Energy policies for sustainable development in South Africa

Options for the future

Edited by
HARALD WINKLER

Lead authors
Ogunlade Davidson, Harald Winkler,
Andrew Kenny, Gisela Prasad, Jabavu Nkomo,
Debbie Sparks, Mark Howells, Thomas Alfstad

Contributing authors:
Stanford Mwakasonda, Bill Cowan, Eugene Visagie

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Private Bag
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The authors are Ogunlade Davidson, Harald Winkler, Andrew Kenny, Gisela Prasad, Debbie Sparks, Mark Howells and Thomas Alfstad, with contributions from Stanford Mwakasonda, Bill Cowan Cowan and Eugene Visagie.

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Executive summary

The purpose of this publication is to present a profile of energy in South Africa, assess trends and analyse some options for the future. It is divided into two parts – Part I presents a profile of energy and sustainable development in South Africa, while Part II uses modelling tools and indicators to assess future policy options for the country.

Part I: Energy for sustainable development – a profile of South Africa

The initial two chapters introduce the concept of energy for sustainable development and sketch the context of energy policy for South Africa. The next two chapters outline the current situation and future outlook for both energy demand (Chapter 3) and supply (Chapter 4), identifying critical issues for sustainable development for the scenario modelling undertaken in Part II. Chapters 5 to 7 consider the social, economic and environmental dimensions.

South Africa's profile of energy demand, characterised by relatively high energy intensity, makes the more efficient use of energy particularly important. Important energy policy initiatives are already underway with respect to energy efficiency and renewable energy. Many interventions have been proposed and studied in detail and these suggest that it makes economic sense to promote end-use energy efficiency and demand-side management. A key policy question, which is examined here, is why greater efficiency is not realised.

Since most projections indicate that coal will continue to be used for some time to come, finding ways of using fossil fuels in a cleaner way is important during the transition to different energy systems. It is suggested that cross-cutting policy instruments, such as energy-environmental taxes, could play an important role in this regard.

The excess electricity capacity, which characterised South Africa's energy profile in the past, has come to an end, and the country now needs to invest in new capacity. Coal-fired power plants provide baseload through some new pulverised fuel plants, and also through fluidised bed combustion. Options that depart from business-as-usual are domestic supply alternatives (various renewable energy technologies and nuclear power) and increased electricity imports (hydro-electricity, and gas for combined cycle gas turbines). In the liquid fuel sector, options examined are the extension of refinery capacity and introduction of bio-fuels, which raise important policy questions regarding energy for sustainable development.

Part I concludes with three chapters, which consider each of the major dimensions of sustainable development in turn – social, economic and environmental. The environmental implications are both local and global. Given its coal-based energy economy, South African is one of the highest emitters of greenhouse gases when compared to other developing countries, whether this is measured in emissions per person or per unit of gross domestic product (GDP). Local air pollution is associated with negative impacts on respiratory health.

A major social aspect is access to modern energy services as a key goal, and Chapter 5 outlines the challenge of making such access affordable for poorer households. Experience with the 'poverty tariff' (which provides 50 kWh per month of free basic electricity for households) raises important issues about the role of subsidies.

In Chapter 6, which examines the economic point of view, the building of local manufacturing capacity for added-value industries is identified as a way of changing existing patterns of investment in sectors that see their competitive advantage in cheap electricity. Changes in energy pricing deserve more attention in this regard. Overall, the issue of energy security and its relation to diversity of supply has implications for the economy as a whole. Another economic dimension concerns job losses in the coal mining and electricity sectors, which raises the need to identify new areas where jobs can be created in energy supply – or indeed in promoting the more efficient use of energy.

Part II: Scenarios of future energy policies and indicators of sustainable development

Part II presents possible energy futures for South Africa and demonstrates how indicators of sustainable development can be used to assess options. A range of energy policies for the period 2000-2025 were modelled and the results are evaluated against energy indicators. The model used – the Markal model framework – is a least-cost optimising tool, rich in technologies and capable of including environmental constraints. The method of using indicators of sustainable development provides a sound means for policymakers to identify synergies and trade-offs between options, and to evaluate their economic, social and environmental dimensions.

Using Markal, the authors analysed both demand-side and supply-side policies for their contribution to energy objectives and also to broader sustainable development goals. On the demand side, the policy options modelled covered industry, commerce, residential and transport sectors; on the supply side, they covered electricity and liquid fuels. The types of policy instruments investigated include both economic and regulatory instruments.

Part II is divided into five chapters: Chapter 8 identifies policy options for the scenario modelling, analysing in greater detail a selection of policies from Part I. Chapter 9 describes the modelling framework and the key drivers of the reference case, which is close to current government policy. The modelling results for each of the policy options are reported in Chapter 10, while Chapter 11 consolidates the assessment against indicators of sustainable development. Conclusions are presented in Chapter 12.

The results show that the tools used in this analysis – a modelling framework combined with indicators of sustainable development – provide researchers and policymakers with a useful way of examining trade-offs, while at the same time providing scope for compromise.

The reference case

The base reference case ('current development trends') is close to the government's Integrated Energy Plan (DME 2003a). For electricity, the second National Integrated Resource Plan (NIRP) (NER 2004a) was used.

On the demand-side, fuel consumption in industry and transport dominates, with transport growing most rapidly among sectors.

On the supply-side, the energy sources used to generate electricity consist of existing and new sources of coal, supplemented by gas turbines and new fluidised bed combustion using discard coal. Smaller contributions come from existing hydroelectric schemes and bagasse (sugar cane husks), electricity imports, existing and new pumped storage and interruptible supply. The supply of liquid fuel is met mostly from some expansion to existing refineries, together with a small proportion of imports of finished petroleum products.

Emissions of both local and global air pollutants increase steadily in the reference case, over the period 2000-2025. Carbon dioxide emissions increase from 337 Mt CO_2 in 2001[1] to 591 Mt CO_2 in 2025 – an increase of 75% over the entire period.

Policies modelled

A set of energy policy cases was modelled and compared to the base case. These were:

Higher energy efficiency in industry. Industrial energy efficiency meets the national target of 12%, less final energy consumption (compared to business-as-usual). This is achieved through greater use of variable speed drives, efficient motors, compressed air management, efficient lighting, heating, ventilation and cooling (HVAC) system efficiency, and other thermal saving. Achievement of this goal depends on forcefully implementing the policy.

New commercial buildings designed more efficiently. HVAC systems are retrofitted or new systems have higher efficiency; variable speed drives are employed; efficient lighting practices are introduced; water use is improved, both with heat pumps and solar water heaters. In addition to specific measures, fuel switching for various end uses is allowed. Achievement of this goal depends on forcefully implementing the policy.

Cleaner and more efficient use of energy in the residential sector. Water heating is provided through increased use of solar water heaters (SWHs) and geyser blankets. The costs of SWHs decline over time, as new technology is accepted more widely in the South African market. More efficient lighting, using compact fluorescent lights (CFLs) spreads more widely, with a further reduction in costs. The shells of houses are improved by insulation, prioritising ceilings. Households switch from electricity and other cooking fuels to liquid petroleum gas (LPG). Subsidies are required to make interventions more economic for poorer households.

Biodiesel production increases. A key policy option regarding liquid fuels for transport is the supply of biodiesel to displace high dependence on petroleum. Biodiesel production increases to 35 PJ by 2025, with a maximum growth rate of 30% per year from 2010. These energy crops do not displace food production, and sustainable production means the fuel is effectively zero-carbon.

The share of renewable electricity increases. The share increases to meet the target of 10 000 GWh (gigawatt-hours) by 2013. The shares of energy from solar thermal, wind, bagasse and small hydroelectric sources increase beyond the base case. New technology costs decline as global production increases

Pebble bed modular reactor (PBMR) modules increase the capacity of nuclear energy production. Nuclear capacity is increased to 4 480 MW by introducing 32 PBMR modules. Costs decline with national production and initial investments are written off.

An increase in imported hydroelectricity. The share of hydroelectricity imported from the Southern African Development Community (SADC) region increases from 9.2 TWh in 2001, as more hydroelectric capacity is built in southern Africa.

An increase in imported gas. Sufficient gas is imported to provide 5 850 MW of combined cycle gas turbines, compared to 1 950 MW in the base case.

Tax on coal for electricity generation. The use of economic instruments for environmental fiscal reform is being considered by the national Treasury. The option of a fuel input tax on

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[1] The base year number is fairly close to the CO_2 emissions reported in the Climate Analysis Indicator Tool (WRI 2005) for 2000 – 344.6 Mt CO_2. It is somewhat higher than the 309 Mt CO_2 from fuel combustion reported in the Key World Energy Statistics for 2001 (IEA 2003a).

coal used for electricity generation is analysed. Such economic instruments could be extended to coal for synthetic fuel (synfuel) production and industrial use. Alternatively, the environmental outputs could be taxed directly, e.g. in a pollution tax, although this is not analysed in this study.

Key results

Key results are presented in Chapters 9, 10 and 11, and a summary of quantitative results can be found in the appendix. Important findings and conclusions are as follows:

On the demand-side, energy efficiency policies were found to be particularly important. The overall strategy of reducing final energy demand by 12% compared to business-as-usual can be implemented most effectively in the industrial sector. Industrial energy efficiency is effective both in lowering the cost of the energy system by R18 billion over 25 years, and in reducing global and local air pollution. Carbon dioxide emissions are reduced by 770 Mt CO_2 over 25 years. Greater efficiency has benefits in delaying the need for investment in power stations, with new base load power stations postponed by four years, and peaking power plant by three years.

Higher energy efficiency in industry. Realising the potential for industrial energy efficiency requires forceful and determined, even aggressive, implementation. Current practice is often not economically optimal and clear signals are needed to induce industry to invest in options that must be shown to make financial sense. The agreement between industry and government to implement the energy efficiency strategy (DME 2005a), and the recent announcement that a dedicated Energy Efficiency Agency is to be established, bode well in this regard.

New commercial buildings designed more efficiently. A strong legal and institutional framework is needed for the commercial sector. The modelling suggests that a 12% energy efficiency target is achievable and can save R13 billion over 25 years. However the results also suggest that the cost of optimal energy efficiency improvements are 2-3% lower than the 12% of the government target and that these savings thus come at a cost (which works out at about 5% of investment costs). Government can play an important role here by taking the lead in making its own buildings and practices more efficient.

Cleaner and more efficient use of energy in the residential sector. The residential sector is particularly important for social sustainability. A sustainable development approach aims to deliver services that meet basic human needs, but in a cleaner and more efficient manner. The policy interventions that are modelled focus on end uses – solar water heaters and geyser blankets, liquid petroleum gas for cooking, efficient housing shells, and compact fluorescent lights (CFLs) for lighting. Making social housing more energy-efficient through simple measures, such as including insulating in ceilings, should be adopted as a general policy.

All policy cases assume near-universal electrification, and in the residential case we find that the share of other commercial fuels (LPG and paraffin) also increases. Overall fuel consumption, however, is lowered compared to the base case (8.13 PJ less in 2025), because of increasing efficiency and the use of solar energy for water heating. Not all interventions are used by all household types – for example, energy efficient houses are only taken up by urban higher-income electrified households. The lower costs of geyser blankets – both upfront costs and costs per unit of energy saved – suggests that geyser blankets are appropriate policy interventions in poor electrified households.

Access to energy in physical terms needs to be accompanied by affordability in economic terms. The findings suggest that a relatively small subsidy can make energy efficiency interventions economic for poorer households. The order of magnitude of the subsidy required to make efficient housing as affordable for poorer households as for richer ones is less than R1000.

Supply-side measures. On the supply-side, four policy cases focused on electricity supply – imported gas, important hydroelectricity, generating electricity domestically from pebble bed modular reactor (PBMR) nuclear, and renewable energy technologies. A sustained move towards greater diversity requires more than a single policy.

An increase in imported hydro-electricity and imported gas. Imported hydroelectric power potentially reduces investment costs, but increases the share of imported energy as a percentage of total primary energy supply (TPES). Imported gas increases the share of imports, while making little difference to total energy system costs.

PBMR and renewable energy options. The pebble bed modular reactor case with imported fuel also shows an increase of imported energy reaching 4.3% of TPES in 2025. Renewable energy technologies perform better, although they too include a substantial proportion of imported components. Investing in the PBMR and renewable energy options increases the costs of the energy system, while imported gas has a much smaller effect, and hydroelectricity imports actually reduce costs. While the increased costs for both the PBMR and renewables are only 0.06% of the costs of the energy system, they nonetheless amount to over R3 billion over the period. In unit costs (R/kW of new capacity), gas is significantly cheaper than other options, followed by a mix of renewable energy technologies, hydroelectricity and the PBMR. These options show quite substantial emission reductions – 246 Mt CO_2 for the PBMR and 180 Mt CO_2 for renewable energy technologies, both over the 25-year horizon. Both reduce local pollutants, notably sulphur dioxide, by 3% and 1.6% respectively.

Biodiesel production. The potential to produce 1.4 billion litres of biodiesel was modelled to start in 2010 and reach a market share of 9% of transport diesel by 2025. Through this, an average of 4 500 barrels/day of oil refining capacity can be avoided. Total reduction in CO_2 reaches 5 Mt CO_2 per annum in 2025 and the cumulative savings are 31 Mt CO_2 for the entire period. There are also reductions in local pollutants. The present value of the total system cost for this scenario is R2.4 billion higher than for the reference scenario.

Tax on coal for electricity generation. The results for a tax on coal for electricity generation show that the reductions of CO_2 emissions from coal for electricity generation are small relative to the reference case. The economic difference lies less in system costs (R67 million over 25 years) and more in the tax revenues. These revenues, while imposing added costs on producers, could also generate economic benefits if recycled. More detailed analysis is required of this policy option, for instance possibly extending the tax to coal for synfuels and industry, and quantifying the indirect economic effects of tax recycling and the impacts on other policy objectives.

Emissions reductions. If combined, the emission reductions achieved by all the policies analysed here add up to 50 Mt CO_2 by 2015 and 142 Mt CO_2 for 2025, which amounts to 14% and 24% of the projected base case emissions respectively. One important conclusion is that significant emission reductions ('avoided emissions') compared to business-as-usual are possible. However this should be understood together with a second conclusion, which is that stabilising emissions levels (e.g. at 2010 levels) would require some *additional* effort from 2020 onwards.

Conclusions

Over the 25-year timeframe considered here, energy efficiency makes the greatest impact when seen against indicators of sustainable development. Industrial efficiency, in particular, shows significant savings in energy and costs, with reductions in air pollution. Commercial energy shows a similar pattern, although at a slightly smaller scale. Residential energy efficiency is particularly important for social sustainability. Even small energy savings can be important for poorer households. In the short-term – the 2006 to 2015 decade – we can conclude that energy efficiency will be critical to making South Africa's energy development more sustainable.

In the longer-term – the next several decades – transitions which include the supply-side will become increasingly important. To achieve greater diversity there will need to be a combination of policies, since single policies on their own will not change the share of coal in TPES by very much. The various alternative electricity supply options show potential for significant emission reductions and improvements in local air quality. However, they will require a policy of careful trade-offs in relation to energy system costs, energy security and diversity of supply.

The global costs (discounted total energy system costs) for the combined scenario are lower than for the base case by some R16 billion over the full 25-year period (2000-2025). Thus the savings due to the combined efficiency measures more than justify the additional costs of investing in a diversified electricity supply.

