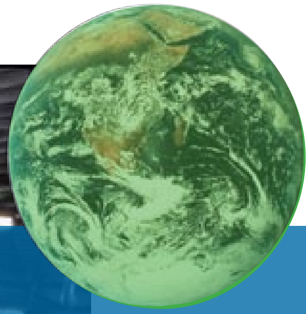

Chapter 6

# Sustainability of electricity supply and climate change in South Africa

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Making energy supply and use more sustainable is a central challenge in South Africa's development path. Energy is a critical factor in economic and social development, while the energy system has impacts on the environment. Managing energy-related environmental impacts is a major goal of energy policy (DME 1998), in addition to making energy development more sustainable at a national level.

Perhaps the most important energy policy objective for South Africa is to provide increasing access to affordable energy services (DME 1998). The goal of 100% access to electricity is often re-stated (Mlambo-Ngcuka 2005; 2004; 2003). While overall electrification has increased from roughly one-third in 1990 to roughly two-thirds in 2004, the majority of the population in rural areas still remains without electric power. Increasingly, there is recognition that connections alone are not enough, and that the *affordability* of using electricity is critical. It was therefore decided by the government to provide a subsidy of 50 kWh per household per month of free electricity. Overall, the energy sector has performed well – relative to other sectors – in meeting development objectives.

We now summarize two case studies, one on electricity supply options and their implications for mitigation; the other on the potential impacts of climate change on hydro-electricity in the region. The implications of the case studies are considered, before turning to an analysis of indicators of sustainable development applied to energy policies in South Africa.

## 6.1 Electricity supply options and their implications for GHG mitigation

This case study examines 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 challenge of increasing access is in tandem with the challenge of providing cleaner energy supply. The 1998 White Paper on Energy Policy has as one of its major goals managing the environmental impacts of energy supply and use (DME 1998). At the household level, air pollution from indoor use of fuels such as coal and biomass have a significant impact on health. In some parts of the country, paraffin is widely used, with associated poisoning, burns and shack fires in poor communities (Winkler et al. 2006).

South Africa's energy depends on fossil fuels. Coal accounts for three quarters of primary energy supply (DME 2003b), and for over 90% of electricity generation (NER 2002a). The energy sector contributes over 78% of national GHG emissions in 1994 (SAINC, 2004). Energy is also a critical factor in any form of economic and social development scenarios. Coal-fired electricity generation is not particularly vulnerable to climate change directly. Indirectly, there may be implications if *local* water availability were reduced. More direct, however, would be the impact of reduced run-off on hydro-electricity. While this is a small share of generation within South Africa, it has significant potential in the Southern African region. Imported hydro-electricity constitutes one of the major future options for diversifying electricity generation away from coal (Winkler 2006a).

### 6.1.1 Energy indicators of sustainable development

To examine the implications of various energy policy options, MARKAL[11] model has been used, linked with analysis of indicators of sustainable development. The specific assumptions made in the modeling for this study on key drivers are outlined in a more detailed paper (Winkler et al. 2006). The modeling results are assessed against a set of quantifiable sustainable energy indicators that are grouped in the major dimensions of sustainable development.

a) Environment

The fuel mix of the energy system is a key indicator affecting environmental impacts of energy supply and use. GHG emissions in South Africa's energy sector focus mainly on carbon dioxide. Here alternative policy scenarios to enhance individual energy supply options are analyzed over a reference scenario. The nuclear Pebble Bed Modular Reactor (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 GW by the end of the period, while renewable energy technologies amount to 4.11 GW and gas 5.81 GW. The investment required over the period in the PBMR is about USD 3.4 billion, compared to USD 3.1 billion in the renewable mix examined in the study. Notably, however, imported hydro reduces the total system costs, while the other three options increase it. The emission reductions are shown graphically in Figure 23.

**Table 11:** $CO_2$ emission reductions for policy cases and reference scenario emissions (Mt $CO_2$)

| Scenario | 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 policy scenarios reported here can avoid $CO_2$ emissions compared to the reference scenario (Table 11). Benefits in reducing local air pollutants, such as $SO_2$, are also reported for all cases. Substantial reductions around in $NO_x$ emissions can be seen in 2025 for all of the electricity supply options.

