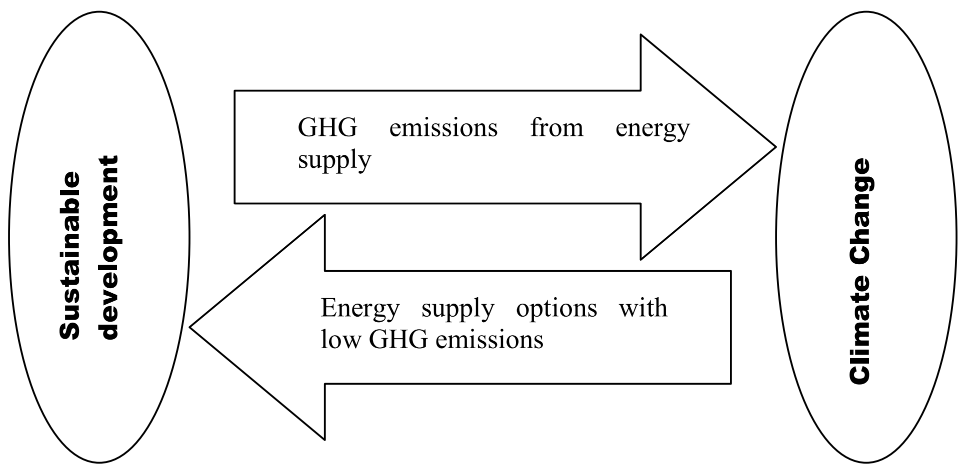
The world has gradually evolved to a state of unprecedented multilateral effort in trying to avert the calamity posed by the changing global climate. By the 2007 Bali climate change negotiations, only a handful of countries were perceived as still being an impediment toward charting a roadmap for a low carbon global community. Evidence is becoming increasingly available and undisputable that if left unabated, global warming to an increased average temperature of 2ºC will result in a substantive disruption of ecosystems and physical features, causing economic and social instability in most parts of the earth.

Time and again the energy sector has been cited to be the largest contributor of greenhouse gases that enhances increases in average earth surface temperature. Invariably, most effort on mitigation of climate change has been observed to focus on fossil fuel consumption, including fuel switch, efficiency improvement or reduced use. It is widely accepted that deep reduction in use of fossil fuels like coal has to go hand in hand with increased use of renewable energy sources like wind, solar, geothermal, nuclear, etc. In translating the multilateral agreement of agreeing to cut down greenhouse emissions to national context, countries need to make a robust analysis of their future emission scenarios and come up with relevant policies and measures to ensure a low carbon future.

Being a non-Annex 1 country with no binding target to reduce GHG emissions, South Africa has generally taken the approach of sustainable development to create a platform for developing into a low carbon society. However, in various studies commissioned by the government, there has been a clear indication that a more vigorous approach to reducing the country GHG emissions might be taken in future.

In the sustainable development paradigm that South Africa pursues, one can find linkages with climate change by identifying synergies between the two. The connection between sustainable development and climate change works in two directions (Munasinghe & Swart 2005). Case studies have been conducted to examine the potential contribution that more sustainable energy development can make to climate change mitigation, as well as possible impacts of climate change on energy development in South and Southern Africa. The interaction in both directions is illustrated in Figure 1 below.

Figure 1: Two-way interaction between sustainable development and climate change



Energy sector, specifically the electricity sector, is the biggest contributor to GHG emission in South Africa. Coal accounts for three-quarters of primary energy supply (DME 2003a), and for over 90% of electricity generation (NER 2002a). As such, the challenge of climate change in South Africa relates to a significant extent on the dependence of the economy on fossil fuels. Industrial processes and agriculture also contribute to greenhouse gas emissions, but energy-related emissions constituted 78% of the South Africa’s inventory of greenhouse gases in 1994 (Van der Merwe & Scholes 1998).

The sustainable development two-way connection in South Africa is therefore particularly marked in the energy sector, the major source of GHG emissions. Future emission and mitigation scenarios in South Africa are primarily an energy issue, making energy supply and use a critical issue in developing to a low carbon society. Effort toward such a low carbon scenario includes a number of alternative energy sources in the country, including renewable energy and nuclear energy.

By and large, achieving the sustainable development objectives of South Africa will require a substantial increase in the supply of modern affordable services to every South African, while maintaining the environmental integrity and social cohesiveness of the country, and allowing economic development to progress. There are three main areas critical to South Africa's future energy scenario with a view to sustainable development;

- Energy efficiency
- Renewable energy
- Cleaner fossil fuels

Energy efficiency and demand-side management

There is great potential for energy efficiency in South Africa, across a range of sectors from industry, commercial, transport to residential. Interventions for energy efficiency in the residential sector can contribute significantly to development for households – improved quality of life at reduced cost. The largest energy savings in absolute terms, however, are found in the industrial and transport sectors (ERC 2006).

Renewable energy

At present, South Africa has limited renewable energy sources that can be exploited commercially, but the cost of renewable energy is expected to continue to decline as the technologies mature. Increased use of renewables will require the introduction of new policies. The Renewable Energy White Paper (2003) has set a target of 4%. A strategy of implementing this target needs to be formulated, honing in on specific projects and their financing.

The government has always outlined its intention to improve the local content of renewable energy technologies used in South Africa. Hence, the most important policy is to set up policies for progressively increasing local content in the manufacture of renewable technologies used. Such a policy should be accompanied with the government supporting enabling conditions for local technology development (ERC2006).

Cleaner fossil fuels

There is a concerted international effort to make advances in developing and implementing cleaner fossil fuel technologies. However, most of these efforts are in developed countries and are in R&D and D networks. An area for policy intervention is for South Africa to become part of these networks and partnerships as this would enhance not only the knowledge basis for suitable selection, but also allow local forces to be part of their development, thus increase their chances of utilisation. South Africa, for example, has made significant advances in the area of synthetic fuels, from both coal and natural gas feedstock, to the extent that it is now exporting such skills to other countries.