Abbreviations and acronyms used

ADMD	after diversity maximum demand
Aids	acquired immune deficiency syndrome
ANC	African National Congress
bcm	billion cubic metres
BESST	basic electricity support service tariff
CBO	community based organisation
CCGT	combined cycle gas turbine
CDM	Clean Development Mechanism
CER	certified emissions reductions
CFL	compact fluorescent light
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COP	coefficient of performance
DBSA	Development Bank of Southern Africa
DME	Department of Minerals and Energy
DSM	demand-side management
EBSST	electricity basic support services tariff
EDRC	Energy and Development Research Centre (forerunner of ERC)
EIA	environmental impact assessment
ERC	Energy Research Centre
ERI	Energy Research Institute (forerunner of ERC)
ESCO	energy service company
FBC	fluidised bed combustion
FGD	flue gas desulphurisation
GDFI	gross domestic fixed investment
GDP	gross domestic product
GEAR	Growth Employment and Redistribution (policy)
GHG	greenhouse gas
GJ	gigajoule (10^9 joules)
GWh	gigawatt-hour (10^9 watt-hours)
HFO	heavy furnace oil
HH	household
HVAC	heating, ventilation and cooling
IBLC	in-bond landed cost
IEP	Integrated Energy Plan
IGCC	integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
IRP	Integrated Resource Plan
kW	kilowatt (10^3 watts)

kWh	kilowatt-hour (10^3 watt-hours)
LNG	liquefied natural gas
LPG	liquefied petroleum gas
Markal	Market Allocation Modelling Tool
mcf	million cubic feet
MJ	megajoule (10^6 joules)
Mt/a	million tons per annum
Mtoe	million tons of oil equivalent
MW	megawatt (10^6 watts)
MW_e	megawatt of electrical power
MWh	megawatt-hour (10^6 watt-hours)
NEP	National Electrification Programme
NER	National Energy Regulator
NGO	non-governmental organisation
NIRP	National Integrated Resource Plan
NO_x	nitrogen oxides (also referred to as 'oxides of nitrogen')
N_2O	nitrous oxide
NMVOC	non-methane volatile organic compounds
O&M	operations and maintenance
OCGT	open cycle gas turbine
OECD	Organisation for Economic Cooperation and Development
PBMR	pebble bed modular reactor
PetroSA	Petroleum Oil and Gas Corporation of South Africa
RDP	Reconstruction and Development Programme
RHE	rural higher income electrified household
RLE	rural lower income electrified household
RLN	rural lower income non-electrified household
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SD-PAMs	sustainable development policies and measures
SHS	solar home system
SIC	standard industrial classification
SO_2	sulphur dioxide
SWH	solar water heater
synfuels	synthetic fuels
tcf	trillion cubic feet
TFC	total final energy consumption
TJ	terajoule (10^{12} joules)
TPES	total primary energy supply
TWh	terawatt-hour
UHE	urban higher income electrified household
ULE	urban lower income electrified household
ULN	urban lower income non-electrified household
UNFCCC	United Nations Framework Convention on Climate Change
VSD	variable speed drive

Part I

ENERGY FOR SUSTAINABLE DEVELOPMENT – A PROFILE OF SOUTH AFRICA

1

Energy for sustainable development: an introduction

Ogunlade Davidson

Energy has been the key to economic development worldwide, but in the way it is sourced, produced and used, two major drawbacks have emerged. First, the overall energy system has been very inefficient. And second, major environmental and social problems, both local and global, have been associated with the energy system.

Up to about 30 years ago, the global energy system was about 34% efficient, meaning that only a third of the world's energy input was being converted into useful energy (Nakicenovic et al. 1998). Since then, improvements to the efficiency of the global energy chain have led to this figure increasing to about 39%. Viewed thermodynamically, there are major 'irreversibilities' in the system, which means that the task of further improving the overall efficiency of the global energy system is a daunting one.

Many environmental and social problems are caused by the way the energy system operates. The combustion, transport and disposal of energy sources as they go through different conversion processes results in harmful emissions. These emissions in turn cause local, regional and global environmental problems, including serious, even fatal, human health hazards. The workings of the energy sector are also socially disruptive – the development of most energy sources results in the dislocation of people and exacerbates differentials among social groups. Reducing the environmental and social burden is thus a major concern for the energy sector.

Before the industrial revolution in England, the world economy was essentially based on agriculture. Energy demand was limited and could be met by biomass and animal power. Then coal fuelled the industrial revolution and the new industrial demand permanently changed the global energy sector. In the early 1900s, the internal combustion engine and the use of petroleum transformed the transport sector. As the electricity and industrial sectors grew, the entire energy sector changed profoundly. Long-distance pipeline technology to transport natural gas proved to be efficient and environmentally acceptable. In the 1970s a series of crises in the oil sector deeply affected the global energy system, forcing countries to re-examine the efficiency of energy production and use, and to search for alternatives to fossil fuels. Together, the ideas of energy efficiency and renewable energy led to the concept of sustainable energy, which is now widely accepted in international energy discourse.

Sustainable energy

Sustainable energy can be defined as energy which provides affordable, accessible and reliable energy services that meet economic, social and environmental needs within the overall developmental context of society, while recognising equitable distribution in meeting those needs (Davidson 2002a). In practice, sustainable energy has meant different things to different people. Some think of it as the energy related to renewable energy and energy efficiency. Some include natural gas under the heading of sustainable energy because of its more favourable environmental quality. Whatever approach is used, sustainable energy always implies a broad context which covers resource endowment, existing energy infrastructure, and development needs.

Sustainable development

The concept of sustainable development, which is closely related to sustainable energy, has also become increasingly important. The development paradigms in operation after the Second World War led to major social and environmental problems. During the 1950s and 1960s, most nations were preoccupied with economic growth and energy consumption, which led naturally to a dramatic increase in energy demand. Economic growth was the major concern, with social and environmental issues being ignored in comparison. After the 1950s, the paths taken to heal the ravages of the Second World War incorporated new realisations about the social deprivation of the majority of the world's population. By the 1970s development paradigms began to include social considerations. There was a new realisation of the social dangers of a world where the richest 20% of the population received 83% of the world's income and the poorest 20% received 1.4% (Davidson 2002b). In the late 1970s and the 1980s there was a growing realisation of the seriousness of the deterioration in the environment, and a significant number of people began to call for development paradigms that would consider environmental issues alongside economic and social issues. The late 1980s saw further concerns being raised about the global environment, the climate change threat in particular. Sustainable development paradigms started to become part of the international agenda.

Sustainable development is defined as development that meets the present needs and goals of the population without compromising the ability of future generations to meet theirs. Because sustainable development involves economic development, social development and environmental development, it requires us to define these. Economic development is economic progress that leads people to be willing and able to pay for goods and services that enhance income and efficient production. It is closely related to economic efficiency. Social development is the improvements in the well-being of individuals and society which lead to an increase in social capital, institutional capital and organisational capital. Environmental development is the management of ecological services and of the human beings that depend on them. Sustainable development takes all three into consideration. How to provide sustainable energy to satisfy the sustainable development of South Africa is the motivation and subject of this report.

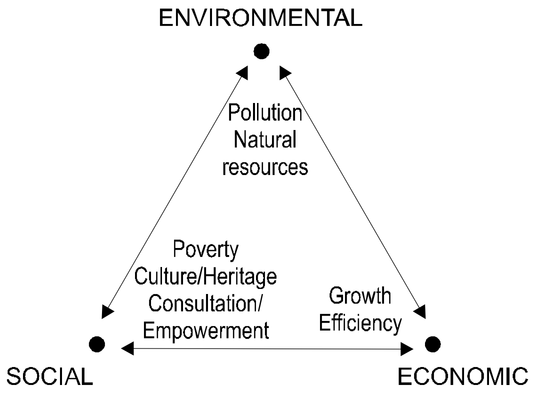

Figure 1.1: Elements of sustainable development

2

Energy policy

Ogunlade Davidson
Contributing author: Harald Winkler

2.1 Introduction to South Africa's energy system

The South African economy is energy-intensive, meaning that the country uses a large amount of energy for every rand of economic output (Hughes et al. 2002). It requires 0.24 tons of oil equivalent to produce 1000 international[2] dollars at purchasing power parity[3] (PPP) of GDP in 2001 (IEA 2003a). Annual per capita energy consumption in South Africa is 2.4 tons of oil equivalent. Although large, this figure is still much lower than that of the United States of America, where it is 8 tons of oil equivalent (WRI 2005).

The national energy supply is secure and well structured. It is dominated by coal, which contributes 70% of the country's primary energy (DME 2005b) and fuels 93% of electricity production (DME 2005b). Currently, 33% of the coal mined in South Africa is exported. Of the total domestic supply, 55% is transformed into electricity, 21% into petroleum products, 4% into gas, and the remaining 20% is used directly (ERC 2003). The industrial, commercial, transport and residential sectors all consume coal directly. Energy supply is therefore carbon dioxide-intensive. Much of the coal mined is of a low quality, and so needs to be beneficiated (DME 2004a). Solid waste is discarded annually – about 6.3 million tons in 2003 (DME 2004a). National coal reserves are plentiful and pressure on supplies is only likely to be felt around 2012, with peak production expected around 2070 (Dutkiewicz 1994).

Petroleum products account for 38% of total final energy consumption (TFC). Liquid fuels are derived from refined crude oil and liquefied natural gas, and from coal via the Sasol coal-to-oil process. Most of the crude oil refined in South Africa is imported – in 2001, crude oil imports totalled 139 million barrels (DME 2005b). Of the TFC of liquid fuels, 72% is derived from crude oil, 23% from coal and 5% from natural gas. Currently there is an imbalance in the diesel to petrol demand from the transport sector. If this situation persists, refined petroleum products may have to be imported. Although there are small oil reserves offshore, petroleum supply is associated with a high import dependency. Synthetic fuel production from coal is expected to be phased out over the next 40 years because of the demand for other chemicals. Gas field reserves are also limited, and the Mossgas installation is unlikely to continue beyond 2010.

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[2] When comparisons are made with purchasing power parity, the value used is the 'international dollar', which is a hypothetical currency unit with the same purchasing power that the US dollar has in the United States at a given point in time. It shows how much a local currency unit is worth within the country's borders. Conversions to international dollars are calculated using purchasing power parities (PPP). It is used mainly for comparisons of gross domestic product (GDP) – both between countries and over time.

[3] Purchasing power parity (PPP) is an alternative exchange rate between the currencies of two countries. It takes into account the fact that some goods such as real estate, and some services such as medical services, and certain heavy items are not traded, and are thus not reflected in the exchange rate.

Gas consumption plays only a small part in the South African energy mix, accounting for 2% of primary energy supply and 1% of final consumption (DME 2005b). The natural gas supply is almost exclusively used by the Mossgas gas-to-oil plant and most of the gas consumed directly is produced by coal gasification. By international standards, gas consumption is low – this is due to small reserves, and the fact that little has been done to establish industrial gas networks. Natural gas is found off the country's shores, with reserves estimated at 30 billion cubic metres (bcm) off the south coast and some very small discoveries of 3 bcm off the west coast. Although these reserves are not large, the opportunity for using this low CO_2 emission fuel has not been sufficiently harnessed.

Electricity supplies 28% of national TFC (DME 2005b). The national supply body, Eskom, supplies 95% of demand, with the remainder coming from small inputs from local authorities. Because of South Africa's inexpensive coal, Eskom boasts the lowest electricity cost in the world. Ninety-one percent of the country's electricity is generated from coal, with small amounts coming from hydro and pumped storage (4%), and nuclear (5%). Sulphur-related emissions from power stations, though significant at 1.5 million tons per year (Eskom 2004; NER 2004b), are relatively low, as the sulphur content of local coal is low. Many existing power stations have control equipment for particulate emissions.

Much of rural South Africa is without access to grid electricity, and the cost associated with grid extension has resulted in an increased use of small-scale renewable generation sources such as photovoltaics and micro-hydro. South Africa has a large off-grid electrification programme. Although small with respect to total generation, these sources are of special significance because of their contribution to meeting 'basic needs'.

Biomass, particularly fuelwood, is an important fuel in South Africa. Commercial and non-commercial biomass is estimated to supply just under 20% of the national final energy consumption. The biomass fuel cycle is unregulated and shortages exist in various areas. Most biomass is consumed directly by households. Small amounts are used for charcoal production, and biomass for industrial consumption is provided by bagasse in the sugar industry and wood wastes in the pulp and paper industry. Most of the household fuelwood is collected from the areas in and around the crowded settlements of fuelwood consumers. This has resulted in the degradation of large areas of otherwise potentially arable land.

2.2 Energy policy – an historical perspective

2.2.1 Introduction

Energy production has been, and still is, one of the main contributing factors to the social and economic development of South Africa. It has lent prosperity and security to the country by providing heat and power for industry, transportation, and household use. The sector has been largely driven by economic and political forces, which have had a profound impact on energy policies.

When considering the country's energy policies, it is best to consider three different periods: the first being the period of the apartheid regime, from 1948 up to 1994; the second the period following the first democratic elections of 1994, up to 2000; and the third from 2000 onwards, after the euphoria of independence had started to recede.

The energy policies of all three periods differed, but all contributed to the growth of the sector. During the apartheid period, due to the political isolation of the country, energy policies were mostly centred on energy security. After the advent of democracy, energy policies were directed to addressing the injustices faced by the majority of the population who had previously been denied basic services – equity and justice were therefore the primary goals. From 2000, energy policies focused on trying to achieve the targets and timetables that the government set itself after 1994. These targets relate to job creation and economic security, and recognise that development paths have to proceed in a sustainable manner and protect both local and global environments.

In South Africa one of the primary environmental issues is adverse emissions from coal. Nitrous oxide and sulphur dioxide from coal combustion cause serious problems for the local environment, while the CO_2 emissions cause climate change. This is challenging to the government – it has to balance affordability with the huge task of providing services for the poor, while at the same time complying with local and international obligations to protect the environment. In general the country's energy policies broadly reflect this new context.

2.2.2 The apartheid period

Before 1994, energy policies were designed to provide energy services based on 'separate development', the apartheid government's euphemism for racial discrimination. In the domestic sector, this meant providing modern energy services to the 'white' population group, which formed 11% of the population, and limited or no services at all to the rest of the population. High priority was given to the needs of the industrial sector because of its role in economic and political security. In general, this meant concentrating on electricity and liquid fuels, as these were crucial to economic and political interests. Security, secrecy and control characterised most of the policies that prevailed.

An important government decision in the 1950s, made for political and economic reasons, was to produce liquid fuel from coal through the government-owned Sasol. Security of liquid fuel supply was the main driver here. At the same time, the decision was made to refine crude oil locally. Up to 1954, all refined oil products had been imported and distributed by BP, Caltex, Mobil, and Shell (Trollip 1996) but now the growing demand for liquid fuels justified the development of refineries. Production of liquid fuel started at Sasol I in 1954 and the Mossgas plant was developed in 1992. Both plants were heavily subsidised by the government (Trollip 1996).

Escom (the Electricity Supply Commission, forerunner of Eskom) had been producing electricity for a long time, supplying the industrial structure including the military complex, and a number of mainly white households. In 1987, some major changes took place, which still significantly affect power sector reforms today. Two key statutes were introduced: the Escom Act of 1987, and the Electricity Act of 1987. The Escom Act defined the responsibility of the utility as providing electricity in the most cost-effective manner, although it said nothing about supplying electricity to all citizens. The Electricity Act defined the structure, functions and responsibilities of the Electricity Control Board and assigned the sole right of electricity supply within municipal boundaries to local government (Eberhard & Van Horen 1995). Five years later, in 1992, a new body called Eskom (now with a 'k') was established in terms of the Electricity Act. Eskom was to be controlled by the Electricity Council whose composition was now more representative of stakeholders. The Electricity Council would appoint Eskom's management board.

2.2.3 After the 1994 elections

The government that took office after the first democratic elections was committed to democratic governance and a new constitution, and it was determined to provide basic services to the poor and disadvantaged majority of South Africans. Modern energy, especially electricity, was considered to be one of the main components of such services. Government focussed its attention on electrification and liquid fuels.

2.2.3.1 Accelerated electrification

Well before the African National Congress (ANC) won the first democratic elections in 1994, a number of groups had been working with the ANC to formulate an energy programme to address the needs of the poor and disadvantaged. To this end a national meeting on electrification in South Africa was held in 1994 by the Department of Economic Planning of the ANC, and organised by the Energy and Development Research Centre (EDRC) of the University of Cape Town. This meeting aimed to formulate an accelerated electrification programme to serve the underdeveloped urban, peri-urban and rural areas where 80% of the population lived, nearly all of them black South Africans. The meeting was attended by different stakeholders, universities, municipalities, and non-governmental organisations (NGOs). The results of the Energy Policy Research and Training Project (EPRET) undertaken by EDRC, provided major inputs to this meeting (ANC 1994; Marquard 1999).

From 1992 to 1994, although a period of political uncertainty, was a time of several negotiating forums between government, business, labour and opposition groups on policy-making and governance in many economic sectors, including energy. EDRC researchers participated in several ANC policy committees (Marquard 1999). These and other forums led to the development of an energy section, including an electrification programme, within the ANC's Reconstruction and Development Programme (RDP). This formed the basis of all energy programmes that followed, including current programmes. The results of the EPRET research greatly influenced the electrification programme and its targets. A number of working groups were formed, covering regulatory framework, structure and policy, financing and tariffs, the electricity supply industry, end use and efficiency.