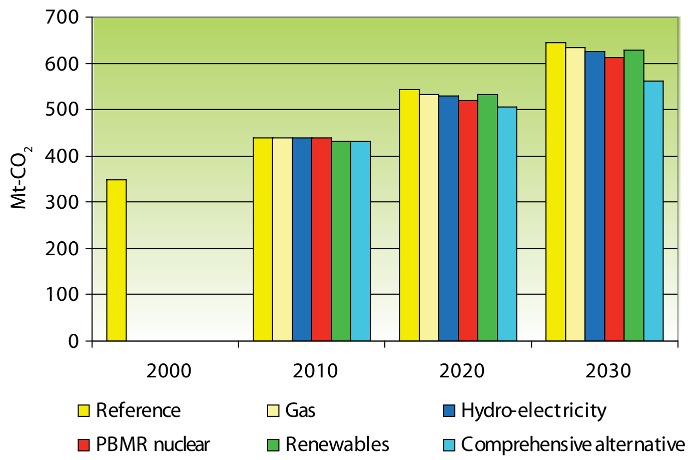


**Figure 23:** $CO_2$ emissions under individual policy scenarios
***Source:*** South Africa, 2006

11 MARket ALlocation (MARKAL) is a multi-period, long-term model for integrated energy system of a geographic or political entity, which encompasses the procurement as well as the transformation and the end-use of as complete a mix of energy forms as is desired (Manne and Wene, 1992). MARKAL provides extensive details on technology and fuel selection for different economic sectors under a consistent framework.

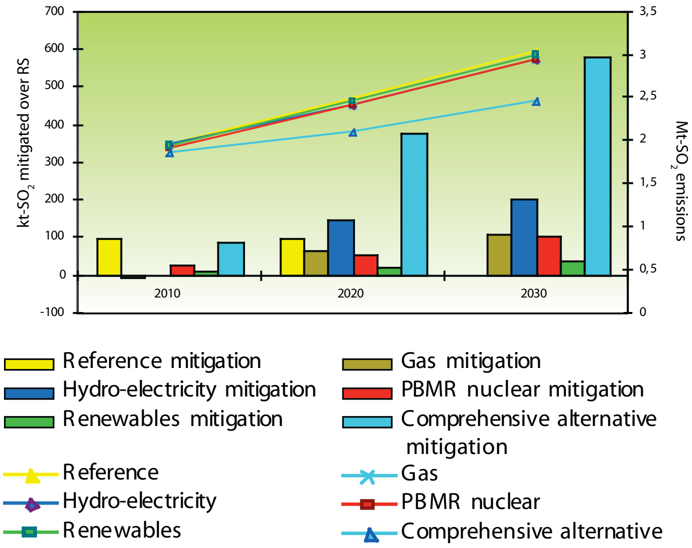


**Figure 24:** $SO_2$ emissions (Mt-$SO_2$) under individual policy scenarios, and corresponding mitigation (kt-$SO_2$) over the reference scenario (RS) emissions
***Source:*** South Africa, 2006

Under a comprehensive alternative policy scenario that combines all the above individual scenarios, the $CO_2$ emission reductions are 36 Mt in 2020 and 84 Mt in 2030, 7% and 13% of the projected reference scenario emissions for each respective year (Figure 23). The $SO_2$ emissions also reduce by 579 kt (-20% in 2030) (Figure 24). The percentage mitigation of $SO_2$ emissions is deeper than that of $CO_2$ emissions for each scenario when compared to the reference scenario, except for PMBR nuclear and renewable scenarios that have lower $SO_2$ mitigation[12]. This implies that energy sector policies for GHG mitigation will also have large local pollution mitigation benefits in South Africa.

The increases in costs for the total energy system are small, although the costing boundary in that case is particularly large. Even with all these reductions (and the associated investments), $CO_2$ emissions would continue to rise from 350 Mt in 2001 to 450 Mt $CO_2$ in 2025. South African emissions consistent with a global 550 ppmv stabilization regime would require substantial additional and climate specific efforts from 2015 onwards.

b) Social

The implications of electricity supply for social sustainability is a key indirect impact of power sector development through the electricity price. Decisions about energy supply and prices are made implicitly by governments, utilities and investors, with less discussion of their social consequences than the indirect effects might merit.
Electricity access and affordability are good social indicators (see Figure 4 and Table 7, chapter 3), in spite of the major achievements, about 30 per cent of the population is yet to be electrified (20% urban and 50% rural), mostly the poor.