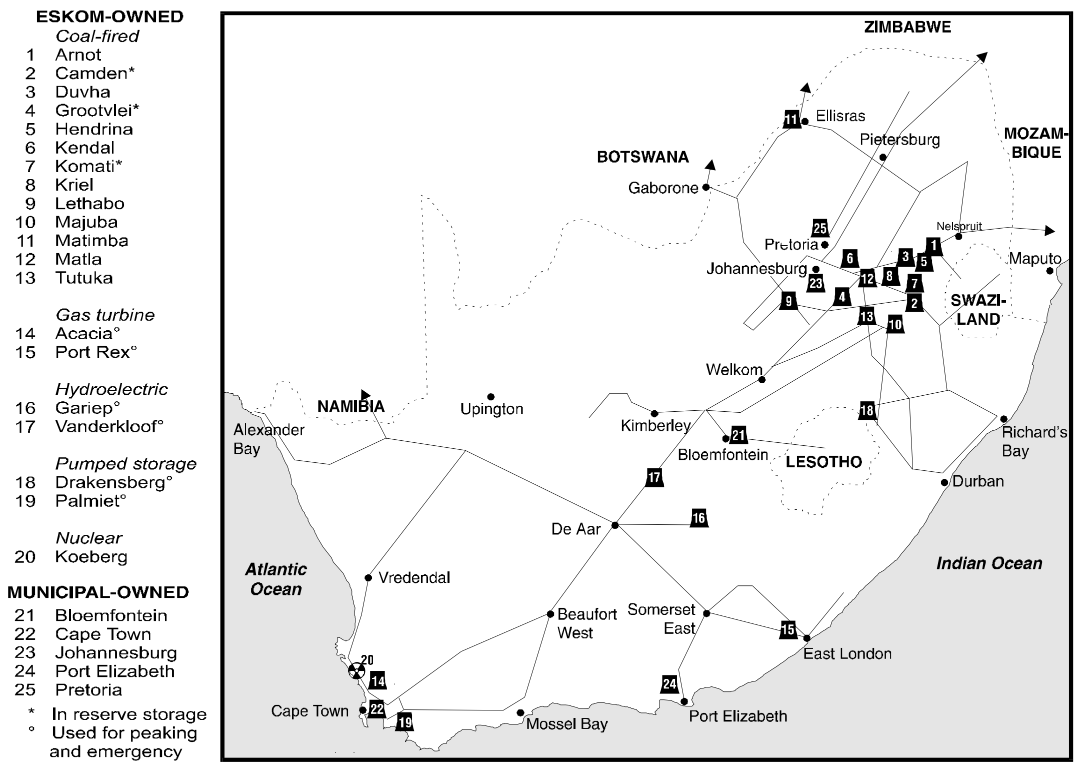
1.2 Current power sector situation in South Africa

Electricity generation and transmission in South Africa is mostly derived from the national power utility, Eskom. The utility generates over 90% of electricity in the country, with municipalities and private auto-generators[2] contributing about 4% of the total generation.

The generating technology in South Africa is based largely on coal-fired power stations. To avoid transport costs, all the large coal power stations are concentrated around the coalfields in Mpumalanga, Gauteng and the Northern Province (see Figure 1).

Figure 1: Map of SA power stations by fuel and ownership

Source: (Spalding-Fecher et al. 2000)



At the end of 2000, there were 50 power stations in the country, of which 20 were coal-fired, accounting for 90% of the total licensed capacity of 43 142 MW (including capacity in reserve and under construction). The only non-coal stations of significance are the Koeberg nuclear station (4.6% of operational capacity) and three pumped storage facilities (collectively 4.0 %) (NER 2001). These stations are the only ones

[2] Autogenerators are industries that generate electricity for their own use, including SASOL, sugar companies and the pulp & paper industry.

that are not located in the northeast of the country and assist with grid stability in the Western Cape.

Table 2 shows the share of electricity sent out by fuel type (note that percentages of capacity and electricity generation can differ, depending on load factors).

Table 2: Net electricity sent out (MWh) by fuel

Source: (NER 2001)

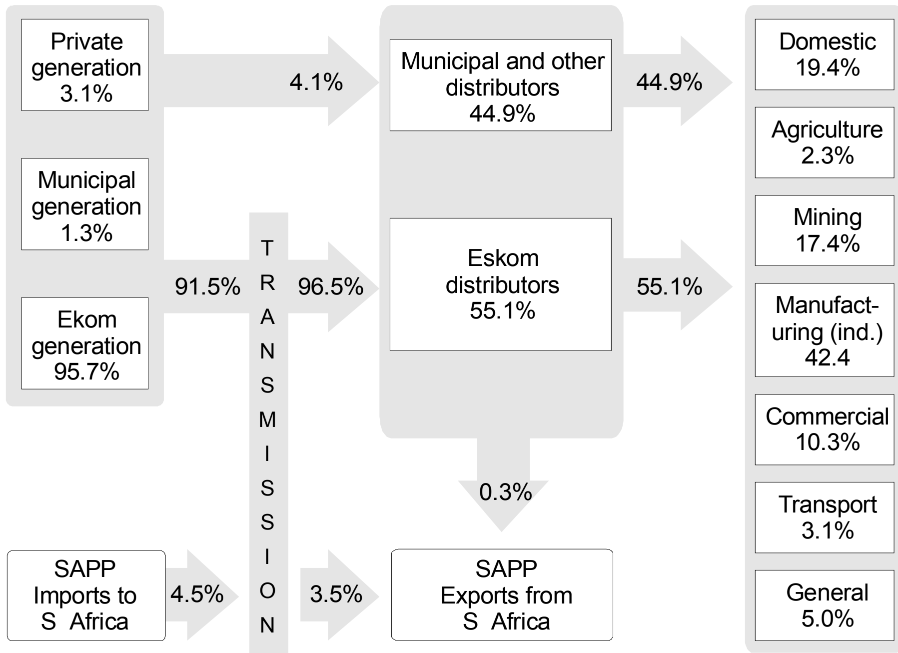
	Eskom	*Municipal*	*Private*	*Total*	*Share of total energy sent out*
Coal	175 222 884	609 676	7 440 075	189,900,811	93.2%
Nuclear	10 718 623	-	-	11,961,744	5.9%
Pumped storage	-769 295	-67 545	-	-816,755	-0.4%
Hydro	2 194 071	9 690	14 288	2,382,048	1.2%
Bagasse	-	-	306 878	259,317	0.1%
Gas	-725 *	5 710	-	5,557	0.003%
Total	195,324,579	1,143,657	7,224,486	203,692,722	

* Negative values: Pumped storage uses more electricity in pumping water up than it generates, and hence is a net consumer. For gas (using aeronautical diesel fuel in jet turbines), Acacia station consumed more for own use in its generation process than it generated in 2000. This is not always the case.

Figure 2 shows the flow of electricity from production, through distribution and to end use customers. In addition to domestic resources, imports (primarily hydro-electricity) are shown.

Figure 2: Energy flow through the electricity supply industry in South Africa[3]

Source: NER (2001)



2.0 Future scenarios towards a 2020/2030 Low-Carbon Society

In trying to align the energy sector and sustainable development, the government of South Africa has instituted policies and measures that in the long run contribute to mitigating climate change. On a larger scale, South has embarked on a number of actions that will reduce the pace of carbon emissions growth. South Africa, as most developing countries, has policies and measures that have been taken for technological, environmental or economic development, but will result in GHG emission reduction or climate change mitigation.

The energy policy is one example that gives a glimpse of what may become the future emission scenario in South Africa. Major objectives of government policy for the energy sector are spelled out in the 1998 Energy White Paper as:

- Improving energy governance;
- Increasing access to affordable energy services;
- Stimulating economic development;
- Managing energy-related environmental impacts; and
- Securing supply through diversity (DME 1998).