2.2.3.2 The National Electrification Programme

The National Electrification Programme was implemented between 1994 and 1999. Its objective was to electrify rural and urban low-income households which had been deprived of access to electricity during the apartheid period. The Programme expected that newly electrified households would switch from using fuelwood, candles and batteries to using electricity for their household needs. Eskom had already embarked on a programme in 1991 called 'Electricity for All'. The Government of National Unity that emerged in 1994 endorsed the electrification programme. Phase 1 of the programme, completed by 1999, aimed at electrifying an additional 2.5 million households on top of the 3 million that had already been electrified, which would bring the national proportion of households electrified up to 66%. The government funded the programme together with Eskom, which had the advantage of tax-free status.

2.2.3.3 The White Paper on Energy

The process leading to the formulation of the White Paper on Energy was contracted to EDRC. There were two stages: consultation and writing, then production and approval. The first stage involved a number of stakeholder forums, leading to a discussion document as a basis for comment. After a period for inviting public comment, a National Energy Summit was held to arrive at a consensus on energy sector goals. The next stage, which was the production and approval part of the process, involved several consultation meetings. These meetings led to a draft paper in June 1996. Because of several political and administrative problems, the draft paper became public only in July 1998. The Parliamentary Portfolio Committee then held a series of public hearings, and the final paper was published at the end of 1998.

The White Paper consisted of four parts: (1) context and objectives for energy policy, (2) demand sectors, (3) supply sectors, (4) cross-cutting issues.

Context and objectives of the White Paper

The White Paper recognised national energy and economic demands, while accepting the international energy agenda and the need to identify appropriate energy supply and use. The following five policy objectives were agreed upon:

1. Increasing access to affordable energy services.
2. Improving energy governance – clarifying the relative roles and functions of various energy institutions in the context of accountability, transparency and inclusive membership, particularly participation by the previously disadvantaged.
3. Stimulating economic development – encouraging competition within energy markets.
4. Managing energy-related environmental and health effects – promoting access to basic energy services for poor households while reducing negative health impacts arising from energy activities.
5. Securing supply through diversity – promoting increased opportunities for energy trade, particularly within the Southern African region, and diversity of both supply sources and primary energy carriers.

Demand sectors

For households, the emphasis of the White Paper was on low-income and rural areas – addressing problems of inadequate energy services to these areas, as well as inconvenient and unhealthy fuels. The White Paper considered access to fuels and their associated appliances, as well as fuel availability and pricing. Another issue that was considered was the building of thermally efficient low-cost housing as an opportunity to promote energy efficiency and conservation.

A further goal was providing greater energy efficiency to industry, commerce and mining, both for its environmental benefits and for its cost benefits such as increasing international competitiveness. The White Paper estimated that greater energy efficiency could save between 10% and 20% of current consumption. Certain obstacles were highlighted: inappropriate economic signals; lack of awareness, information and skills; lack of efficient technologies; high economic return criteria; and high capital costs. Despite these obstacles, government committed itself to facilitating greater energy efficiency.

The need to provide equitable access to affordable public transport was noted, and the challenges were identified. The provision of energy for specific sectors was also noted, with priorities being smallholder agriculture, rural schools, clinics, roads, and communication infrastructure.

Supply sectors

Electricity: The White Paper proposed restructuring the electricity distribution industry into independent regional distributors, at the same time making a commitment to the goal of universal household access to electricity. Government supported gradual steps towards a competitive electricity market while it investigated the desired form of competition. Eskom was to be unbundled into separate generation and transmission companies. The Southern African Power Pool (SAPP) would be supported.

Coal: Almost 72% of South Africa's primary energy is from coal, over half being used to generate electricity and a quarter being used for synfuels production. The coal industries are privately owned and deregulation in 1992 allowed greater competition in the market. This left government with the role of monitoring the industry. According to the White Paper, the coal industry would remain deregulated and government would continue to investigate options for the utilisation of coal discard streams.

Liquid fuels: The White Paper proposed minimum governmental intervention and regulation of the liquid fuels sector, while emphasising international competitiveness and investment, appropriate environmental and safety standards, sustainable employment and the inclusion of local black interests in ownership.

Deregulation of crude oil procurement and refining would be promoted, as would the removal of price control. The development of the gas industry and of coal-bed methane would be promoted, and there would be legislation for the transmission, storage, distribution and trading of piped gas.

Other energy sources: The future development of nuclear energy would depend on the environmental and economic merits of the various alternative energy sources. Exploration and production of oil and gas would continue under the principles of ‘use it and keep it’, and ‘the polluter pays’, with offshore rights continuing to be vested with the state. Renewable energy was considered to be advantageous for remote areas that were not economically feasible for grid electricity supply. The government would facilitate the sustainable production and management of solar power and non-grid electrification systems largely targeted at rural communities. The promotion of appropriate standards, guidelines, code of practice, and suitable information systems for renewal energy would be considered.

Cross-cutting issues

These issues included the need for:

- Integrated energy planning
- Good statistics and information
- The promotion of energy efficiency
- A balance between environmental, health and safety and development goals
- Energy supplies and the private sector to carry out appropriate research and development
- Development of human resources
- Capacity building, education and information dissemination
- The facilitation of international energy trade and co-operation
- The alignment of fiscal and pricing issues by the use of levies, tax differentials and support for more environmentally benign and sustainable energy options, including energy efficiency

2.2.3.4 Energy legislation

Several pieces of energy legislation were passed in the 1987-2000 period, of direct relevance to the future of the energy sector in the country. They include:

Escom Act 40 of 1987

Defines the responsibilities of Eskom.

Electricity Act 41 of 1987

Defines the structure, functions and responsibilities of the Electricity Control Board, and assigns the sole right of electricity supply within municipal boundaries to local government authorities.

Electricity Amendment Act 58 of 1989

Amends the Electricity Act of 1987 to provide for a levy on electricity; ensures that a licence shall not be required for the generation of electricity; and provides for the transfer of servitudes on the transfer of undertakings; and other incidental matters.

Nuclear Energy Act 3 of 1993

Brings all nuclear activities funded by the state under the control of the Atomic Energy Corporation, with specified exceptions.

Electricity Amendment Act 46 of 1994

Amends the Electricity Act, 1987 by providing for the continued existence of the Electricity Control Board as the National Electricity Regulator (NER), and applying certain provisions of the Act to other institutions and bodies.

Electricity Amendment Act 60 of 1995

Amends the Electricity Act of 1987 further to establish the NER as a juristic body; it makes provision for the appointment, conditions of employment and functions of the chief executive officer and employees; and for the funding and accountability of the NER. The objectives of the NER are given as:

- Eliminating monopolies in the generation and sales/supply sectors
- Rationalising end-use prices and tariffs
- Giving customers the right to choose their electricity supplier
- Creating an electricity market
- Introducing competition into the industry, especially in the generation sector
- Addressing the impact of generation, transmission and distribution on the environment
- Permitting open, non-discriminatory access to the transmission system
- Creating similar opportunities for all distributors of electricity

The 1999 National Nuclear Regulation Act

This Act amends the governance of nuclear energy.

2.2.4 After 2000

After 2000, there was renewed discussion about reform in the energy sector. There were suggestions that some regulation should return to the deregulated market, starting with the gas and electricity sectors. The concern to extend social benefits of electrification was reflected in the ‘poverty tariff’, which provided 50 kWh of free electricity to poorer households. New policy, for example on renewable energy, continued to emerge. Many of these considerations were combined in the first Integrated Energy Plan in 2003.

The 2001 Gas Act

Made for the orderly development of the piped gas industry and established a National Gas Regulator.

The 2001 Eskom Conversion Act

This Act made Eskom into a public company.

The 2002 Gas Regulator Levies Act

This Act provided for the imposition of levies by the National Gas Regulator.

The 2003 Petroleum Pipelines Bill

The Bill seeks the establishment of a national regulatory framework for petroleum pipelines, and provides for the licensing of persons involved in the manufacturing or sale of petroleum products.

Merging of the energy regulators

In April 2003, the Minister of Minerals and Energy announced that the NER, the Gas Regulator and the Upstream Petroleum Regulator would merge into a single entity within five years.

2.2.4.1 Integrated Energy Plan

At the end of 2003, the Department of Minerals and Energy (DME) published an Integrated Energy Plan (IEP). This plan provided a framework for taking decisions on energy policy and for the development of different energy sources and energy technologies in the country. The Energy Research Institute was contracted to undertake a computerised analysis of the plan based on energy reserves, energy demand, and consumption up to 2020, using different scenarios of the South African economy. These scenarios show future energy use from different energy sources, and evaluate the associated pollution, including emissions of greenhouse gases.

2.2.4.2 Oil and gas industry

South Africa depends heavily on imported crude oil, which is then refined locally. Historically, several different government institutions have been involved in various areas of the petroleum industry such as importation of crude oil, exploration activities, and strategic fund development.

Liquid fuels production, importation and consumption account for approximately 20% of South African total primary energy supply (TPES). Currently consumption is about 450 000 barrels/day. Net imports account for about 255 000 b/d, with the balance being synthetic fuels from coal produced by Sasol, and natural gas from Mossgas.

The petroleum sector is governed by a complex system of agreements between government and the oil industries. These agreements essentially regulate the price of petrol and diesel and determine how it is to be distributed, produced, transported and sold, although the operations themselves are undertaken by the respective companies. With the exception of pricing, the petroleum sector is not yet deregulated.

In 2003, DME introduced a new price mechanism, changing from the ‘in-bond landed cost’ (IBLC) to a basic fuel price set by the DME that will give back to motorists and the economy an amount of R1 billion over 12 months.

The DME, in collaboration with the Department of Transport (DT), has recommended the use of diesel fuel in minibus taxis as a means to reduce air pollution. To be effective as a policy, this will require more diesel vehicles and good collaboration between the oil industries and car manufacturers.

In 1991 the government deregulated refinery industries in South Africa. The income of refineries is determined by import parity cost of fuels, and there is no control over refinery margins. In summary:

- The government will not extend regulatory control over crude oil refining.
- There is no need for South Africa to build another refinery, since the current total refinery capacity is sufficient to meet the present demand.

- The DME still sets the price of fuels.
- The DME advises the ministries of Transport and Finance on the energy-efficiency implications of alternative transport and subsidy policies.

The overall quantity of South Africa natural gas resources is yet to be fully explored. At present, natural gas is produced by Mossgas from the F-A Field off the Mossel Bay area. In 1997 it accounted for about only 1.6% of total primary energy in the country. Sasol also produces gas amounting for about 1.1% of net energy consumption – this is mostly consumed by large industries in Gauteng and Mpumalanga. There are possibilities to increase the use of gas and to draw on the natural reserves from the neighbouring countries of Mozambique and Namibia.

2.2.4.3 Government institutions

Soekor (Pty) Ltd was formed by the government in 1965 and is responsible for petroleum exploration offshore activities in the country, including related policy and regulatory functions. Early on in its history Soekor worked with several international oil companies but most of them withdrew due to international sanctions. It has the mandate to carry out joint exploration ventures and to allocate areas for exploration. Soekor operates beyond South Africa, and has interests in Angola and South East Asia.

Mossgas was established by the government in 1992 to be responsible for the production of gas from Mossel Bay and convert it to liquid synthetic fuels. Its production capacity is 45 000 barrels per day of crude oil equivalent; the product is refined to produce petrol, diesel, kerosene and LPG from a feedstock comprising 4.9 million cubic metre day of natural gas (IEA 1996: 180).

Petroleum Oil and Gas Corporation of South Africa (PetroSA) was established in July 2000, merging Mossgas and Soekor. The goal of PetroSA is to be a leading integrated provider of oil, gas and petrochemicals competitively in African markets and beyond. The overall production of PetroSA is 8% of the liquid fuel requirement of South Africa, and its products are produced under different brand names in the Southern Cape and parts of the Northern and Eastern Cape. Alcohols and small quantities of transportation fuels are exported worldwide.

The Strategic Fuel Fund is a subsidiary of the Central Energy Fund. Its function is stockpiling strategic reserves of crude oil. In 1988, the Strategic Fuel Fund stocked one and a half years' supply. By 1995 this was reduced to about half a year's supply. The government has approved a stock of four months supply, about 35 million barrels (Trollip 1996).

2.2.4.4 Promotion of renewable energy

The expansion of renewable energy in South Africa has taken place mostly in the rural areas, where poor households are electrified with solar home systems (SHSs) in places where the national grid cannot penetrate economically. In many cases renewable energy is the lowest cost energy for these households. The broader approach known as 'energisation', which combines renewable energy technologies with sources like LPG, is also being considered.

The government considers the use of renewable energy as a contribution to sustainable development. Most of the sources are indigenous and naturally available, and the use of renewables therefore strengthens energy security because it is not subject to disruption by international crisis. In August 2002 a White Paper on renewable energy was published by the DME for public comment. Some of its key objectives were:

- To ensure that an equitable level of national resources is invested in renewable technologies, given their potential and compared to investments in other energy supply.
- To introduce suitable fiscal incentives for renewable energy.
- To facilitate a good investment climate for the development of the renewable energy sector, so that it can attract foreign and local investors.

The following policies were proposed:

- To develop an appropriate legal and regulatory framework for pricing and tariff structures in order to support the integration of renewable energy into the energy economy and attract investors.
- To develop an enabling legislative and regulatory framework to integrate independent power producers into the existing electricity system.
- To develop an enabling legislative framework to integrate local producers of liquid fuel and gas from renewable resources into their respective systems.

Further policies proposed were:

- To promote the development and implementation of appropriate standards, guidelines, and codes of practice for the appropriate use of renewable energy technologies.
- To support appropriate research and development and local manufacturing to strengthen renewable energy technology and optimise its implementation.

2.2.4.5 Electricity basic service support tariff (EBSST)

In 2003, as a social responsibility measure, the government decided to provide free electricity to all connected households as a way of meeting the basic needs of the poor. Fifty KWh monthly was considered sufficient to cover basic lighting, media access and some water heating. Many municipalities across the country had already introduced free electricity as of July 2001, varying from 20 KWh to 100 KWh monthly. The funding for the EBSST programme was to come from government allocations to the municipalities and from cross-subsidies.

A major impact of the EBSST has been to reduce the fee paid by the users of SHSs in the non-grid electrification programme. Households, which had been paying R58 per month, can now pay R18 as a result of the EBSST.

2.3 Energy for sustainable development – critical issues

To achieve its objective of sustainable development, South Africa needs to substantially increase the supply of modern affordable energy services to all its citizens, while at the same time maintaining environmental integrity and social cohesion. This is not an easy path to follow.

Fuel for cooking is a major problem, especially in peri-urban and rural areas where most poor and disadvantaged South Africans depend largely on firewood, charcoal, coal and kerosene for their cooking needs. Sustainable development implies replacing firewood and charcoal with more modern energy sources, while at the same time introducing technological innovations to improve the efficiency and environmental problems associated with coal and kerosene. It also means providing electricity to those without it – some 20% of urban and 50% of rural people. Sustainable development also implies the provision of electricity and other modern fuels to the commercial and industrial sectors to promote their economic competitiveness and future prosperity, as well as greatly improving the public transport system both with regard to service to commuters and technologically.

Accomplishing these tasks raises critical issues for energy sector policy. The major issues are: energy provision to the poor and disadvantaged, access to cleaner technologies, complying with both local and international environmental legislations, and energy integration and security in Africa as a whole. We now look at these issues one by one.

2.3.1 Energy provision to the poor and disadvantaged

The government has stated that it wants 100% access to electricity by 2010, although it is not clear if the intention is 100% grid electricity or if some of this will be off-grid. The quantity of electricity to be available to each household has yet to be decided. Originally the plan was to supply households with 350 kWh/month, but experience has shown that newly connected households choose to consume between and 75kWh and 250 kWh per month, with an average of about 100 kWh/month (Prasad & Ranninger 2003). Provision should still be made for higher consumption, because it is known that providing electricity leads to the development of other productive activities that use electricity. Further policies will be required, as discussed below.