Energy security in terms of share of imported energy in TPES can also have major social implications since large import of fuels can imply price increases as a reflection of high international oil prices. The shares of energy import change over time with each of the policy scenarios. The overall variation in import shares is relatively small, with crude oil domination (Table 12).

**Table 12:** Imported energy as share of total primary energy supply

| Scenario | 2010 | 2020 | 2030 |
|---|---|---|---|
| Reference | 23.5% | 24.6% | 23.8% |
| | *Percentage point change* | | |
| Gas | 0.0% | 0.9% | 2.2% |
| Hydro | 0.0% | 1.3% | 0.8% |
| PBMR nuclear | 0.0% | 1.2% | 4.3% |
| Renewables | -0.2% | -0.2% | 0.2% |

Unsurprisingly, the imports of gas or hydro-electricity imply an increase in import dependency. Perhaps less obvious is that the import of nuclear fuel raises the share of imported energy by 4.3% of TPES in 2025 for the PBMR case, assuming that nuclear fuel is imported. Domestic supply options, including renewable energy technologies, perform better in this regard.

c) Economic

Key economic parameters are the total investment costs over the whole period, as well as the installed capacity that results in each policy case. Table 13 shows that domestic investment costs in capacity in the hydro scenario are lower, and to a lesser extent this is also true for gas. The largest investment requirement is needed for the PBMR scenario. The additional investment needed for the renewables scenario lies between the base and PBMR cases. A larger electricity supply system is needed, given the lower availability factor. In unit cost, imported gas is cheapest, with hydro and renewables next at roughly similar levels.

12 Renewables emit $SO_2$ while are considered carbon-neutral, while nuclear scenario replaces more coal-based power plants with FDG technology.

**Table 13:** Investments in electricity supply options and installed capacity by 2025

| | Total investment cost 2001 - 2025, discounted, USD billion | Installed capacity by 2025, GW |
|---|---|---|
| Reference scenario | 22 | 57.7 |
| Gas scenario | 19 | 57.8 |
| Hydro scenario | 14 | 51.5 |
| PBMR scenario | 25 | 57.7 |
| Renewable scenario | 23 | 58.5 |

### 6.1.2 Summary

South Africa has had excess generation capacity, developed in the 1970s and 1980s and lasted into the 1990s, but this will soon end. Over the next two to three decades, some 17 000 MW will need to be built at approximately 1 000 MW per year. After 2025, many large stations will near the end of their lives, and although options for refurbishment will then be considered, a significant portion of existing capacity will need to be replaced. The broad options for electricity supply include all available energy resources and conversion technologies – coal, nuclear, imported gas and hydro, and renewable energy. There is an opportunity to mitigate GHG emissions, and also improve electricity access and affordability through more imported gas and hydro from nearby countries. However coal dominance may be better for long-term energy security of supply. The new coal plants have to be however cleaner and more efficient than the existing ones to ensure lower environmental and social burdens of development.

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 with 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, has to be seen in an international context where coal exports from South Africa can decrease as a consequence of global GHG emission reduction efforts. This will make coal more abundant and probably cheaper in South Africa and will tend to make it more attractive to use coal in electricity generation domestically. 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.

## 6.2 Regional electricity cooperation, hydro-power and climate change

One of the major options for diversifying the fuel mix for electricity in South Africa is by importing hydro-electricity from Southern Africa. South Africa already imports electricity from the Cahora Bassa dam in Mozambique[13]. The scale of this is dwarfed by the potential at Inga Falls in the Democratic Republic of Congo (DRC), estimated to range between 40 GW for run-of-river to 100 GW for the entire Congo basin (Games 2002; Mokgatle & Pabot 2002).

The hydro-potential from Inga Falls could be, however, affected by climate change in future. The change in temperature and rainfall has the potential to affect hydro-electric installations in four major ways: evaporation, reduced run-off, flooding, and siltration. This impact potential was studied under the development, energy and climate change project.

Increasing temperature generally results in an increase in the potential evaporation and, given that temperature is expected to increase in both the Congo and Zambezi catchments, it can be expected that evaporation on large open waters would increase.