For future sustainable energy supply, South Africa is looking to more Southern African regional resources, as opposed to purely domestic resources, especially within

[3] The original diagram gives no percentages for imports and exports. For 2000, however, 5 294 GWh were imported from SAPP utilities and 3 967 GWh exported. As a percentage of gross energy sent out of 198 206 GWh, imports constituted 2.6% and exports 2.0%. It is not exactly clear how this would change the percentages above, but the impact of 1 327 GWh difference between imports and exports is unlikely to result in changes in front of the decimal point.

the Southern African Development Community (SADC), which has considerable hydropower and natural gas potential. The Southern African Power Pool (SAPP), composed of the national utilities of all SADC countries, now has an operational control centre in Harare that will facilitate increased electricity trading in the region. Eskom, the national power utility, has identified more than 9 000 MW potential for regional imports, even without considering the massive potential of the Grand Inga scheme in the Democratic Republic of Congo, which has the potential of over 40 000 MW in the longer term. Regional co-operation on energy development is also a major drive within the New Partnership for Africa's Development.

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

Table 3: Sector development, sustainable development and GHG emissions

Source: Winkler et el (2007)

Development objectives	***Possible shift to more sustainable development***	***GHG reduction or increase relative to business-as-usual (current stated policy)***
Housing		
Low Cost Housing Program: Approximately 300 000 new units per year.	All new low-cost houses built with energy efficiency measures (ca. R2,000 per household for a package of thermal interventions) Energy-efficient housing standards – mandatory through building regulation, etc.	0.05 and 0.6 $MtCO_2$-equivalent per year, if aggregated across all low-cost housing
Energy		
Increased access to affordable energy services - Continue electrification under restructured market, at 300 000 connections per year.	Aim for *universal access* to modern energy services - Off-grid electrification with renewables where appropriate, {but also using LPG, modern biomass, mini-grids and other systems (links to diversity)} - Implement free basic electricity (poverty tariff) of 20- 50 kWh / household / month for 1.4 million poor households	Health benefits from reduced indoor air pollution, but increased GHG emissions from power generation Increase of 0.146 $MtCO_2$ (upper bound estimate)
Improving energy governance - Restructuring of Electricity Distribution Industry (EDI) - Restructuring of Electricity Supply Industry (ESI)	Regulation under restructuring to ensure that national energy efficiency programme is implemented. Opportunity in restructuring for renewable energy IPPs, but also barriers. Require minimum of renewable energy in generation. Adopt Renewable Energy White Paper with quantified targets for renewable energy generation.	Reductions in CO_2 emissions; not quantified

Stimulating economic development	Remove energy trade barriers & facilitate investment in energy sector, including power-purchase agreements for renewable IPPs National energy efficiency programme to ensure 5% reduction in electricity consumption by 2010 - 39 000 additional jobs and R800 million additional income More intensive demand-side management by utility Industrial energy efficiency Adjust tariffs to allow return on investment in energy efficiency Include external costs in cost-of-supply approach to electricity pricing	Reduce CO_2 emissions by 5.5 million tons in 2010 Demand-side management leading to reductions of annual CO_2 emissions of 8 $MtCO_2$ in 2010 and 19 $MtCO_2$ in 2025. Potential reductions of 60 200 tons CO_2 p.a. from a single plant
Managing energy-related environmental impacts	Improve air quality by reducing energy-related emissions - indoor: LPG, extend low smoke fuels - outdoor: Promulgate National Ambient Air Quality Standards (SO_2 draft exists) - urban Integrate strategies between with transport and energy sectors	Study required to quantify links between reduced local air pollution and reduced GHG
Securing supply through diversity - Stimulate use of new & renewable energy sources - Develop gas markets - Develop Southern African Power Pool (SAPP)	Renewable Energy Portfolio Standard (REPS) . 5% of electricity generation by 2010, and 20% by 2025. Develop large-scale wind and solar thermal IPPs Use Mozambique gas for residential and commercial applications in Gauteng Explore additional imports of gas, from Namibia and West Coast Import additional hydro power (run-of-river)	Reductions in CO_2 emissions of 10 MtCO2 in 2010; and 70 $MtCO_2$ in 2025 (based on baseline emissions projections for bulk electricity). Need to include comparative costs.

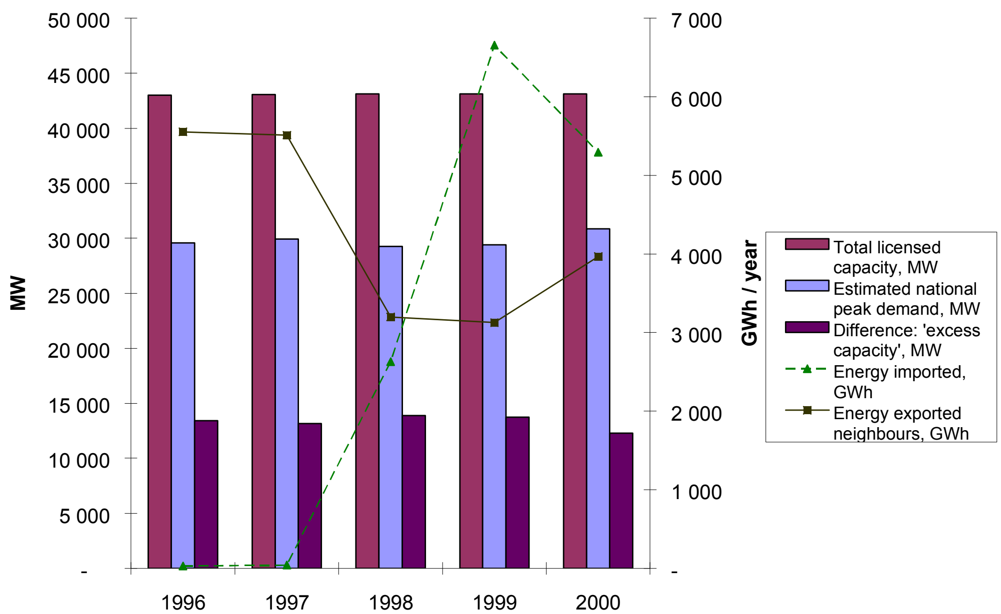
Transport		
Increased public transport (modal shift) Reduce cost of transport Reduce air pollution from transport (local emissions and GHGs)	Taxi recapitalisation Phase 2 with compressed natural gas Replace air travel with high-speed rail Use natural gas in Cape Town for range of transport interventions Using alternative fuels and phasing out leaded fuel	Reductions in CO_2 emissions; not quantified
Agriculture, forestry, land and rural development		
Forestry: - privatise state commercial forests - promote community forestry	Sustainable and community forestry	Reductions in CO_2 emissions; not quantified
Basic human needs and social services		
Industrial development and trade		
Investment and industrial strategy	Energy-intensive spatial development initiatives replaced by less energy-intensive sectors, e.g. tourism	Relative decrease in GHG emissions

2.1 Power sector development and low GHG emissions scenarios

For about 25 years massive investment in coal-fired power plants in South Africa led to excess capacity (NER 2003). Historically, the energy sector has been driven mainly by energy security concerns, especially during the period of isolation. The situation has drastically changed, whereby peak electricity demand significantly surpasses supply, resulting in power shedding during the winter of 2007. To alleviate the low capacity generation problems, measures undertaken and contributing to lower GHG emissions include demand side interventions (residential and industrial/ commercial; load management and end-use energy efficiency; interruptible load).