Grid and off-grid electricity supply

Generally, the overall macro-economic environment will determine the extent of electrification for the remaining 20% of unelectrified households in urban areas and 50% in rural areas, even though the multiplier effect of grid electricity can be significant if well planned. Eskom (2002) has shown that the cost of new connections is declining, but it is nevertheless clear that the cost of connecting the remaining urban and rural residents will be very high. Supplying grid electricity to some rural areas is difficult because of their remoteness and low population density, so cost becomes prohibitive, and a weak rural economy makes cost recovery even more difficult. However, policy approaches based on 'taking electricity to the people' or 'bringing the people to electricity' should be explored.

Some problems have arisen because of the belief that 'electricity for all' means grid electricity for all. The government is presently supporting off-grid SHSs by allocating concessions, subsidising up to 70% of the capital cost and about 80% of the maintenance costs. The results, from the systems installed so far, are mixed, and the cost to the government is high (Afrane-Okese & Muller 2003). Policy attention will be required to ensure the sustainability of the off-grid project.

A limited programme carried out at Lwandle in the Western Cape shows that with the right policy, solar water heaters can be viable (Lukamba-Muhiya & Davidson 2003). The use of liquefied petroleum gas (LPG) is not yet widespread in South Africa, though it is increasing. Some barriers can be addressed by certain policies and measures (Cowan 2005; Lloyd 2002) and South Africa can learn from successful programmes in Botswana, Senegal and Ghana (Davidson & Sokona 2003).

There are some ongoing programmes aimed at introducing improved cooking stoves for kerosene and coal. The Cape Technikon in Cape Town is working on improved kerosene stoves, and the government is promoting low smoke fuel stoves using coal. These technologies, if widespread, would improve efficiency and reduce health hazards.

Access to high quality transport fuels

Sustainable development requires the improvement of petroleum fuels and the introduction of cleaner transport fuels. It requires public transport to be greatly improved to provide essential travel, especially for the poor and disadvantaged. South Africans have far too great a reliance on private transport, which is not sustainable. However, such systems will require major improvements in road and communication infrastructure. Developing this infrastructure will require significant investments, and energy provision is only one of the features needed.

Real steps are being taken in South Africa to improve the environmental qualities of petrol and diesel. The use of unleaded petrol is growing, and the government intends to phase out the use of leaded fuel within a few years. The rehabilitation of the Natref refinery to produce low-sulphur diesel has been another move by the government to improve the effect on the local environment. The government also intends to use up to 5% biodiesel, which will also reduce adverse emissions. Some cities, such as Gauteng and Cape Town, are planning to use compressed natural gas in public buses, which will result in both local and global environmental benefits (Davidson & Xhali 2003).

2.3.2 Access to cleaner technologies

The cleaner technologies available to South Africa in the short and medium terms can be divided into cleaner fossil fuel, technologies that are more energy efficient, and renewable energy

2.3.2.1 Cleaner fossil fuel technologies

South Africa's coal reserves are huge, and coal will remain a significant fuel for the country for the foreseeable future. However, current technologies cause serious local and (especially) global environmental problems. Natural gas is about 60% cleaner than coal in terms of CO_2 emissions, and significant progress is being made to improve technologies associated with natural gas use. But natural gas currently contributes only about 1.5% of the country's needs, although the government intends to increase this share to 10% by 2010. Crude petroleum accounts for over 75% of the country's transport needs and nearly all of this is imported. The government is beginning to address some of the environmental consequences of petroleum product use. Some further clean technology options are discussed below.

Cleaner coal technologies

Technologies to reduce sulphur dioxide and nitrogen oxides are used in many industrialised countries, but they are expensive and require significant investment. However if the overall economy improves, electricity consumers could possibly be taxed to contribute to the increased investments needed.

Major technological progress is expected in coal technologies for power production, though most of these will only be available in the medium term. Such technologies include pulverised fuel combustion and integrated gasification and combustion technologies, and, in the longer term, coal-powered fuel cells. These technologies could reduce CO_2 emissions from current levels of 1200 kg CO_2/MWh to about 500 kg CO_2/MWh, while at the same time increasing efficiency from about 30% to 70%. In the longer term, technologies for carbon capture and storage will be available – South Africa has many old coalmines where carbon dioxide can be stored. Future coal power plants may need to include some end-of-pipe treatments, such as flue gas desulphurisation, although these add some 30% to the cost of stations (see chapter 4).

Cleaner oil and gas technologies

Power production technologies using oil and gas are also improving, and in the longer-term improved oil powered technologies are expected to reduce CO_2 emissions by half. Similar efficiency improvements are expected with oil-powered fuel cell technologies and with gas-powered technologies with improved turbine systems and fuel cells.

2.3.2.2 Energy efficiency technologies

There is room for significant improvement in energy efficiency in South Africa, especially in the power and industrial sectors, but also in the household sector. However, major policy changes will be needed to achieve these gains. The changes would have to be a combination of regulatory and market-based policies and institutional changes. At present the NER, along with Eskom, has embarked on load management and demand-side management programmes in the residential, industrial and commercial sectors, aiming to achieve gains between 1000 MW and 3000 MW by 2010.

2.3.2.3 Renewable energy technologies

Compared to the total energy used, the usage of renewables is very small, but the government intends to increase it to about 14% by 2014 (Mlambo-Ngcuka 2003). A White Paper on renewable energy was published in 2003.

2.3.3 Complying with environmental regulations

Because of South Africa's extensive use of coal and petroleum fuels, adverse impacts on both the local and global environment are significant.

The extraction of large quantities of coal leads to noticeable environmental impacts and 'upstream' emissions. For example, most of the methane released from the South African energy sector is as a result of coal mining. Land scarring is caused by pit digging and discard dumping. Discard dumps are prone to spontaneous combustion, water pollution from run-off, and increased surrounding particulate concentrations. The conversion of coal to petroleum products is about 40% efficient, resulting in significant emissions. Coal power generation is relatively efficient, operating at about 35%. Power stations produce large amounts of CO_2, SO_2, NO_x and ash, although stacks that penetrate the inversion layers, and effective ESP particulate controls, minimise impacts of all but the CO_2 emissions.

South Africa is presently drafting stricter air quality standards. The country is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and at the same time it is Africa's highest emitter of greenhouse gases. It is very likely that targets will be imposed on South Africa as soon as these apply to developing countries. Complying with such obligations, both local and global, will be expensive. To ensure sustainable development, this should not be done at the expense of the country's socio-economic development.

2.3.4 Energy integration and security in Africa

South Africa is a member of the SAPP – made up of the different power utilities in Southern Africa, with a secretariat in Harare, Zimbabwe. SAPP started operations in 2002, with the aim of optimising the use of electricity in the region. South Africa has the biggest electricity utility in SAPP, and its future will be affected by SAPP's activities. Eskom is currently working in 39 African countries, confirming South Africa's importance for energy integration in the continent.

As an example of regional energy cooperation, South Africa has embarked on diversifying its energy supply base and reducing its reliance on the coal that accounts for 75% of its energy supply. Substitution of coal for natural gas from Mozambique is one such measure: full operation of this system started in early 2004. It is intended to use the gas to produce power in combined cycles. Work with Namibia to develop its natural gas potential is also under way. Concerning oil, while over 70% of current supplies of crude oil come from the Middle East, South Africa is now increasing its share from Nigeria. South Africa is also working with the Democratic Republic of Congo to develop a 100 GW hydropower plant.

2.3.5 Conditions for a sustainable energy system

A sustainable energy system can be defined as one that provides for present energy needs without compromising the ability of future generations to satisfy their energy requirements (Goldemberg & Johannson 1995). At the same time, the system has to be affordable to users and contribute to socio-economic development. If South Africa is to take the path of sustainable energy, it is important to establish the real costs of energy (including environmental costs) and to integrate the energy system with national development goals. The lower the real cost of energy, the more competitive the system is.

To optimise an energy system, three approaches must be applied simultaneously. Firstly, an evaluation of future energy scenarios and technology options must be made, together with their associated impacts. Secondly, information should be clearly disseminated so that the market can drive the energy system optimally. Thirdly, until the parties concerned are empowered, steps should be taken to encourage external cost accountability and longer-term energy planning. Initially government can coordinate these steps, but over time they should be self-perpetuating.

It is important to model technically accurate energy scenarios and their impacts on the economy, resources, society and the environment, for both the medium to longer term. From such analyses, we can derive information that is vital for policy construction and investment (DME 2003a). Areas of specific interest and research direction includethe following:

- The possibility of current energy sector development leading to future over-dependence on finite resources, or on imports.
- The potential for longer-term national savings that could be brought about by extending local, national and regional resources.
- The technical potential of power pooling in the region, taking into account the various energy demand growth rate predictions for neighbouring countries.
- The potential for distributed power generation, especially where piped gas supply may be cheaper than electricity distribution.
- The impact of novel technologies.
- Case studies to establish the applicability of technologies and energy strategies for the South African situation. These could be either national or international in scope, depending on the nature of the economic challenges involved. For example, Indian and South African coal reserves are similar, so a joint integrated gasification combined cycle (IGCC) pilot plant project holds potential savings (currently Eskom is completing the construction of a fluidised bed plant with an Indian consortium). Another example is biomass depletion and the health impacts from biomass burning, which is a common theme in African rural energy supply. Coordinating research between different African countries could lead to potential savings and African-specific solutions.
- The determination of energy efficiency potentials, and technological options for the demand-side as a function of cost.
- The establishment of the real cost of energy and externality costs in the context of national development goals.

2.3.5.1 Real costs and externality costs

An externality cost can be defined as the change in utility or welfare of an agent when brought about by another, when this change in welfare is not compensated for, or appropriated (Van Horen 1996) by the second agent. When we add externality costs to the supply cost of energy, we get the real cost of this energy to society. Externality costs, whether positive or negative, give us a basis for penalising or reimbursing energy users for their impact on the environment or society. Due to the somewhat subjective nature of evaluating actual or potential impact costs, methodologies used for externality derivation must be transparent and related to the context of economic growth in the short, medium and longer terms. Externality data, if derived correctly, can provide important elements for constructing an optimised energy system.

Information dissemination is vital for the establishment of a national, sustainable energy system, and the most effective driver for the system should be the free market. However, this is only possible if those involved can base their decisions on clear authoritative data. For example, it is often said that energy savings are possible for South African industry and commerce with significant medium-term financial gains. Such options are not being pursued primarily because of a lack of accessible authoritative data.

The lower the real cost of energy, the more competitive the economy becomes – an essential prerequisite for economic growth. This is why energy efficiency information and externality costs, including the potential impacts of CO_2 emissions restrictions on production, must be made known. Meaningful databases should be built up for fuel use for all energy cycles, from generation to efficient demand-side consumption, and this information should be made accessible. It should include, for example, all feasible options for rural electrification and energy supply. Such information would encourage optimal energy development and form the basis for sound policy. With the right information and market forces, South Africa's energy system will evolve.

In the short term, government encouragement of a sustainable energy development is essential, with a clear analysis of the most socially economic development paths. Possible means of encouraging integrated energy planning include:

- physical controls such as short-term supply rationing;
- investment policies;
- education policies;
- taxes or subsidies;
- market controls such as regulating residential coal prices;
- establishing energy efficiency agencies.

In implementing regulation, careful consideration must be given to ensuring that externality costs are borne by the parties responsible, and that controls do not restrict free market activity (Spalding-Fecher & Matibe 2003). Control measures should be seen as temporary and, in time, diminish. In the case of externalities, as the parties affected become empowered, a laissez-faire situation would ideally evolve – so that, for example, a polluter and the parties affected by the pollution would bargain to establish an optimum pollution level and an associated cost compensation. Thus energy supplied will be at the lowest real cost to society.

2.4 Outlook for the future – technologies and policies

The South African energy sector faces a twofold challenge – to address the unacceptable lot of the poor, and to employ technologies and practices that will provide inexpensive energy for a competitive economy without straining resources of the national, regional and global environment. Within the context of responsible research, information dissemination, fiscal influences and market forces, there are opportunities for an energy system optimised economically, socially and environmentally. How do we provide the lowest cost energy to society as a whole for the short, medium and long term? Clearly there are many possible future energy scenarios. Although many of the technologies we describe below are not new, they are presented in timeframes that probably best fit sustainable solutions. They are presented in the categories of electricity supply and the SAPP, energy efficiency, renewable energy technologies, and cleaner fossil fuels.

2.4.1 Energy supply and the SAPP

In the short term, changes in electricity supply will come through the SAPP and new local power stations. The power supplied to SAPP from outside of South Africa will be generated mostly by hydro, with some gas.

The largest hydro reserves in this region are in the Democratic Republic of Congo where there is a technical potential of 100 000 MW, of which 40 000 MW of run-of-river may be harnessed. Currently, South Africa has a generation capacity of 48 000 MW, while the rest of the region has a capacity of 6 000 MW. Hydroelectric power imports hold the potential of significantly reducing the CO_2 emissions that would come with extra coal use. However, these imports are bound to be limited by political and supply-security considerations. Conventional wisdom suggests a limit in the short term of about 9%.

In the medium term, international pressures placed on fossil fuels may result in increased imports from the SAPP, depending on energy supply constraints, and political and security considerations. It is possible that increased gas supply could come from piped methane from the Waterberg area and also from pre-mining extraction. Other sources may include coal gasification and biogas from landfills, sewerage works, liquefied natural gas imports (LNG) and possible gas imports from Mozambique.

Another supply option is increased domestic nuclear capacity. Of particular interest for South Africa is the local development of the pebble bed nuclear reactor. This reactor has the advantages of being small, of low energy density, inexpensive, intrinsically safe, of modular design, and gas-cooled. At present, plans are underway for pilot plant feasibility studies, as the pebble bed system holds potential for distributed generation.

More efficient storage will allow for energy supply integration, and thus more commercial scope for intermittent generation of renewables. In the medium term, new energy carriers and mixes are likely to become important. Also in the medium term, energy and pollutant efficiencies should improve dramatically due to market forces.

The longer term is harder to predict. It seems likely that low-temperature superconductors will revolutionise energy storage and generation. Fast breeder nuclear reactors are likely to be in use, extending nuclear fuel reserves significantly. It has been suggested that nuclear fusion will be viable and will be able to supply large quantities of hydrogen fuel, most likely to be stored in the form of methanol for easy handling. Other technologies that are expected to play a large role in the longer term include advanced solar technologies, including molten salt ‘power towers’ and the artificial photosynthesis of sunlight into energy carriers. In the long term, costs will include externalities and be optimised by market forces.

2.4.2 Energy efficiency

There are many possibilities for future energy policy in the field of improving energy efficiency, which could have a major impact on sustainable development goals. While some progress has been made, many potential gains remain.

In the residential sector, for example, the savings to households from greater energy efficiency can directly contribute to alleviating energy poverty. Turning current voluntary guidelines for new housing into mandatory standards (especially in middle- and upper-income housing) would facilitate this. But even before this happens, building codes in the commercial sector, which has greater financial capacity, should become mandatory. Government is taking the lead in some of its own buildings in this regard, but more could be done. Government procurement could impose energy efficiency standards on a wider range of equipment. Standards for a diversity of equipment (such as variable speed drives, air compression, heating, ventilation and cooling (HVAC) systems) can help increase industrial energy efficiency. Appliance labelling and mandatory energy performance standards are other measures that should be considered. All efforts to improve industrial energy efficiency would contribute to economic development.

The transport sector is a large sector of energy consumption at municipal level, with large emissions of both local and global pollutants. Improved fuel efficiency standards would increase the energy efficiency of the national fleet. Vehicle emissions standards are currently being considered by the Department of Environmental Affairs and Tourism.

Implementing efficiency measures requires institutional support. The institutional framework needs to be strengthened, both within and outside government. A national agency championing energy efficiency would consolidate efforts, possibly working in collaboration with energy service companies. Research, development and demonstration would be of particular importance.

2.4.3 Renewable energy

At present, the commercial exploitation of South Africa's renewable energy sources is limited, but it is clear that the cost of renewable energy will continue to decline as the technologies mature. Increased use of renewables will require the introduction of new policies. The White Paper on Renewable Energy (2003) set a target of 4% of projected electricity demand for 2013 (DME 2003b). A strategy for implementing this target needs to be formulated, focussing on specific projects and their financing.

The government has often stated its intention to improve the local content of renewable energy technologies used in South Africa. Hence a policy should be set up for progressively increasing local content in the local manufacture of renewable technologies. Such a policy should be accompanied by government-sponsored enabling conditions for local technology development.