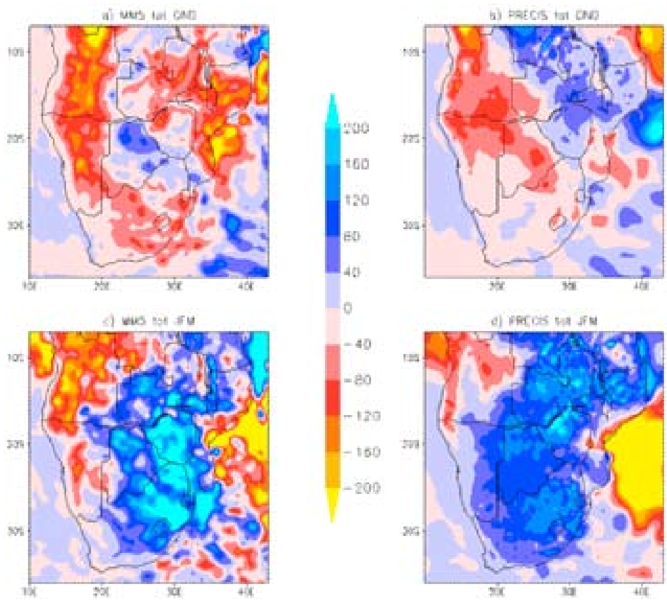

**Figure 25:** Simulated change for 2070 in seasonal rainfall (mm) during Oct-Dec (OND) and Jan-March (JFM)
***Source:*** Tadross, Jack and Hewitson (2005)

13 The average cost of existing electricity imports was USD cents 2.15 /kWh, well below the cost of South African generation in 2001 (NER 2001). It is not certain that such low prices will continue into the future.

The run-off is reduced as a direct impact of droughts and consequently the storage in dams is negatively affected. Because the duration of the droughts cannot be predicted with any certainty, it may be necessary to impose restrictions on the use of water. Where restrictions are necessary, water to meet basic needs will always receive priority in allocations, followed by strategic uses such as power generation and key industries. Climate change models indicate minimum changes in the hydrology of the Congo basin, whereas other basins may have significant vulnerability to climate change (IPCC 2001b). For both these catchments, the average annual rainfall is expected to increase in the long term (Figure 25), resulting in occurrence of occasional flooding.

The overall assessment of potential climate change impacts on large hydroelectricity in Southern Africa is shown in Figure 26. Essentially, climate change is not likely to affect the run-off to these major facilities; however, increase in evaporation and siltration may be impacts to consider. In summary, climate change is projected to increase both the temperature as well as the annual rainfall in the Congo and Zambezi River catchments. Overall there may not be any appreciable adverse effect on hydro-potential from Inga Falls due to climate change.

This analysis was used in the MARKAL model to enhance share of imported hydro-electricity for South Africa in future. This mainly replaces domestic coal based power, therefore reducing related $CO_2$ and other pollutant emissions. The average cost of electricity also gets reduced due to this regional hydro-electricity cooperation (Table 14).

Imports of hydro-electricity are only one of several options for South Africa. From the country study, it is apparent that regional hydro cooperation could bring substantial socio-economic benefits to South Africa and also to the Southern African region as a whole. These benefits, however, may not be realized due to concerns relating to energy security in a very basic sense - political stability in the DRC would be required, but is highly uncertain. That is apart from the large regional investments required. Moreover the interconnections between the national grids within Southern African Power Pool (SAPP) would need to be strengthened. A Western Corridor project plans to connect South Africa, Namibia, Botswana, Angola, and the DRC with transmission lines. Several of the initiatives under NEPAD are inter-connectors (NEPAD 2002).

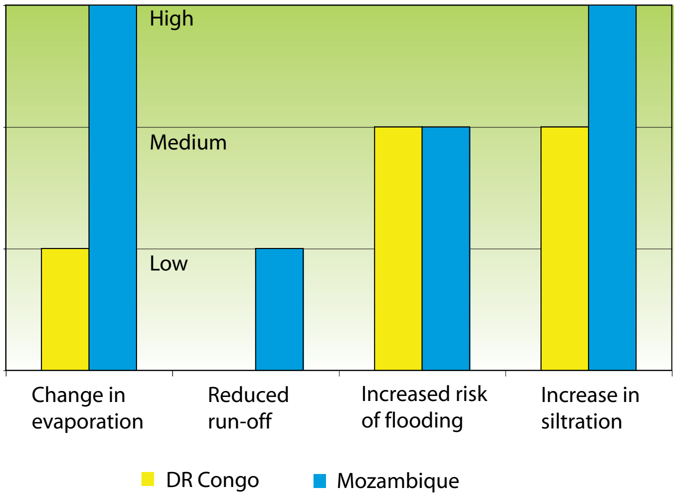


**Figure 26:** Potential impact of climate change on hydro-electric facilities in Southern Africa

Having focused specifically on hydro-electricity - both the potential benefits but also the uncertainty – a broader perspective on options for electricity supply needs to be taken. For the electricity supply options, there are no clear 'winners'. Figure 27 draws together the evaluation of a few ´developmental indicators that could directly or indirectly capture some social, economic and