Figure 4: Excess capacity for all power stations 1996-2000

Source: NER (2004)



On a long term power generation strategy, an important objective of government policy for electricity supply is that of the 1998 White Paper on Energy Policy, namely to 'ensure security of supply through diversity' (DME 1998). The strong commitment to ensuring security of supply and to do so by pursuing all energy sources has been restated by then Energy Minister in her budget vote speech (Mlambo-Ngcuka 2004).[4] Government will examine all available energy technologies, and plan for future capacity needs based on planning to select the least-cost option. Major options for electricity supply increase include de-mothballing of coal-fired power stations, new pulverised fuel plants, fluidised bed combustion, open cycle gas turbines (for peak

[4] She said that 'the state has to put security of supply above all and above competition especially' (Mlambo-Ngcuka 2004).

generation), and combined cycle gas turbines. Other options considered include nuclear power from the Pebble-Bed Modular Reaction (PBMR) and various renewable energy technologies, notably wind, solar thermal electricity, biomass and landfill gas.

Coal used in the production of electricity in South Africa has always been that with a lower quality, as the best quality coal is exported and earns the country its third-largest export revenues after gold and platinum. The use of low quality coal has been one of the main factors for the significant GHG emissions in the power sector. South Africa's carbon emissions are higher than those of most developed countries partly because of the energy-intensive sectors (such as mining, iron and steel, aluminium, ferrochrome, and chemicals) which rely heavily on the low quality coal. Regardless of coal's dominance, power sector development in view to attaining a low carbon society dimensions in South Africa requires diversification of energy resources to other energy forms such as natural gas and renewable energy. This will be in line with the policy objectives of improving both supply security and environmental performance. Renewables are aimed to deliver the equivalent of 10 000 GWh by 2013, from electricity, bio-fuels, and solar water heaters. Some studies suggest that significant effort is needed to turn this aspirational target into reality (Alfstad 2004).

At the regional level, the major new opportunity lies in the Southern Africa Popwer Pool (SAPP), particularly hydro-electricity in the Democratic Republic of Congo (DRC). The potential at Inga Falls in DRC is equivalent to the current size of the South African grid at approximately 40 GW. The Mepanda Uncua hydro power project in Mozambique also has the potential to add a further 1300 MW to the SAPP (NER 2004a).

Proposals for the New Partnership for Africa's Development (NEPAD) include interconnectors within the region (Eskom 2002), building on the SAPP. The summary of NEPAD action plans on energy stated that "guaranteeing a sustainable supply of affordable energy is one of the best ways to address poverty, inequality, and environmental degradation everywhere on the planet" (NEPAD 2002).

Linkages are not limited to the electricity sector. Gas networks are also expanding, with the pipeline from Mozambique's Pande and Temane fields already delivering gas from 2004. Initially, this is focused on providing SASOL's synfuel and chemical plants with a cleaner fuel (switch from coal to gas). Possibilities for brining in Liquefied Natural Gas (LNG) and building gas-fired power stations are being talked about.

2.2 Modeling of future electricity supply in South Africa

2.2.1 Base case

A number of studies have been undertaken in modeling of future electricity supply in South Africa, on the basis of the National Electricity Regulator (NER, now National Energy Regulator of South Africa, NERSA) 'base plan', which aims at minimising costs, assuming moderate growth in electricity demand and moderate penetration of demand side management (NER 2001/2). One such modelling study uses a base plan for 2001-2025, with the following electricity supply scenarios:

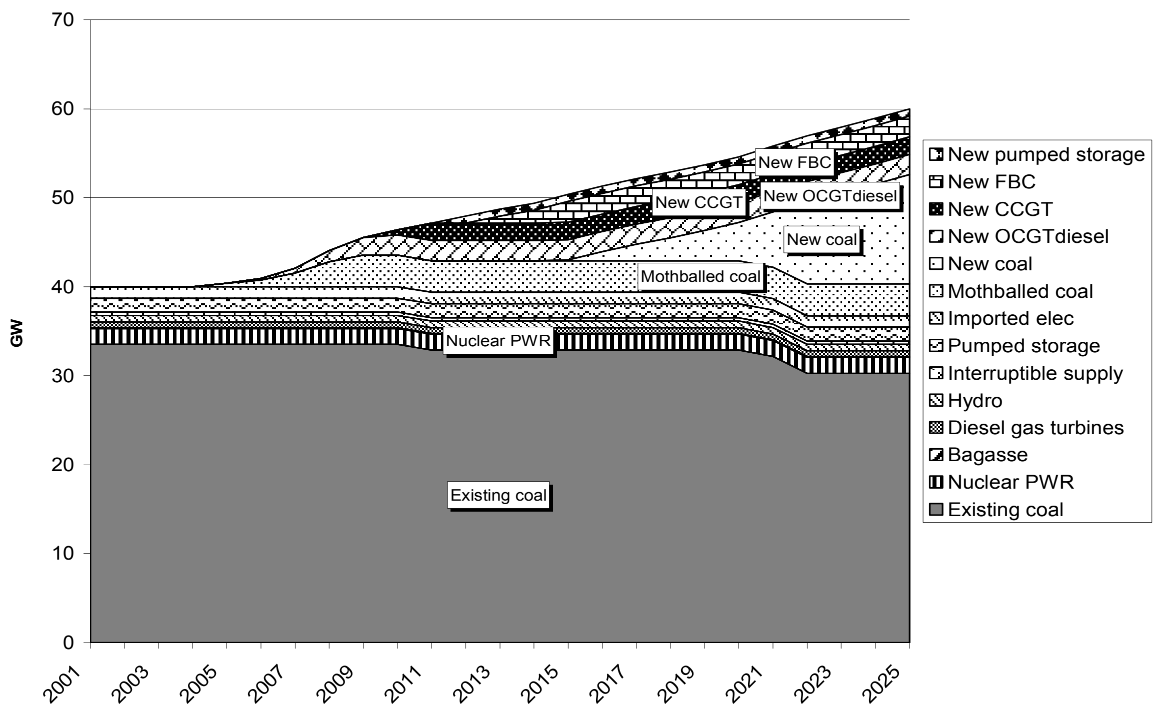
- The return to service of four mothballed coal-fired power stations or units within stations, mainly for peaking and mid-merit operation (total 3 556 MW). This would start from 2007, when demand forecasts are expected to exceed supply.