Strengthening the regulatory framework for promotion of these technologies within the NER will help their development. Financial support for renewables in the form of subsidies and tax incentives should be considered, targeted for a limited period. Initially, it appears that the national Treasury will set aside funds on a once-off basis, but in the longer term, financing schemes will have to be considered. They could include:

- feed-in tariff mechanisms;
- portfolio quotas with or without tradable certificates;
- tax incentives;
- green pricing.

In late 2005, the Renewable Energy Finance and Subsidy Office was established. The Office's mandate includes the management of renewable energy subsidies and provision of advice to developers and other stakeholders on renewable energy finance and subsidies, including size of awards, eligibility, and procedural requirements (www.dme.gov.za/dme/energy/refso.htm).

2.4.4 Cleaner fossil fuels

As mentioned above, technological progress is being made in developing and implementing cleaner fossil fuel technologies. However, most of these efforts are in developed countries and are restricted mainly to research and development networks. Policy intervention could bring South Africa into participating in these networks and partnerships. This would not only enhance the knowledge basis for suitable selection of technologies, it would also allow local forces to be part of their development, thus increase their chances of utilisation.

The international community has ratified the Kyoto Protocol to help reduce global greenhouse gas emissions. The Clean Development Mechanism (CDM) allows developed countries to invest in greenhouse gas mitigating projects that are 'additional' – meaning that they would not otherwise have gone ahead. CDM projects should further the host countries' sustainable development goals, and emissions that are thus saved will be credited to the developed country's CDM project investors. An amount of approximately 21 million tons of CO_2 equivalent[4] is currently expected to be saved over the period from 2005 to 2012 in South Africa from the CDM (DME 2005b).

Other opportunities will also have positive environmental effects. The national electricity regulator assumes that all future coal-fired plant will comply with World Bank emissions standards (NER 2004a). New coal-fired (fluidised bed) plant is being considered which can burn currently discarded coal waste. Although it will increase emissions from power stations, wider availability of electricity will reduce much severe indoor air pollution (DME 2003a). The poverty tariff, providing 50 kWh per household per month of free basic electricity (UCT 2002), is designed to promote the uptake of electricity and make its use more affordable for newly connected households.

Other initiatives include the promotion of Basa Njengo Magogo, a scheme to reduce the emissions from coal and wood burning in residential areas using informal stoves (DME 2005b), and the deployment of 'Energy Centres' dispensing clean fuels in low income areas.

2.4.5 Cross-cutting issues

Financial instruments tend to have effects that cut across economic sectors. Particular kinds of energy efficiency – notably for low-income households – would require subsidies. For sectors that can pay for the capital costs, government needs to invest in programmes promoting options with payback times short enough to attract investment by users themselves.

Pollution taxes – possibly targeted at local pollutants rather than greenhouse gases – are a crosscutting measure that would both meet environmental objectives and generate revenues. Care should be taken that the energy burden of poor households is not increased by such measures, but with appropriate targeting and recycling of revenue, this would be avoided. More generally, funding for social and environment public benefits requires more attention, particularly as deregulation increases competition.

Another suggestion for policy intervention is developing an adequate policy framework for technology development and transfer. Policies could enhance a national system of innovation, improve technology databases, and optimise human and financial resources for technology acquisition.

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[4] Gases other than CO_2 contribute to global warming. For simplicity, they are reported as the greenhouse effect of tons of 'carbon dioxide equivalent'.

Improvement of beneficiation from energy-intensive industries in South Africa would provide macro-economic advantages, help technology development significantly, and reduce technology imports. Some attempts in this respect are being made in the manufacturing sector, but much more needs to be done.

An important issue is research and development and training institutions. Energy policy development in South Africa is done by the government, which in turn contracts various institutions to undertake selected policy studies. This system works fairly well, but it can be improved. The government needs a well-organised structure that undertakes screening and synthesis of the many options available. This structure should also have strong international linkages. An important role of the structure would be to identify critical areas where the government needs intellectual input for policy-making.

Government needs to fund institutions that develop highly qualified energy policy technocrats. At present this is done on an ad hoc basis, which does not give optimum results. Using different mixes of short- and long-term programmes will greatly enhance the capacity of government to make adequate policies.

Promotion of public awareness programmes around energy for sustainable development is particularly important, as sustainable development is a new paradigm which needs deliberate effort.

3

Energy demand

Harald Winkler

3.1 The current situation

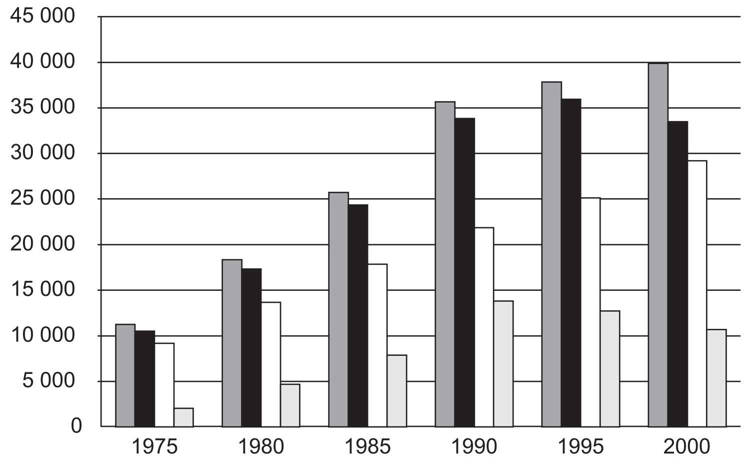
If we analyse energy needs for sustainable development, it is better to do this in relation to a common demand such as 'the cost of cooking a meal for a poor family of six' rather than simply assessing this family's overall access to electricity. Such an analysis is more useful from the sustainable development point of view because it reflects not just energy costs but also the efficiency of the appliances and the fuels available to that particular household.

Applying this logic to a whole energy system, we should start with energy services – heating, lighting, cooking, water heating, transport, and energy for productive and industrial activities. We should then work backwards to look at useful energy, the appliances required to deliver that energy, and finally the energy-to-energy supply. To help contextualise this analysis, we begin with a historical perspective on energy demand.

3.1.1 History of energy demand

Energy has been a key factor in the shaping of South Africa's economy. In the early part of the twentieth century, electricity supply was driven by demand from the mining industry. In the 1950s, concerned about energy security, the apartheid government decided to develop a synthetic fuels programme to meet demand for liquid fuels and to lessen its dependence on energy imports. In the 1960s and 1970s, massive power station projects were initiated (including some nuclear capacity) on the assumption of continued rapid increases in electricity demand. These left the national utility with large excess capacity in the 1980s and 1990s. The excess capacity has helped to keep electricity prices low, but it is now practically exhausted (Eskom 2000). There has been little need for new investment in recent decades, and therefore debt has been reduced, as most of the capacity has already been paid off. However, when new investments are needed, the capital costs and electricity prices can be expected to rise. Figure 3.1 shows the excess capacity, expressed as the difference between total licensed capacity and peak demand.

South Africa's low energy price, mainly because of coal-generated electricity, has been one of the country's key competitive advantages, and continues to a large extent to drive new investment in industry. However a note of caution should be raised here. Due to a lack of knowledge about the market structure and the absence of specific data, the country's low energy price conceals inefficient energy use and accelerated national reserve depletion. The extra energy intensities involved require increased extraction and transformation processing, which have led to significant increases in pollution. Low energy costs also have the effect of retarding the development of new energy sources, thus limiting the diversity of the fuel mix, its associated supply security, and possible efficiency improvements.



	1975	1980	1985	1990	1995	2000
▨ Eskom licensed capacity	11 242	18 349	25 716	35 673	37 840	39 870
■ Net maximum power produced	10 522	17 339	24 359	33 843	35 951	33 461
□ Peak demand	9 185	13 668	17 852	21 863	25 133	29 188
□ Difference: licensed minus peak demand	2 057	4 681	7 864	13 810	12 707	10 682

Figure 3.1: Eskom licensed capacity and peak demand (MW)
Sources: Eskom (1987, 1996); National Energy Regulator (NER) (2000)

Historically, energy demand in South Africa has been dominated by heavy industry and mining, which have determined the economic and energy structure of the country. Much of the manufacturing sector is linked to mining activities through minerals beneficiation and metals production. These industries are all energy intensive, and rely on the availability of inexpensive coal and electricity. Figure 3.2 (SANEA 2003) shows how the industry and transport sectors dominate final demand. (The 'non-energy' segment of Figure 3.2 refers to resources such as coal, oil, gas and wood, which could be used for energy but which are converted to other products like chemicals and paper).

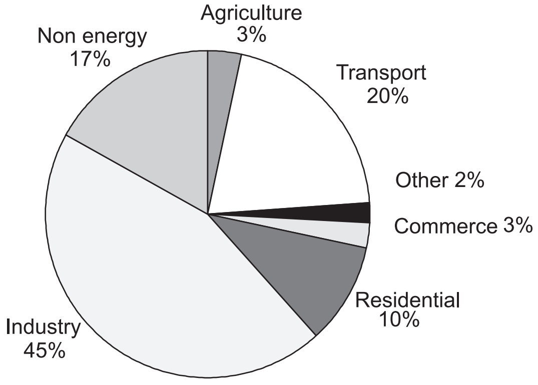


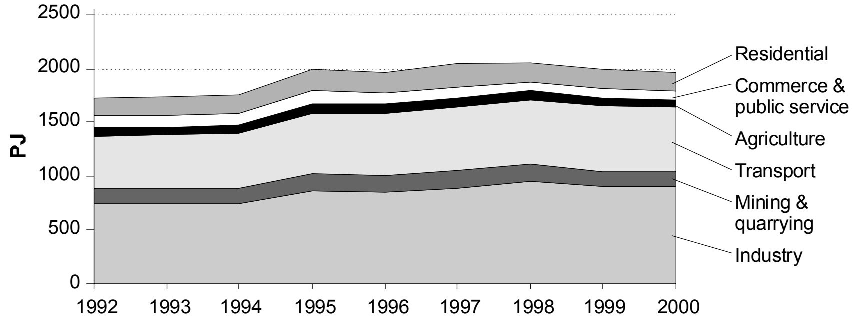
Figure 3.2: Share of final energy consumption in South Africa, 2000
Source: Based on SANEA (2003)

In recent years, industrial demand has been the major source of growth across all energy carriers (see Figure 3.3). Some growth can be seen in the transport sector, while in mining production the demand declined slightly towards the end of the past decade.

3.1.2 South Africa's energy demand in a comparative perspective

Let us consider how energy demand has changed on an international scale. Globally, total final energy consumption for coal declined from 627 to 546 Mtoe from 1973 to 2000, while industry's share of this grew from 44% to 75%. World oil consumption increased over the same period from 2 139 to 2 950 Mtoe, with transport being the fastest growing sector (South Africa showed a similar trend). Consumption of natural gas almost doubled from 672 to 1 115 Mtoe, although the share of consumption by industry declined from over 50% to 44%. The greatest increase in global consumption was in electricity final consumption, from 439 to 1 089 Mtoe; the share of industry and transport have declined in relative terms, while other sectors have increased their share (IEA 2002a).

If we look at the regional share of global consumption, the OECD countries continue to consume more than half of total final energy, although their relative share declined from 62% in 1973 to 52% in 2000. African energy consumption has risen from 2.8% to 5.5% over the period. The biggest growth worldwide has been in Asia (5.2% to 12%) and China (5.8% to 11.4%).



Note: does not include consumption of renewables and waste, due to uncertainties in biomass data

Figure 3.3: Energy demand, 1992-2000
Source: Based on data in energy balances (DME 2002a)

Compared to other developing countries, the total primary energy supply (TPES) for South Africa per person is relatively high (see Table 3.1). The two-thirds of South Africa's population who have access to electricity consume close to 50% of Africa's electricity although they make up only 5% of Africa's population. Because of South Africa's strong industrial base, its energy consumption levels, particularly of electricity, are significantly higher than those of many other developing countries, although some other rapidly industrialising countries, such as South Korea, do have a higher consumption per capita. Table 3.2 gives an international comparison of electrification rates in 2000.

Table 3.1: Global energy and electricity consumption, 2000

Source: IEA (2002a)

	Total primary energy supply /capita	*Electricity consumption*
	Toe/capita	*TWh*
South Africa	2.51	194
Africa	0.64	399
South Korea	4.10	279
Indonesia	0.69	82
Non-OECD	0.96	5 038
OECD	4.78	9 077
World	1.67	14 115

Note: TPES is shown per person, while electricity consumption is the total for whole countries or regions

Table 3.2: Global electrification rates in 2000

Source: IEA (2002b)

	Electrification rate	*Population without electricity*	*Population with electricity*
	%	*million*	*million*
South Africa	66.1	14.5	28.3
Africa	34.3	522.3	272.7
Indonesia	53.4	98.0	112.4
Developing countries	64.2	1 634.2	2 930.7
OECD	99.2	8.5	1108.3
World	72.8	1644.5	4 390.4

3.1.3 Demand for electricity

Electricity has played, and continues to play, a particular role in the South African economy. It represents a modern energy service to those who have been denied access in the past, and it is a major input of industrial development. It makes up 22% of final energy demand in the country, but this figure understates the role that electricity plays as a high quality energy carrier. In industry and manufacturing, the electricity-intensive industries are some of the largest contributors to economic growth and exports, and they take up more than 60% of national electricity sales (Trollip 1996; Berger 2000; DME 2000). Figure 3.4 breaks down final energy demand by carrier, and shows that liquid fuels and gas make up the largest single share, followed by coal and electricity.

The flow of electricity from production, through distribution, to end use customers is shown in Figure 3.5. (Note: the percentages for different sectors in Figure 3.5 are for electricity only, while those in Figure 3.2 are for all forms of energy).

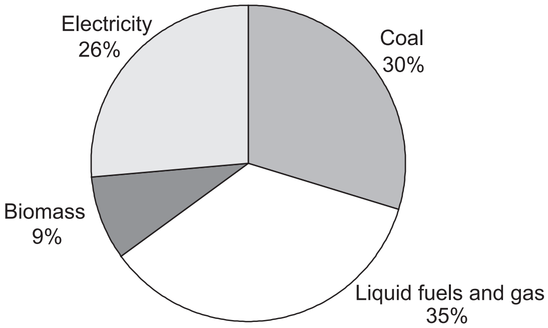


Figure 3.4: Share of final energy demand by energy carrier
Source: Based on data from DME (2002a)

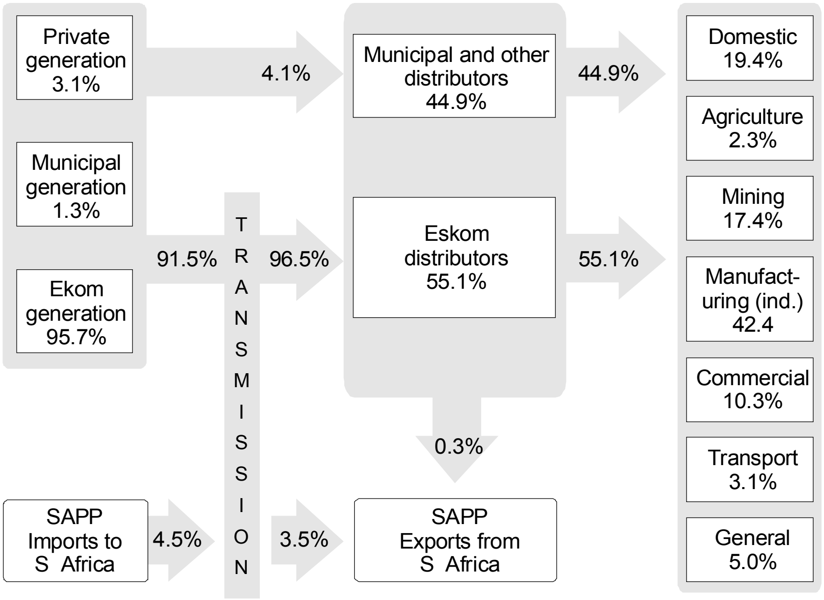


Figure 3.5: Energy flow through the electricity supply industry in South Africa[5]
Source: NER (2001a)

The largest proportion of electricity is consumed by the industrial sector (42%). Mining and residential are the next two largest, with these sectors also showing the greatest growth in electricity demand in recent years.

The typical pattern of electricity demand during the working week shows two distinct peaks (shown in Figure 3.7) – one in the morning and a higher one in the early evening. In winter, peak demand is more pronounced than in summer, because of the demand for space heating. To meet peak demand, additional capacity is required. Eskom peak demand in 2001 was 30 599 MW, almost 50% higher than average demand, which was approximately 20 000 MW (NER 2001a).