**Table 14:** Energy, environmental and cost implications of enhanced regional hydro-electricity cooperation for the year 2030

| Parameter | Reference scenario | Enhanced regional hydro-electricity cooperation |
|---|---|---|
| Capacity of coal-based generation in national power consumption | 45.4 GW | 44.4 GW |
| Decrease in national $CO_2$ emissions over reference scenario | - | 19 Mt-$CO_2$/ year in 2030 |
| Decrease in national $SO_2$ emissions over reference scenario | - | 92 kt-$SO_2$/ year in 2030 |
| Average cost of electricity (USD cents/ kWh) | 2.64 | 2.57 |

***Note:*** Only Mependa Uncua has been modeled here and not the entire Grand Inga. The benefits are therefore relatively lower.

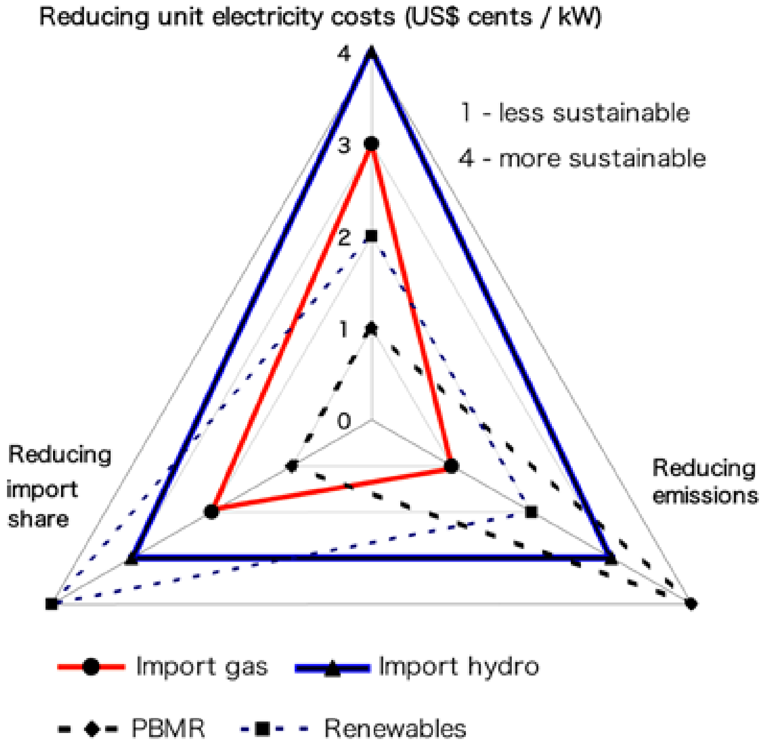


**Figure 27:** Electricity supply options ranked on selected development indicators
***Source:*** Winkler 2006b

environmental aspects of sustainable development. For example, reducing imports could enhance energy security, reducing electricity costs could improve electricity affordability for the poor households, and reducing emissions could provide environmental and social benefits. Only rank orders are shown in the figure, with 1 representing a less sustainable outcome, and 4 a more sustainable outcome. In other words, policy cases closer to the outer sides of the largest triangle are ranked higher in that dimension and therefore represent a more sustainable outcome. There is no attempt to define sustainability, merely an indication that one policy case makes residential energy development more sustainable than the others. If a triangle completely contains another, it would be higher-ranked in all three dimensions. If the triangles overlap, there are trade-offs.[14]

## 6.3 Conclusions

The methodology adopted in these studies explicitly started from development objectives. Much of the contribution that this 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 provides a possible basis for South Africa to engage in the next round of negotiations under the UNFCCC.

14 See Munasinghe (2002: 174). for a discussion on 'win-win' cases and trade-offs in multi-criteria analysis of energy policies against indicators of sustainable development.