- Building two new pulverised coal plants starting from 2013 for base-load (14 080 MW). [5]
- Gas-fired plants, simple from 2011 and one combined cycle from 2014 (1 950 MW). However, there are alternative uses for gas – chemicals and liquid fuels at Sasol; heat; reducing agent for iron. CCGT has been explored for converting Cape Town's Athlone power station, but is relatively expensive (Kenny & Howells 2001).
- Pumped storage facilities from 2011 (3 674 MW).
- Demand side interventions (residential and industrial/ commercial; load management and end-use energy efficiency; interruptible load) distributed over the period (equivalent to 4 807 MW).

The expansion of electricity generation capacity is shown in **Error! Reference source not found.**, grouped by plant type.

Figure 5: Electricity generation capacity by plant type in the base case

Source: Winkler et el (2007)



The base case is dominated by coal, as can be seen in **Error! Reference source not found.**. Existing coal continues to supply most of the capacity in the base case, even though some of them may come to the end of their life around 2025, unless new investments are made to refurbish. Mothballed coal stations are brought back into service, and new pulverised fuel stations are built. New fluidised bed combustion,

[5] The second NIRP only showed two coal-fired stations, built between 2007 and 2019, totalling 7 700 MW (NER 2004a).

using discard coal, are also included in the base case. Hence existing and 'cleaner coal' technologies are included.

On a low GHG emission scenario, major other sources of new capacity in the base case are gas (open cycle and combined cycle). Smaller low GHG emission contributions come from existing hydro and bagasse, electricity imports, existing and new pumped storage.

2.2.2 Policy cases

South Africa over the next two to three decades will need to build 17 000 MW at approximately 1 000 MW per year. After 2025, many large stations will near the end of their life, and although options for refurbishment will then be considered, significant portion of existing capacity will need to be replaced. As mentioned above, the broad options for electricity supply include all available energy resources and conversion technologies – coal, nuclear, imported gas and hydro, and renewable energy.

Key characteristics of the electricity supply options are summarised in

Table , and the policy case supply options are summarised as follows;

- Base-load coal stations, with flue-gas desulphurisation (FGD);
- 'Cleaner coal' technologies, in particular the Fluidised Bed Combustion (FBC) technology;
- Nuclear technology in the form of the Pebble-Bed Modular Reactor;
- imported hydro-electricity from Mozambique, Zambia or the DRC; and
- imported gas, and
- renewable energy technologies (wind, solar thermal, biomass, domestic small hydro).

Table 4: Characteristics of new power plants

Source: NER (2004b)

	Units of capacity	Investment cost, undiscounted	Fixed O&M cost	Variable O&M cost	Lifetime	Lead Time	Efficiency	Availability factor
Type	MW	R/kW	R / kW	c / kWh	Years	Yrs	%	%
Coal								
New pulverized fuel plant	642	9,980	101	1.1	30	4	35%	252%
Fluidised bed combustion (with FGD)	233	9,321	186	2.9	30	4	37%	88%
Imported gas								
Combined cycle gas turbine	387	4,583	142	11.5	25	3	50%	85%
Open cycle gas turbine (diesel)	120	3,206	142	16.2	25	2	32%	85%
Imported hydro								
Imported hydro	9200 GWh / yr			2.1	40	6.5		
Renewable energy								
Parabolic trough	100	18,421	121	0	30	2	100% #	24%
Power Tower	100	19,838	356	0	30	2	100%	60%
Wind turbine	1	6,325	289	0	20	2	100%	25, 30, 35%
Small hydro	2	10,938	202	0	25	1	100%	30%
Land fill gas (medium)	3	4,287	156	24.2	25	2	n/a	89%
Biomass co-gen (bagasse)	8	6,064	154	9.5	20	2	34%	57%
Nuclear								
PBMR initial modules	165	18,707	317	2.5	40	4	41%	82%
PBMR multi-modules	171	11,709	317	2.5	40	4	41%	82%
Storage								
Pumped storage	333	6,064	154	9.5	40	7	storage	95%

(#) Note: Assume 100% efficiency for renewable energy technologies, with the availability factor reflecting issues relating to intermittency.

2.3 Emission reduction scenario

From the two scenarios shown in section 2.2 above,

Table 5 shows emissions reductions for the various policy cases. The first row gives the total annual CO_2 emissions for the base case as a reference value, while the emissions reductions (difference between that case and the base case) are shown in the rest of the table.

Table 5: CO_2 emission reductions for policy cases and base case emissions (Mt CO_2)

Source: Winkler et el (2007)

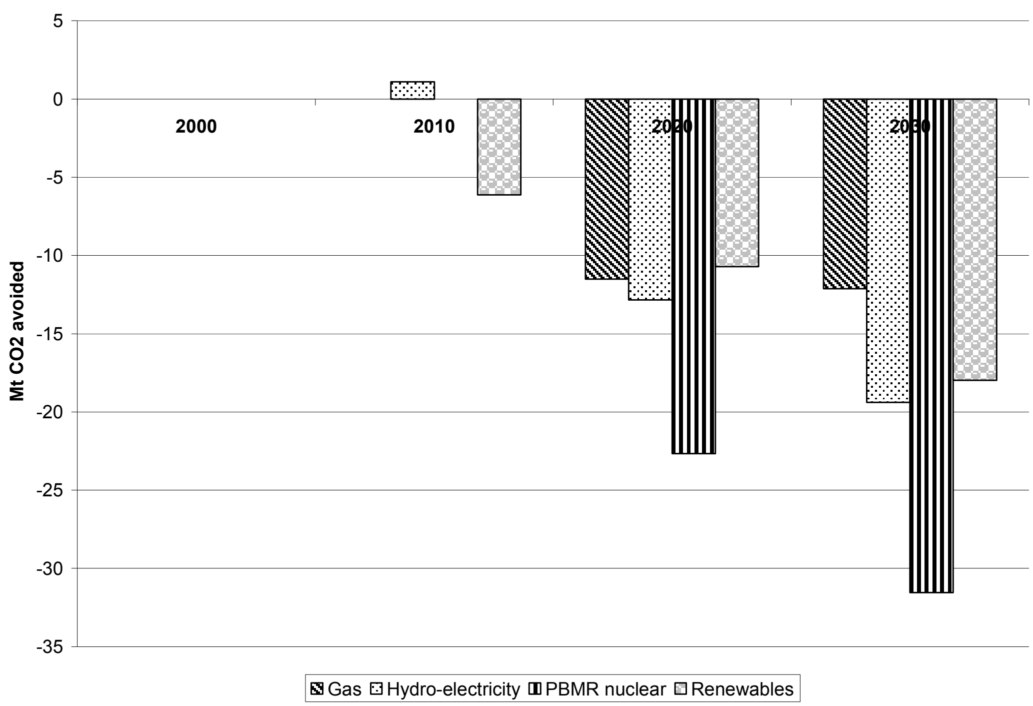
	2000	*2010*	*2020*	*2030*
Base	350	438	543	645
Gas	0	0	-12	-12
Hydro-electricity	0	1	-13	-19
PBMR nuclear	0	0	-23	-32
Renewables	0	-6	-11	-18