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[5] The original diagram gives no percentages for imports and exports. For 2000, however, 5 294 GWh was 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 a 327 GWh difference between imports and exports is unlikely to result in changes of as much as one percentage point.

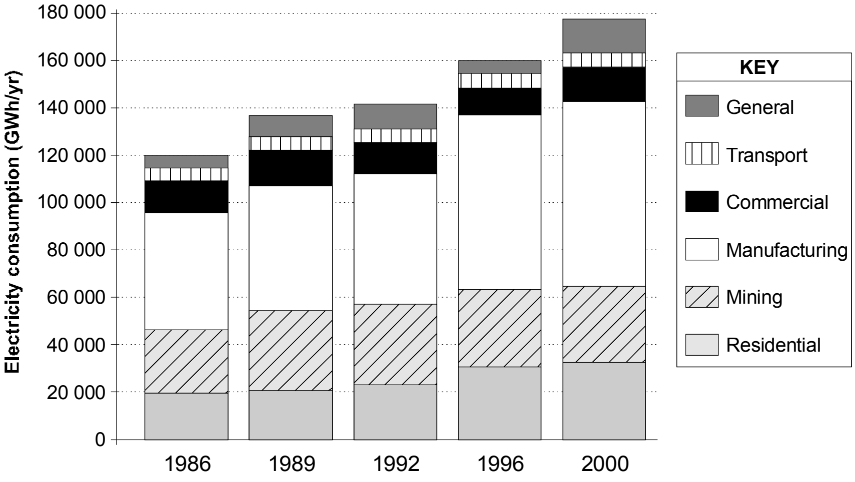

Figure 3.6: Electricity demand, 1986-2000
Source: Davis (1998), NER (2000)

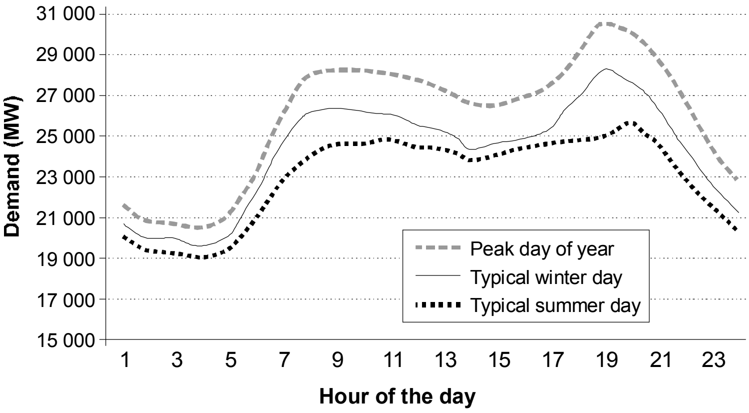

Figure 3.7: Weekday electricity demand profile (average across seasons)
Source: NER (2001a)

A key policy objective of the South African government has been universal access to electricity. This objective formed part of the post-1994 government's Reconstruction and Development Programme (ANC 1994), and in 1998 it was included in the White Paper on Energy Policy (DME 1998). The National Electrification Programme in its first phase, from 1994 to 1999, aimed to connect 2.5 million households. By 1999, electrification rates among South African households had increased from about one third to about two-thirds. According to statistics provided by the National Energy Regulator (NER), in 2001 the overall rate of electrification in the country was 66% (NER 2001b; 2001a), and during 2002 a further 338 572 homes, 974 schools and 49 clinics were grid-electrified, as well as 5 321 SHSs installed (Mlambo-Ngcuka 2003).

By 1999 the total investment in the electrification programme was about R7 billion, all of which had been financed domestically by Eskom. Without cross-subsidy from Eskom, electrification would not be viable (Borchers et al. 2001). Electrification is now being taken over by government with financing from Treasury allocated to the Department of Minerals and Energy, so direct government subsidies will be required. Estimates are that a capital subsidy of R840 million per year will be required from government to Regional Electricity

Distributors (REDs) for the first five years and R560 million per year thereafter (PWC 2000: 14). This works out to a subsidy of R2 800 per connection.

Interestingly, consumption levels for newly connected households have remained low for several years at about 100-150 kWh per month – well below the planning estimate of 350 kWh. This reflects problems of affordability. Despite the 'low' electricity tariffs, research suggests that many electrified households continue to use traditional, highly polluting fuels (Mehlwana & Qase 1998; Thom 2000). High rates of electricity cut-offs and community protests against cut-offs further confirm the affordability problem. Added to this, there are a variety of social and cultural reasons why people still choose to use non-electric fuels (Mehlwana 1999).

3.1.4 Demand for liquid fuels

Demand for liquid fuels, shown in Figure 3.8, is dominated by petrol and diesel. The transport sector accounts for some 80% of the demand for these fuels, with most petroleum products being used in road transport (DME 2002a). Consumption of other liquid fuels is much smaller. Jet fuel is obviously used in aviation, while kerosene and liquid petroleum gas (LPG) are important in the residential sector. Fuel oil is typically used by heavy industry.

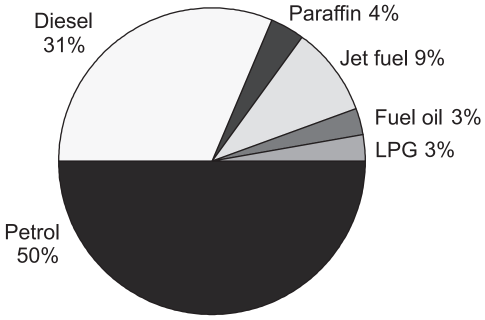

Figure 3.8: Consumption of major liquid fuels, 2001
Source: DME (2002b)

Over the period 1988-2000, two trends can be noticed (see Figure 3.9 and Table 3.3). One is that the consumption of jet fuel has grown rapidly. The other is that in the last few years the consumption of petrol has been declining, while that of diesel has been increasing. Comparing 2000 to the previous year, petrol sales dropped by 4.3%, while diesel grew by 4.3%, against the backdrop of an overall decrease of 1.6% for liquid fuels (SAPIA 2001).

Table 3.3: Inland consumption of petroleum products
Source: SAPIA (2001); SANEA (2003)

Year	*Petrol*	*Diesel*	*Kerosene*	*Jet fuel*	*Fuel oil*	*LPG*
1988	7 995	5 409	641	784	524	406
1989	8 395	5 350	678	835	546	432
1990	8 612	5 273	723	866	576	434
1991	8 906	5 130	725	861	526	464
1992	9 171	4 950	743	1 009	549	465
1993	9 202	4 940	834	1 095	595	454
1994	9 630	5 110	875	1 193	633	485
1995	10 153	5 432	850	1 368	616	472

Year	***Petrol***	***Diesel***	***Kerosene***	***Jet fuel***	***Fuel oil***	***LPG***
1996	10 566	5 759	917	1 601	704	450
1997	10 798	5 875	970	1 777	635	502
1998	10 883	5 959	1 052	1 877	574	523
1999	10 861	5 993	1 054	1 995	561	540
2000	10 396	6 254	857	2 020	555	567
2001	10 340	6 448	786	1 924	555	599

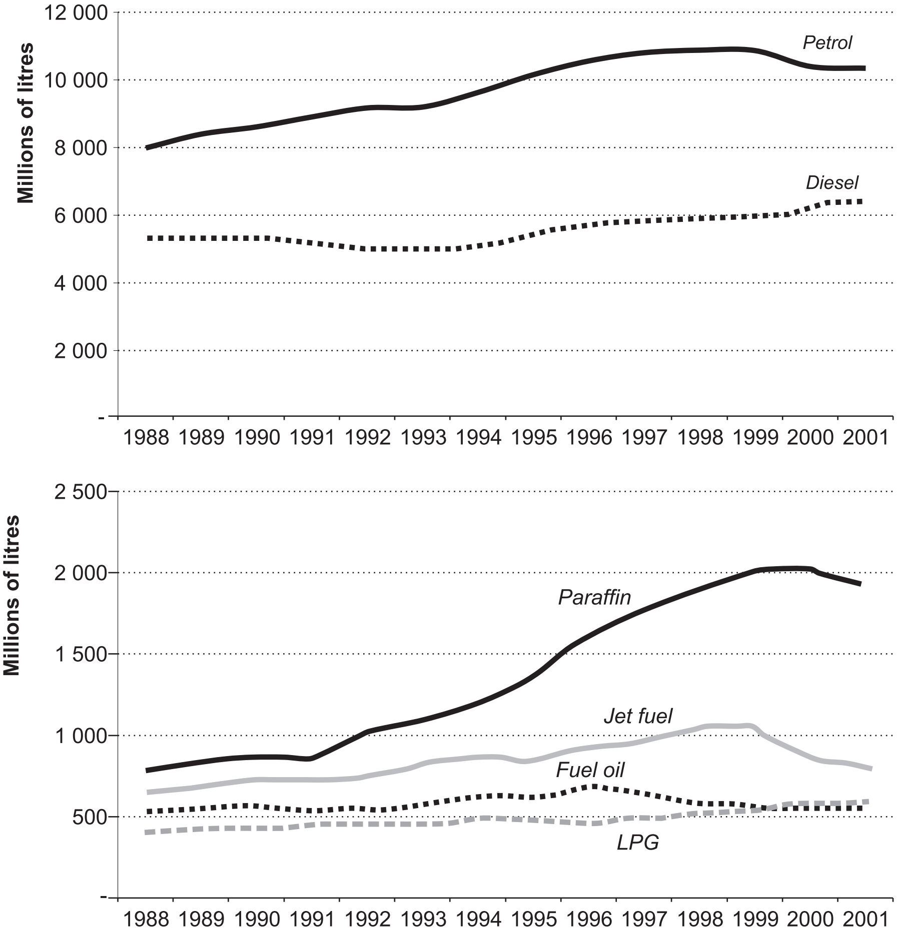

Figure 3.9: Trends in petrol and diesel consumption (upper figure) and other liquid fuel consumption (lower figure), 1988-2001
Source: SAPIA (2001); SANEA (2003)

3.1.5 Final energy consumption by sector

The breakdown of final energy consumption by economic sector has been described in some detail in *Preliminary energy outlook for South Africa* (ERI 2001), a document which sets out the basis for an integrated energy plan (IEP). Another recent publication is the *South African Energy Profile* (SANEA 2003) compiled for the South African National Energy Association (an affiliate of the World Energy Council), although most of the data is for 2000/1. This data has been used and supplemented by unpublished modelling data from the Energy Research Centre (ERC 2003).

3.1.5.1 Industry

Industry is the largest user of energy in South Africa in final energy consumption, as can be seen from Figure 3.3. Within the industrial sector, the major sub-sectors are mining, iron and steel, pulp and paper, non-ferrous metals, chemicals and petro-chemicals, food and tobacco, and other (see breakdown in Figure 3.10).

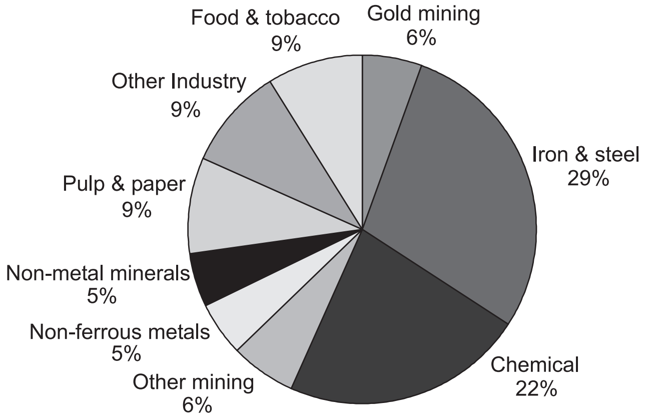

Figure 3.10: Final industrial energy consumption by sub-sector (2001 total: 1302 PJ)

Mining in particular is a large energy-consuming sector, and is sometimes shown separately from industry (for example, in electricity statistics). The chemical and iron and steel industries are also large sub-sectors. Figure 3.11 gives the same information as Figure 3.10 in a different form, illustrating the energy carriers – coal and electricity – that dominate consumption in the industrial sector. In mining, demand from gold mining is decreasing, but the demand from 'other mining' is growing. With only about 75% of energy in the 'other mining' sub-sector coming from electricity, the share of that carrier is likely to increase in future. This sub-sector is expected to grow more slowly than gross domestic product (GDP), unlike most other industries which are expected to keep pace with or even exceed the rate of economic growth (ERI 2001).

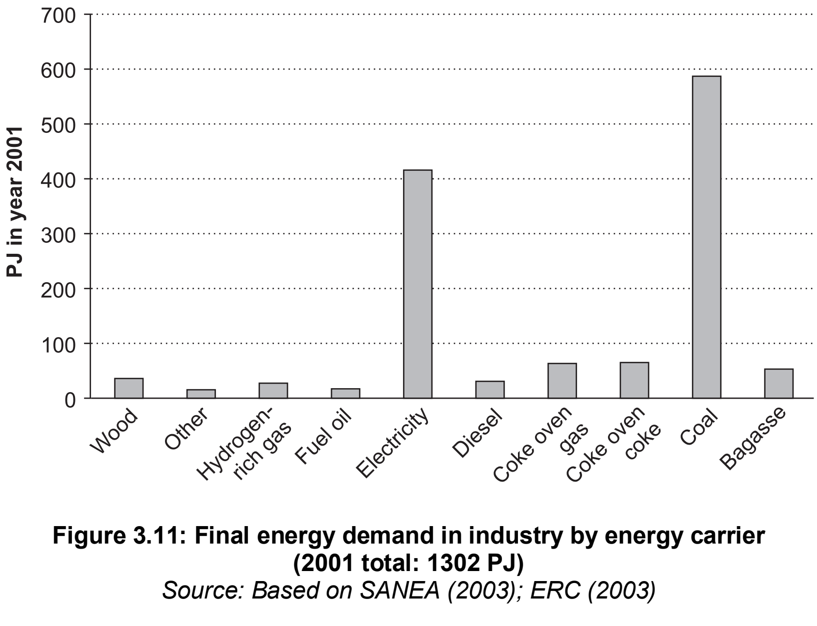

Figure 3.11: Final energy demand in industry by energy carrier (2001 total: 1302 PJ)

Source: Based on SANEA (2003); ERC (2003)

The industrial sector consumes just over 50% of final energy, of which 51% comes from coal, 33% from electricity, 12% from petroleum products and 3% from gas (DME 2005b). Energy intensities are high relative to Organisation for Economic Cooperation and Development (OECD) countries, and certain industries consume up to twice as much energy per ton of output. It has been estimated that a 9-12% energy saving is possible through improved efficiency standards compared to current specific intensity, with attendant pollution decreases and a five-year payback period (Dutkiewitz & De Villiers 1995; Trikam 2002).

The low cost of energy has given South Africa a competitive advantage, and encouraged the growth of energy-intensive industry such as aluminium smelting and mining. The use of this low-cost energy is inefficient, though there are significant opportunities to save energy and to lower the related environmental impact costs through energy efficiency measures (ERI 2000; Trikam 2002). These measures will move the economy towards better practice and increased profitability (Laitner 2004).

3.1.5.2 Transport

Transport energy use is dominated by liquid fuels, notably petrol and diesel (see Figure 3.12). Land passenger transport is the largest consumer of energy, followed by land freight (SANEA 2003). Road transport is a much larger consumer than rail and air (DME 2001). The use of energy for transport is expected to grow more quickly than GDP.

The transport sector currently consumes 27% of final energy consumption, of which about 97% is petroleum products, 3% electricity, and 0,2% coal (DME 2005b). Energy intensities in this sector are high due to various inherited problems and poor fiscal control. The national transport fleet is old, poorly maintained, and has low occupancy. Commuting patterns, shaped by the geography of apartheid settlements, increase fuel consumption and hence emissions. Loading and maintenance regulations are not enforced and efficient public transport systems are poorly planned. The results are substantial smog levels and increased road damage.

3.1.5.3 Commercial

Electricity is the predominant energy carrier in the commercial sector (Figure 3.13). All government and office buildings, financial services, information technology, educational and recreational institutions use lights, air conditioners, heaters and office equipment. The commercial sector, like transport, shows higher growth rates in energy consumption than other sectors, and energy consumption can be expected to grow faster than economic output (SANEA 2003).

The commercial sector consumes only 6% of the national total final energy consumption (TFC), in the proportion of electricity 64%, coal 35% and gas 1%. Currently there are no thermal efficiency standards for South African buildings, which means the costs of temperature control remain high. Utilities costs are normally borne by tenants, so there is little incentive for developers and property owners to focus on energy efficiencies. If energy-efficiency standards were made mandatory for commercial buildings, significant savings could be made. Studies estimate that 20-40% energy savings are possible in this sector, decreasing emissions, with a 2- to 3-year payback period (IEA 1996). Increases in efficiencies also offer proportional decreases in pollution.

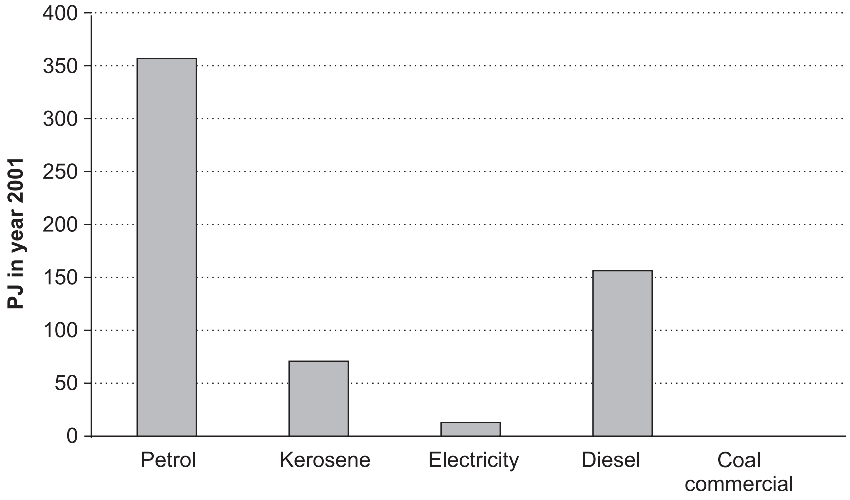

Figure 3.12: Final transport energy demand by energy carrier (2001 total: 596 PJ)
Source: Based on SANEA (2003) and ERC (2003)

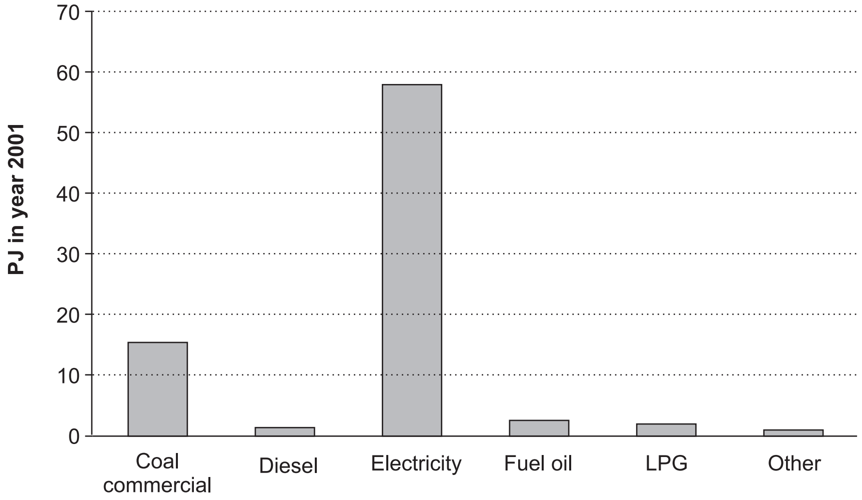

Figure 3.13: Final energy demand in the commercial sector by energy carrier (2001 total: 79 PJ)
Source: Based on SANEA (2003) and ERC (2003)

3.1.5.4 Residential

Energy use in the residential sector is characterised by a multiplicity of fuel types and a variety of appliances (Figure 3.14). Within this sector, especially with its increasing rate of domestic electrification, electricity is the largest source of energy, although many other fuels are also used, such as kerosene, coal, fuelwood and LPG.

Within this sector, as with commercial buildings, there is significant potential for energy-efficiency improvements. An important distinction needs to be made, however, between the low-income residential sector and those of other income levels. Relatively cheap energy conservation interventions (such as installation of ceilings) are mostly not affordable for poor households and would probably require subsidies; on the other hand middle- and upper-income households generally have the means to invest in various forms of energy saving, for example by installing solar water heaters.

The three major challenges faced by the residential sector are: firstly, the provision of energy needs and environment reclamation, where population pressure on fuelwood gathering has depleted traditional biomass supplies and damaged large areas of land; secondly, the provision of lighting as a precursor for the education and economic empowerment of rural people; and, thirdly, a more widespread adoption of 'clean energy' in order to reduce concentrations of pollutants within residential houses.

Energy costs for the poor are high; thus improved efficiencies are of special importance. In the current low-cost housing programmes, 50-90% efficiency savings are attainable with only a 1% to 5% increase in costs (IEA 1996) – a significant window of opportunity to improve the energy efficiencies and emissions of residential dwellings. By 2015, an estimated 7 million new houses will be constructed in South Africa.

The residential sector consumes 16% of final energy, of which biomass contributes 14%, electricity 62%, coal 8%, paraffin 12%, and LPG and candles 2% each. Patterns of household energy demand differ significantly in rich and poor households, and in urban and rural households (Simmonds & Mammon 1996; Mehlwana & Qase 1998; Mehlwana 1999). Electricity contributes a larger share of household energy use in urban areas than it does in rural areas, while the reverse is true for fuelwood. Electrification is taking place rapidly. Recent estimates suggest that by 2025, 92% of households will be electrified, with 87% using electricity only, and 5% using electricity together with other fuels. Off-grid electricity supply is being delivered to community centres such as schools and clinics, and to households. The most common technologies are photovoltaics, diesel generators and micro-hydro schemes. Several energy service companies have obtained concessions from DME to install and maintain SHSs.

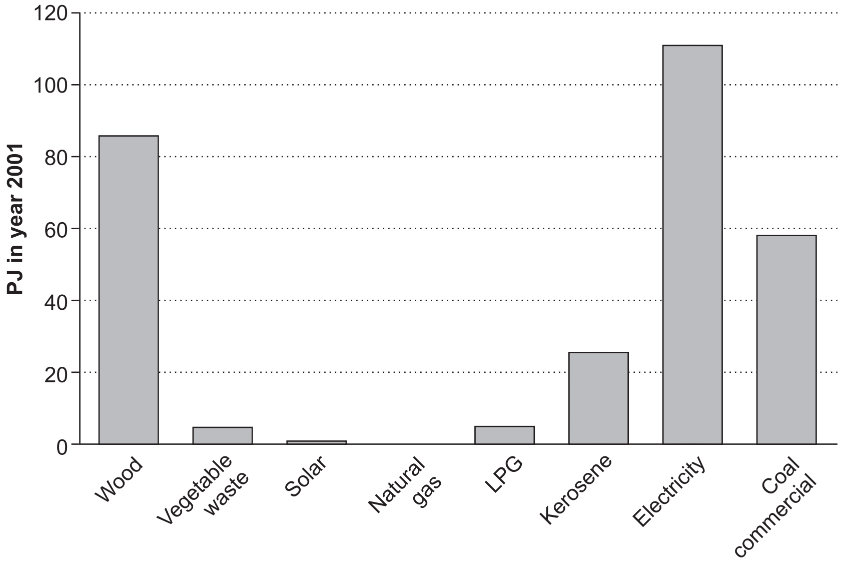

Figure 3.14: Final residential energy demand by energy carrier (2001 total: 288 PJ)
Source: Based on SANEA (2003) and ERC (2003)

Drastic health impacts result from coal and biomass combustion in the houses of poor people, where ventilation is often minimised in an attempt to increase thermal insulation. These conditions have led to respiratory disease being the second highest cause of infant mortality in the country. As fuelwood is depleted, the ecosystem is damaged, and more time is spent in the collection process with losses in opportunity costs.

The adoption of clean energy in the residential sector requires energy use that reduces particulate and noxious gaseous emissions. The short- to medium-term options include grid electrification, non-grid electrification, transition to low-smoke fuels, clean-burning stoves, solar hot water heaters and general housing efficiency improvements. The primary obstacles are the establishment of fuel distribution networks, and cultural acceptance of new clean energy forms and appliances. The energy systems involved are new technologies, such as clean-burning stoves, and photovoltaics; new fuel management systems, such as community woodlots; and the use of new commercial fuels such as biofuels.

3.1.5.5 Agriculture

Of South Africa's 122.3 million hectares, 13.7% (16.7 million ha) is potentially arable, 68.6% (83.9 million ha) is suitable for grazing land, 9.6% (11.8 million ha) is protected by nature conservation, 1.2% (1.4 million ha) is under forestry, and 6.9% is used for other purposes. Of the 16.7 million hectare arable portion, 2.5 million hectares is in the former homelands, and 14.2 million is farmed by commercial farmers in the former 'white' areas. A total of 9.5 million hectares is used for field crops (NDA 2000: 5-6). Most energy use in agriculture is on commercial farms, which are tending to increase in size and decrease in number.

Traditional peasant farming barely exists, having been destroyed by colonial and apartheid policies (Bundy 1979). Even agricultural activity categorised as 'subsistence' is questionable, since the homeland system created rural settlements so dense that they do not even allow for subsistence. These dense rural settlements do not quite fit either the agricultural or the urban residential settlement models. There is little data on energy use by these settlements or by subsistence farmers, except for some isolated studies (Auerbach & Gandar 1994). Land restitution and land reform under the new government is increasingly aiming at creating a new class of small black farmers.

Agriculture's share of the economy has been in decline for many years. In 1965 its share of GDP was 9.1% and by 1998 it was only 4.0% (NDA 2000). This trend is likely to continue in future. With a declining share of GDP, agriculture can expect very slow growth in energy demand, although exactly what this will be is difficult to predict.

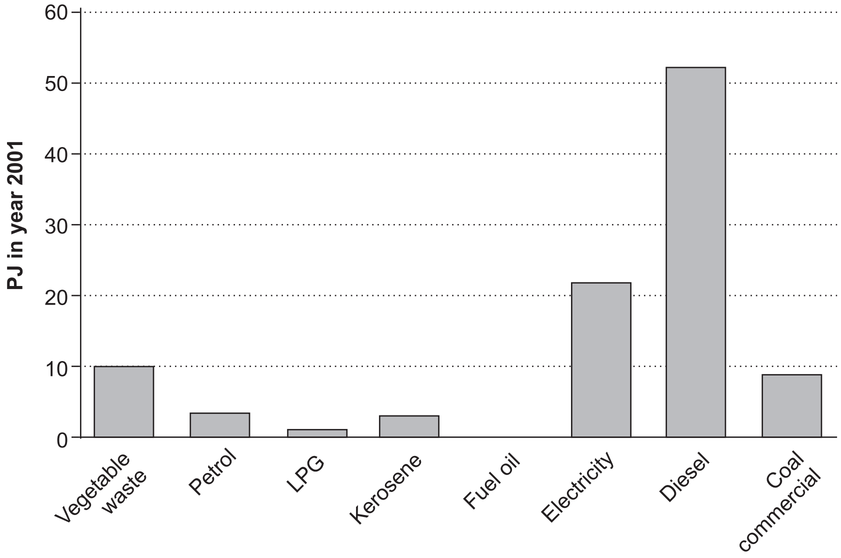

Figure 3.15: Final energy demand in agriculture by energy carrier (2001 total: 100 PJ)
Source: Based on SANEA (2003); ERC (2003)

Agriculture requires energy primarily for draft power and other tasks of land preparation, which are necessary for the effective utilisation of land (Auerbach & Gandar 1994). Energy for water pumping is the second major use, followed by smaller energy demands for activities such as crop processing, transport and lighting. Energy in agriculture is used primarily in the form of diesel, followed by electricity and coal (Figure 3.15).

3.2 Energy for sustainable development – critical issues

The use of energy has significant environmental implications in addition to supply-side impacts. This section focuses on South Africa's 'energy intensity' – the amount of energy used per unit of economic output – and in particular the potential for more efficient technologies and cleaner fuels.

3.2.1 Energy intensity

Overall South Africa's energy intensity is high – it is a country with a high energy input per unit of gross national product. Low energy costs combined with an abundance of mineral deposits have led to an emphasis on primary extraction and processing, activities which are inherently energy intensive. Most energy-intensive enterprises are part of South Africa's 'minerals-energy complex' (Fine & Rustomjee 1996).

The Integrated Energy Plan (DME 2003) acknowledges that by international standards, South Africa has a high energy intensity. Table 3.4 shows South Africa's energy intensity between 1993 and 2000. After 1995, GDP rises and final energy consumption falls, resulting in a lowering of energy intensity over that period.

Table 3.4: National energy intensities between 1993 and 2000 (DME 2003)

	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
GDP- All industries at basic prices (R billion; constant 1995 prices)	472	486	500	521	534	538	549	571
Total final energy consumption (renewable and waste excluded; PJ)	1 766	1 789	2 016	1 996	2 071	2 098	2 026	2 003
Energy intensity (Total energy consumption/GDP; PJ/R billion)	3.74	3.68	4.03	3.83	3.88	3.90	3.69	3.51

If we compare South Africa to an industrialising nation like South Korea, South African energy intensity is higher in relation to GDP, similar if adjusted for power purchasing parity, and lower if measured by per capita consumption of primary energy. South Africa's energy intensity is close to that of Indonesia, although with a higher level of primary energy and electricity consumption per capita.

If we compare South Africa to other middle-income countries, there is clearly room for energy efficiency improvements (Simmonds 1995; Clark 2000). The best areas for improvements are those industries that require high levels of energy per unit of output – mining, iron and steel, aluminium, ferrochrome, and chemicals – the same sectors that make up a large share of South African exports.

Low energy prices do not provide much incentive for energy efficiency, because it makes economic sense to use more energy if energy is cheap.[6] Nonetheless, South Africa has made improvements in some sectors, notably iron and steel. Even here, while South Africa's energy intensity for iron and steel improved from 40 TJ per ton of steel in 1971 to 30 TJ/ton in 1991, in Taiwan the improvement over the same period was from 31 to 14 TJ/ton. In gold mining, while annual production has been generally declining since the 1970s, the input of energy per unit (TJ/ton) has been increasing over time. An effective comparison of intensity levels would require more detail regarding resource endowment, type of mining and industrial processes.

Table 3.5: Energy consumption and intensity indicators, 2000

Source: IEA (2002a)

	TPES/capita (Toe/capita)	*TPES/GDP (Toe/000 1995 US$)*	*TPES/GDP (Toe/ 000 PPP 1995 US$)*	*Electricity consumption per capita (national average) (kWh/capita)*
South Africa	2.51	0.63	0.29	4 533
Africa	0.64	0.86	0.32	501
South Korea	4.10	0.31	0.30	5 901
Indonesia	0.69	0.70	0.25	390
Non-OECD	0.96	0.74	0.28	1 028
OECD	4.78	0.19	0.22	8 090
World	1.67	0.30	0.24	2 343

TPES = total primary energy supply, toe = tons of oil equivalent, PPP = purchasing power parity (adjusted to remove distortions of exchange rates), GDP = Gross domestic product

While South African industry is dominated by primary extraction and relatively low-grade processing, it will remain a heavy user of energy; but as the industrial sector diversifies into more high-technology manufacturing and processing, its energy intensity should reduce. On the other hand, there are pressures for the energy intensity of the sector to increase: international trends show that countries like South Africa become receptors of investment in energy-intensive activities as developed countries shed these activities in favour of more service-oriented and lucrative activities using more skilled labour. Recent investments in South African aluminium smelters and iron and steel mills, and also the SAPP strategy, indicate future industrial trends. To some extent, especially in the short term, this allays fears that lower purchases of coal by Annex I countries with emission limits will threaten South African coal exports.

3.2.2 Energy efficiency and inefficiency

The Energy Research Institute has conducted benchmark studies of energy efficiency in the industrial, residential, transport and commercial sectors in South Africa (Hughes et al. 2002). Whole sector studies are broad approximations, because of large differences within each sector due to variations in products, raw materials, and processes. Examples from

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[6] This section deals with energy intensity and energy efficiency. Economic efficiency is a different concept, referring to the optimal allocation of resources, theoretically derived from the intersection of supply and demand (marginal cost and benefit). It may be *economically* efficient to use more energy if it is cheap, *if* the price of energy is correctly set by the market. The market 'optimum' does not usually coincide with social or environmental optima, which might internalise environmental costs or add expenditure for social benefits.

specific sub-sectors would possibly be more illuminating. Further research is needed in this area and data quality remains a problem.