The PBMR and renewables actually have the same reductions by 2015, but by 2020 and 2030, the PBMR has increased to a capacity where its reductions are higher. To compare across electricity cases, the installed capacity, load factor and associated costs need to be borne in mind. The PBMR has reached 4.48 GMW by the end of the period, while renewable energy technologies amount to 4.11 GW and gas 5.81 GW. Notably, however, imported hydro has reduces the total system costs, while the other three options increase it. The emission reductions are shown graphically in

Figure. Emission reductions increase over time, but cannot simply be added up.

Figure 6: Emission reduction by policy case for selected years

Source: Winkler et el (2007)

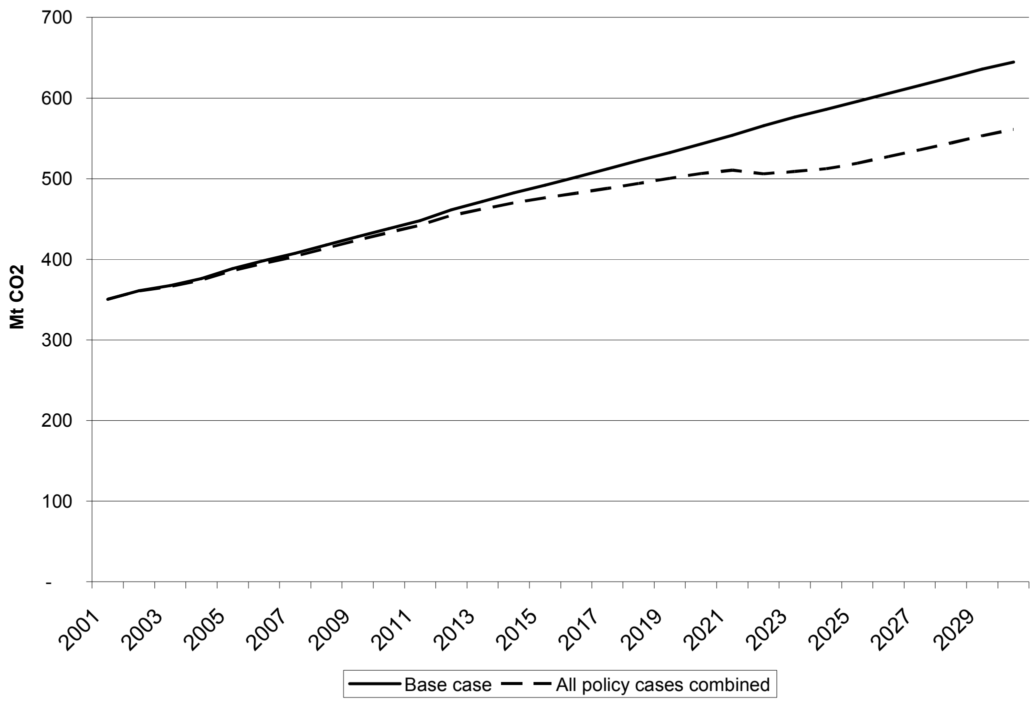


To assess the effect of combining electricity options, a further scenario was set up to avoid double counting. The emission reductions of individual policy cases, when added up, may overlap. Therefore, the total effect of implementing all policies at the same time may be less than the sum of emission reductions in the policy cases added up. Combined, the emission reductions achieved by the electricity supply options analysed here add up to 36 Mt by 2020 and 84 Mt CO_2 for 2030, 7% and 13% of the projected base case emissions for each respective year.

Figure shows that combining all the policies analysed here would reduce emissions below their projected growth. All policy cases were included in a combined scenario, to avoid double-counting within the energy system.

Figure 7: CO_2 emissions for base and with emissions reductions from all policy cases combined

Source: Winkler et el (2007)



However, these are reductions from business-as-usual. Even with all these reductions (and the associated investments), CO_2 emissions would continue to rise from ca. 350 Mt in 2001 to 450 Mt CO_2 in 2025. Stabilising emissions levels would require some additional effort from 2020 onwards.

2.4 Economic impacts of low carbon emission scenarios

Key economic parameters on future emission scenarios are the total energy system costs. System costs are useful in understanding the impact on the entire energy system, representing its interactions in a consistent framework. It draws a wide costing boundary, i.e. all costs are included from a power station through transmission and distribution system right down to end-use appliances and equipment. Total energy system costs are discounted to present value (assuming the discount rate of 10%), and take into account the changes in the energy system. These costs are *not* the same as the total investment required, which do not take into account savings or avoided investment in alternative policies or technologies.

Table 6: Total energy system costs for base and policy cases

Source: Winkler et el (2007)

	Discounted total system costs over the period	*Difference to base case*	
	R billion	*R million*	*Percentage*
Base case	5,902		
Gas	5,902	95	0.00%
Hydro	5,890	-11,525	-0.20%
PBMR nuclear	5,905	3,706	0.06%
Renewables	5,905	3,488	0.06%

A comparison with a different costing boundary is presented in Table. The table shows the total investment costs over the whole period, as well as the installed capacity that results in each policy case. Clearly, domestic investments in capacity in hydro case are lower, and to a lesser extent this is also true for gas. The largest investments requirement is needed for the PBMR case. Installed capacity in that case is the same as for the base case. The additional investment needed for the renewables case lies between the base and PBMR cases. A larger electricity supply system is needed, given the lower availability factor.

Table 7: Investments in electricity supply options and installed capacity by 2025

Source: Winkler et el (2007)

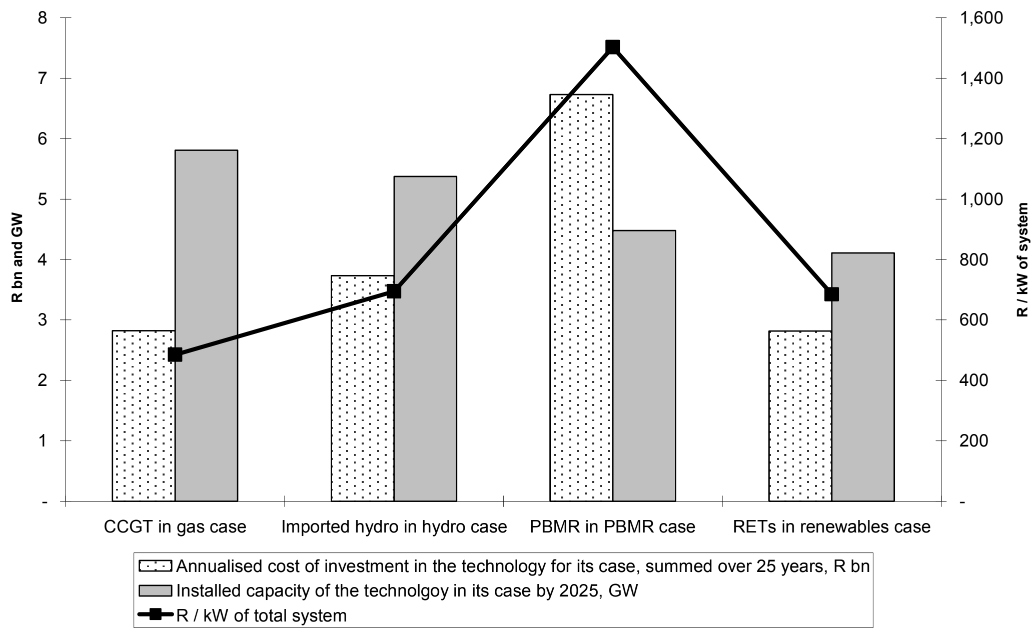
	Total investment cost 2001 - 2025, discounted, R bn	*Installed capacity by 2025, GW*
Base case	134	57.7
Gas case	114	57.8
Hydro case	84	51.5
PBMR case	153	57.7
Renewable case	142	58.5

A comparison with a different costing boundary focuses on the investment required for technology in *its* policy case, e.g. the PBMR in the the PBMR policy case, or various renewable energy technology in the renewables case.

Figure shows three items – the discounted investment costs in the technology over 25 years (derived by summing annualized investment costs), the capacity of that technology at the end of the period, and the cost per unit (kW) of capacity added to the total system.

Figure 8: Investment requirements for electricity supply technologies in their policy case, capacity provided in 2025 and cost per unit

Source: Winkler et el (2007)



The PBMR shows the largest investment requirement. It also adds more capacity than renewables, but less than from gas or imported hydro. In unit cost, imported gas is cheapest, with hydro and renewables next at roughly similar levels. Note that these numbers are not the same as the upfront investment costs.

2.0 Barriers and necessary actions to realize LCS

The main paradigm a low carbon South Africa future has been mentioned to be around energy efficiency, renewable energy and cleaner fossil fuels. The last two options are areas well known to be associated with significant marginal costs of investment in comparison to use of the traditional coal in South Africa. The general challenge for South Africa in moving toward a low carbon society is being an energy-intensive economy with high dependence on coal for primary energy. Coal is also one the most significant exports of South Africa, in the same league with gold and platinum.

With energy efficiency, the improvement indicator would be South Africa's energy intensity – the amount of energy per unit of economic output. The extent to which energy efficiency measures can be implemented are influenced by relatively low energy prices, which do not provide much incentive for energy efficiency. It makes economic sense to use more energy if energy is cheap, but does not promote energy efficiency. South Africa is regarded as having low energy costs compared to most developed and developing countries. Such low energy costs are not inducing industry and households to adopt energy efficiency measures and hence perpetuating a high GHG emission profile in South Africa.

Furthermore, being a non-annex I country, South Africa does not have emission reduction targets in the first commitment period that runs from 2008-2012. This can create a zone of comfort and reluctance among policy makers in taking robust plans toward achieving low carbon scenarios. However, with the high GHG emission profile among developing countries, the government in South Africa recognises that adequate measures have to be taken as the effort against escalating GHG emissions becomes more urgent.

Participation by South Africa in a multilateral front to abate GHG emissions, like for many other developing countries, could take many forms, the extreme code being taking on quantified emission reduction targets. One approach that has been of considerable debate amongst developing countries has been one that focuses on implementing policies for sustainable development. This approach revolves on the premise developing countries like South Africa already have policies and measures that have been taken for technological, environmental or economic development, but result in GHG emission reduction or climate change mitigation. This approach, referred to as sustainable development policies and measures (SD-PAMs) would build on the right to sustainable development by non-annex I countries, as outlined in the UNFCCC. The SD-PAMs approach is built on the national development objectives and priorities, and streamlining these to meet sustainable development pillars of economic, environmental and social criteria. This is achieved either by putting in place more stringent policies or by implementing new measures that align the development path to follow a sustainable course (Winkler et al. 2002).

For South Africa, the SD-PAMs approach would therefore focus on development objectives of economic growth, job creation and access to key services, such as, to mention just a few, housing, water, transport and access to modern energy services. Such an approach would not only enhance reduction of GHG emissions, but would also acknowledge country's unique circumstances and development objectives.

3.1 Sustainable development policies and measures (SD-PAMs)

The SD-PAMs pledge builds on existing commitments of developing countries. Almost all developing countries are signatories to the Convention. Under Article 4.1(b), all Parties commit themselves to 'formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases.' This commitment is currently not quantified for developing countries in the same way as for industrialised countries listed in Annex B of the Kyoto Protocol. SD-PAMs as a pledge-to implement policies for sustainable development would be consistent with Article 10 of the Protocol, which re-affirms existing Convention commitments and aims to 'advance the implementation of these commitments in order to achieve sustainable development' UNFCCC 1997.

The SD-PAMs pledge would be to implement and accelerate national sustainable development plans. The 'commitment' would not be measured directly in GHG emissions units, but rather in SD units – building a 100 000 energy efficient homes, rather than a specified reduction in tons of CO_2 emissions. Indirectly – as a co-benefit – SD-PAMs contribute to considerably lower emissions than current development trends. The motivation for taking action, however, is to pursue sustainable development at the national level, and hence the pledge is framed in terms of action taken.

SD-PAMs commitments would initially be voluntary, although they could be made mandatory for at least some developing countries. To formalise the approach, some need for reporting and oversight through the Climate Change Convention would be necessary. Reporting would assist in monitoring whether SD-PAMs are actually implemented, and this would require some institutional capacity in the pledging country. At the same time, reporting can help to correct the mis-perception that developing countries are doing nothing on climate change.

While the SD-PAMs commitment would initially be voluntary, a simple reporting system should be established in order to formalise the commitment of those countries who pledge to implement SD-PAMs. National capacity to monitor, report and verify that targets are being met systems at the national level would be an important dimension of the national capacity to implement SD-PAMs.

At the international level, reviewing the pledges would require a decision of the Conference of the Parties to establish a registry of SD-PAMs. Rather than creating an entirely new institution, a special SD-PAMs reporting registry would be created within the existing framework of the UNFCCC (Bodansky et al. 2004). Such a registry would record data based on regular reporting by Parties on their SD-PAMs, and support from the Secretariat for maintaining the records of implementation. If voluntary reporting proves successful, a next step would be to make reporting of SD-PAMs mandatory for a group of middle-income developing countries. Some developing countries might view this as intergovernmental control over national policy making, which could present a political obstacle. However, there need be no prescribed list of SD-PAMs, leaving it to the country to define its own policies, much as this study has examined energy policies that would make South Africa's development more sustainable.

In short, developing countries would formulate, implement and report on SD-PAMs. Reporting and international review seem consistent with a facilitative approach to compliance.

3.2 Financing SD-PAMs

Determining who pays for SD-PAMs is integrally related to the question of formalising the pledge in the manner suggested above. Countries are unlikely to fulfil pledges unless they have the resources for implementation. Under Article 4.3 of the Convention, developed country Parties are already committed to paying 'full agreed incremental costs' of activities under Article 4.1. The commitment to funding is repeated in Article 11 of the Protocol. If SD-PAMs are adopted under Article 4.1b, the question of payment should in principle be decided already. The challenge is to ensure that funds actually flow.

The sources of funding would differ between those SD-PAMs that have synergies with GHG reduction and those that are neutral or conflict. SD-PAMs that do not decrease GHG emissions would need to use development funding, both domestic, bi-lateral and multi-lateral.

4.0 Conclusion

The South Africa power sector has been the main focus for a discussion on moving toward a low carbon society. Essentially, two approaches have been touched on for moving to a low carbon society; one stemming from targeted policy action, and the other from a sustainable development perspective. Much of the contribution that the latter approach can make lies in considering the specific energy policies that can meet national development objectives. Reaching them in a more sustainable manner has co-benefits for climate change. The approach to climate change mitigation, then, is not one that seeks the least-cost solution to reducing GHG emissions from the energy sector. A durable approach is one which combines 'win-win' policies with those that trade off some economic optimality for local and global environmental benefits. The approach explored in this study provides a possible basis for South Africa to engage in the next round of negotiations under the UNFCCC.

It should be noted here that this paper presents quite a small glimpse of South Africa future emission scenario, which focuses main on the power sector. A more in-depth study of future emission scenario is currently underway, conducted by the Energy Research Centre, University of Cape Town and commissioned by the Department of Environmental Affairs and Tourism of South Africa. This study, known as the *Long Term Mitigation Scenarios; Strategic Options for South Africa,* looks at the 50 year context of GHG mitigation potential in South Africa across all the economic sectors. The intended objective is to provide a sound scientific analysis from which government can come up with climate change policy frameworks. It is also envisaged that the results of this study will ensure that South African stakeholders understand and commit to a range of realistic strategies for future climate action.

For future South Africa's emission scenario in this paper, the main contention is starting from development objectives rather than climate change targets. The form of climate action which it investigates is sustainable development policies and measures (Winkler et al. 2002). While sustainable development measures might in practice be similar to climate policy, the motivation is different – the one pursues emission reductions, the other local development. Making development more sustainable locally is a higher policy priority for most developing countries than addressing a global problem such as climate change, particularly since the latter has been caused mainly by industrialised countries. South Africa has a rather atypical emissions profile for a developing country – high emissions per capita and per GDP. A development-focused approach seems more likely to be implemented than the imposition of GHG targets by the international community – especially as the country has adopted development targets such as the Millenium Development Goals and promoted the Johannesburg Plan of Action.

The paper considers options in the electricity sector. Making electricity development more sustainable can contribute to climate change mitigation. The paper focuses both on domestic options (beyond the base case) in South Africa, as well as considering the climate impacts on hydro-electric imports from the Southern African region.

Turning to domestic options, the paper observes that both renewable energy and the PBMR nuclear option can contribute to diversifying the fuel mix and eventually to low carbon scenarios. The base case sees electricity generation continuing to be dominated by coal over the period up to 2030. A renewables policy case increases the share of those technologies, resulting in a coal / nuclear / renewable mix. The PBMR case makes a small shift from coal to nuclear.

The policy cases reported here can avoid emissions compared to the base case. Initially, both these domestic options show similar co-benefit in terms of CO_2 emission reductions, but eventually the larger investment of the PBMR case yields greater reductions. To avoid double-counting of emission reductions, a combined policy case was briefly considered.

Combined electricity supply options that move away from dependency on coal-fired plants can reduce local and global pollutants. The combined case could reduce 84 Mt CO_2 for 2030 (13% less than reference) and 579 kt SO_2 (-20% in 2030). The increases in costs for the total energy system are small, although the costing boundary in that case is particularly large.

An expedited shift from a coal dependency to a diversified energy source scenario would, however, require significant policy and regulatory upheavals. Incremental cost considerations for such change may require stronger motivation than that which would emanate from compliance to multilateral agreements and obligations. Positive incentives may be needed, through which the international community might help make a transition. While electricity supply options other than coal show potential for significant emission reductions and improvements in local air quality, they require careful trade-offs in order to take into account the implications for energy system costs, energy security and diversity of supply.

At the same time, diversifying from coal, if done for climate change policies, would not be done by South Africa alone. The overall impact from a global perspective would be to curtail coal exports from South Africa and make it more abundant and probably cheaper domestically. This would make the continued domestic use of coal in electricity generation.

Maintaining a coal based energy option, on the other hand, would require a gradual shift toward cleaner coal technologies. In the long term, inclusion of environmental externalities could bring this option to comparatively similar capital and operating cost as other sources of energy. Continued research on nuclear Pebble Bed Modular Reactors (PBMR), for example, has indicated decreasing generating costs over time as compared to the traditional nuclear Pressurised Water Reactor (PWR) (Eskom 2006). Whether these cost estimates are achieved in practice remains to be seen if and when the first modules are built. Similarly, the costs of renewable energy technologies are expected to decline as global installed capacity is increasing rapidly (Turkenburg 2000; IEA 2003).

Looking beyond the South Africa borders for natural gas and hydro based electricity would require South Africa to critically assess long term political scenarios in the region. Risks in this regard need to be balanced against the costs of developing domestic energy sources. External energy sourcing would also call for consolidation for regional cooperation terms and an active role in contribution toward peace and political stability in neighbouring countries. In the long run this could prove to be more costly than home based coal options for energy sources.

The imports of crude oil dominate the share of South Africa's energy imports, oil as an alternative in the electricity supply sector is and will continue to be comparatively small. Imports for electricity, whether in the form of gas or hydro-electricity –

obviously adds to the share of imports. For the PBMR, while fuel is imported, its potential advantage in terms of using a domestic energy source is not realised.

Transitions that include the supply-side are important. Greater diversity of supply will need a combination of policies, since single policies do not change the large share of coal in total primary energy supply by much when taken on their own.

The various electricity supply options show potential for significant emission reductions and improvements in local air quality. However, they require careful trade-offs in order to take into account the implications for energy system costs, energy security and diversity of supply.

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