Industrial production in South Africa has shifted over time from mining to manufacturing, with major contributions to economic output coming from iron and steel, chemicals and petrochemicals, pulp and paper, and mining. A greater shift is expected in future towards the production of technically advanced products, which require lower energy input but make high value-added contributions (Hughes et al. 2002). Differences in final energy demand by industrial sub-sector from 1996 to 2000 are shown in Figure 3.16.

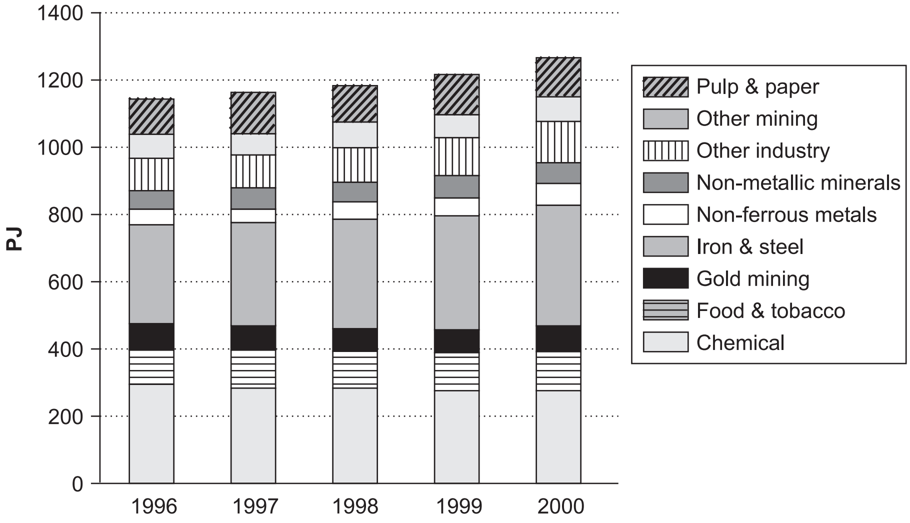

Figure 3.16: Final energy demand by industrial sub-sector (PJ of final energy demand)
Source: (Hughes et al. 2002)

Two examples of South African industrial sub-sectors which are relatively inefficient compared with OECD countries are pulp and paper, and iron and steel, both of them sub-sectors with relatively high energy intensities. Recent innovations, such as the Corex and Midrex production processes for steel making, are expected to lower the energy intensity of the steel industry significantly, but this is not reflected in current data. Without such innovation, use of standard technology could not achieve much gain in efficiency. In the pulp and paper industry, South Africa produces pulp at an energy intensity per gross product output higher than that of other pulp-producing countries. Paper, on the other hand, is produced at a similar energy intensity to many of the countries running best-practice programmes in this industry (see Table 3.6).

High energy intensities imply that there is potential for improvements in efficiency, at least in theory (Thorne 1995). For most sectors there is insufficient information for an accurate estimate of potential energy savings; however, attempts have been made to identify areas where savings are possible. There are a number of standard energy efficiency measures that can be applied. Schemes with payback periods as short as one year can lead to significant reductions in energy demand and savings for industry (Hughes et al. 2002). These initiatives could be supported by labelling schemes, energy audits, and awareness and training programmes.

Table 3.6: Energy intensity in the pulp and paper sector

Source: Hughes et al. (2002)

	GJ/ton	*Pulp production (Ktonne)*	*Paper production (Ktonne)*
South Africa	34.13	2138	2226
USA	26.36		
UK	26	743	4824
Brazil	20		
Sweden	23.5	10215	8419
Canada	29.21	9756	25971

3.2.3 More efficient technologies and cleaner fuels

3.2.3.1 Energy efficiency and demand-side management

There is great potential for energy efficiency measures in South Africa, across all sectors from industry and commerce, to transport and residential. The largest energy savings, in absolute terms, can be made in the industrial and transport sectors. Interventions aimed at improving energy efficiency in the residential sector can contribute significantly to improving the quality of life of households while reducing costs (Clark 1997; Simmonds 1997; Spalding-Fecher et al. 1999; Winkler et al. 2000).

There is already a pool of existing experience in innovative technologies and programmes for energy efficiency and demand-side management (DSM). Eskom's DSM programme has focused on three key areas: load management, industrial equipment, and efficient lighting. Interventions include both load management (typically carried out by the utility) and energy efficiency improvements normally carried out by end-users. The NER included estimates of potential future savings in its *Integrated Electricity Outlook* (2002). This report expresses savings from energy efficiency as the equivalent cumulative electricity generation capacity (in MW) that would be avoided by these interventions up to 2010 and then up to 2020. Market penetration of energy efficiency is key to the results, so the estimates reflect different penetration assumptions, as shown in Table 3.7.

Table 3.7: Potential future savings from energy efficiency and demand side management (cumulative capacity equivalent in MW)

Source: NER (2002b)

	Low penetration		*Moderate penetration*		*High penetration*	
	2010	***2020***	***2010***	***2020***	***2010***	***2020***
Industrial and commercial energy efficiency	567	878	889	1 270	890	1 270
Residential energy efficiency	171	514	537	930	537	930
Industrial and commercial load management	355	444	428	535	510	535
Residential load management	222	735	443	936	669	936
Total	1 315	2 571	2 297	3 671	2 607	3 671

Theoretical gains are not always realised in practice, for technical or economic reasons. Removing key barriers – informational, institutional, social, financial and market, and technical – is critical to the full realisation of energy efficiency measures (see detailed discussion of barriers in EDRC (2003)). Important success factors to implement efficiency measures include: a government policy setting out standards, incentives, and recovery of programme costs that enable greater efficiency; electricity pricing mechanisms that do not penalise efficiency; and the effective DSM delivery agencies (NER 2002b). Energy efficiency will also be affected by potential reforms in the power sector (Barberton 1999; Clark & Mavhungu 2000; Tyani 2000).

3.2.3.2 Demand for 'green electricity'

Renewable energy technologies for electricity generation are primarily a supply issue, but demand for 'green power' products is also a significant factor. A small pilot project was established to supply the Johannesburg based World Summit on Sustainable Development with 'green electricity'. Building on this initiative, the NER has indicated a commitment to regulate the development of a 'green' electricity market (NER 2002a). Developing niche markets is an important first step. Potential customers include large municipalities, provincial governments, national departments, environmentally conscious companies and a small market of residential customers.

The city of Cape Town has recently agreed to buy 'green power' from the Darling wind farm, according to newspaper reports (SAPA 2003). Once the facility comes onstream, the city will offer customers the option of buying electricity from a renewable source, although this will be sold at a premium. The available electricity from this source would be 3 GWh per year, a very small contribution to the 9 000 GWh consumed by the city.

3.2.3.3 Solar water heaters

Solar water heaters (SWHs) deliver a development service – hot water. They save energy and therefore reduce emissions. But they have not been extensively pursued in South Africa, despite DME support from the Global Environmental Facility project for a National Solar Water Heating Programme (DME 2001b). As a result of the limited market for solar water heaters, the South African industry is weak and rather fragmented. The only significant project has been in Lwandle township near Somerset West (Thorne et al. 2000; Ward 2002; Lukamba-Muhiya & Davidson 2003). Most installed solar water heaters, other than for the Lwandle project, have been sold by private entrepreneurs to middle-to-high-income households, primarily so that these households can save costs of electricity. Solar water heaters have been installed using mortgage financing and, predominantly in the case of retrofits, using supplier finance. One scheme to get solar water heaters into the market is based on a hot water utility/ESCO model whereby hotels purchase hot water from a supplier who finances the installation of the solar water heaters.

3.2.4 Concluding remarks on main issues

This section has discussed energy efficiency, energy intensity and demand-side measures to encourage cleaner energy. As already mentioned, South Africa's energy intensity is relatively high, and this, combined with the dominance of coal in the local fuel mix, results in high levels of local emissions and greenhouse gases. At the same time, compared to other middle-income countries, there is much room for improvement of energy intensities in South Africa. Interventions to lower the level of energy intensity can assist basic development needs in the residential sector, and provide major energy savings in the industrial and transport sectors. On the demand side, two areas of demand for cleaner energy supply that are receiving particular attention are solar water heaters and 'green electricity'.

Probably the most critical issue for sustainable development on the demand side is the unequal access to affordable energy services, despite the progress that has been made with electrification. Issues of access to electricity are considered in Chapter 6, which deals with social issues. Similarly, the environmental impacts of demand are discussed in more detail in Chapter 7.

3.3 Outlook for the future of energy demand

3.3.1 How is demand expected to change in future?

A default assumption in many scenario-modelling exercises is that energy demand grows with economic output (GDP). In section 3.1.5 above, we noted that in some sectors this assumption might not hold for South Africa's future energy demand. Let us now consider what factors might drive overall changes in the energy demand.

Some of the relevant assumptions used in the Integrated Energy Plan are (DME 2003):[7]

- \$1 = R8 (1 Jan 2001).
- Net discount rate: 11%.
- Inflation rate: 5.5% (SA Reserve Bank target 3-6%).
- Population growth: 2000 = 44 million, 2010 = 50 million (1.3% p.a.), 2020 = 57 million (0.87% p.a.).
- GDP growth: 2.8% average annual growth over period.

3.3.1.1 Changes in electricity demand

Overall consumption – as recorded by total sales of electricity in GWh – has grown fairly consistently over the past 50 years. However, as shown in Figure 3.17 below, percentage change compared to the previous year has been dropping over the past decades. From the 1950s to 1970s, the percentage change ranged between 6% and 13%; whereas in the 1980s to 1990s it ranged between 1% and 4%.

In Figure 3.18, historical electricity sales data is combined with projections for the future, based on the Integrated Resource Plan (IRP). The IRP explored assumptions of GDP growth of 1.5%, 2.8% and 4% per year, and a 'moderate outlook' on growth in electricity sales between 2% and 3% (NER 2002b: 5-6).[8] These assumptions were used to construct future projections. While the percentage increase is in the low range of changes shown in Figure 3.17, it should be noted that earlier increases started from a much lower base.

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[7] Further assumptions are contained in the DME report released late in 2003, which can accessed from www.dme.gov.za.

[8] These very broad assumptions are based on much more detailed demand modelling in Eskom's eighth Integrated Strategic Electricity Plan. The IRP, however, only publishes the broad growth figures used here. Economic growth rates 'include total national sales, as well as sales to foreign countries', including contracts between Eskom and other countries, but do not include imports, which are modelled as supply-side options (NER 2002b).

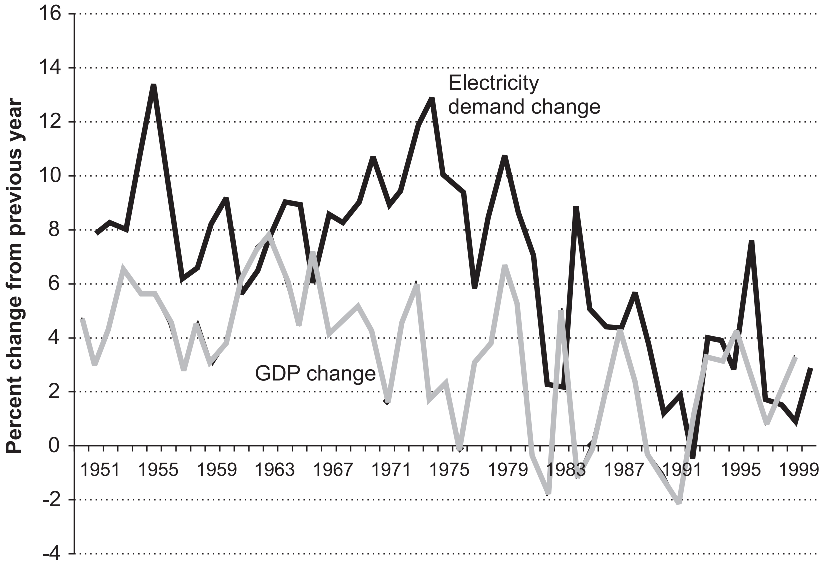
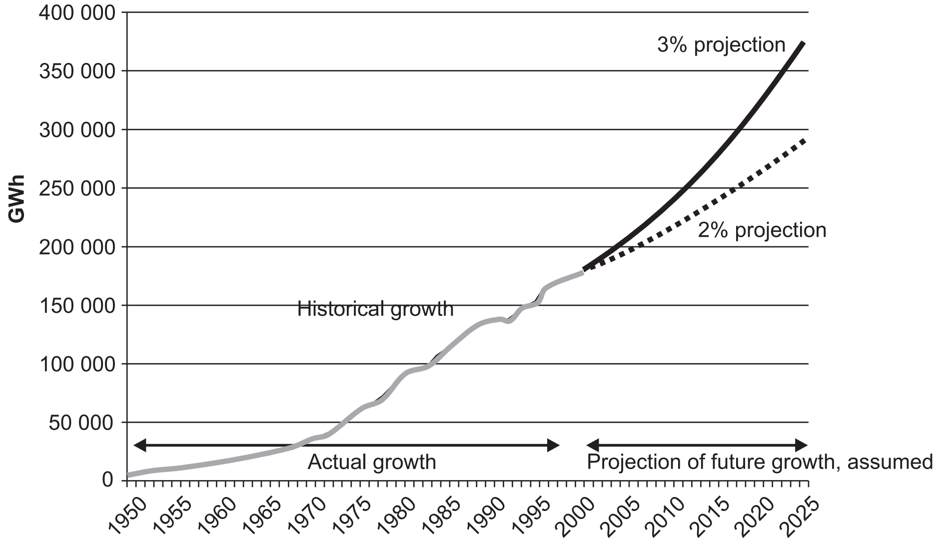


Figure 3.17: Percentage changes in Eskom electricity sales and change in real GDP at market prices
Source: Eskom (1987, 1996); NER (2000); SARB (2002)



Note: projections follow assumptions in the IRP (NER 2002b)

Figure 3.18: Growth in electricity sales, actual historical and future projections
Source: Historical data from Eskom (1987, 1996); NER (2000)

3.3.2 Drivers of energy demand

The fundamental drivers of energy policy in South Africa have shifted from the supply-side to the demand-side. During the apartheid years, top-down planning and concerns around energy security (amongst other factors) lead to large investments in synthetic fuels from coal, nuclear power generation and predominantly coal-fired electricity generation.

Since the first democratic elections in 1994, socio-economic development has become the key driving factor for all policy. The new government was determined that energy should not only support economic development, but also improve the lives of the poor – the black majority. Among the many priorities, job creation stands out as the most important, given that South Africa has an unemployment rate of 41.6% according to the strict definition of the 2001 Census, or 29.5% according to the Labour Force Survey (see discussion in chapter 5) (SSA 2003). In the energy sector, this has meant giving more attention to demand-side management and to delivering energy services, including productive energy for all South Africans and domestic energy for cooking.

Economic growth is an important driver for energy demand, and GDP is its usual expression. But using GDP as a measure is not without its problems. GDP fails to account adequately for natural resources and external costs, and its focus by definition is on overall growth, which diverts attention from the structure of the economy. The emphasis of economic and industrial strategy, depending on how it falls between the primary, secondary and tertiary economic sectors, has major implications for future energy demand. The tertiary sector, for example, is much less energy intensive per rand GDP.

Demographic trends are also an important driver of energy demand. While the direct impact on final consumption in the residential sector is relatively small at 10% (see 3.1.5.4), indirect effects would be felt through reduced consumption of industrial goods and other factors that are reflected in GDP. Another factor is HIV/Aids, which is having a major effect on population growth (ASSA 2000). For its effects on energy demand, the Development Bank of Southern Africa (DBSA) analysis, which examines the uncertainty of a low or high impact of Aids on the population, seems a reasonable approach (Calitz 2000b, 2000a).

The rate of technological change in the future is another important driver. Technologies for energy efficiency are of particular importance here. International developments may offer opportunities for savings, but the actual ‘nega-watts’ delivered depend on the rate of implementation of such technologies. The NER’s Integrated Resource Plan has projected a total saving of 4 784 MW over the period 2001-2025 (NER 2002b).

Plans for power sector reform are being driven both by local concerns and international agendas. They include significant changes to the electricity distribution industry. An electricity distribution industry holdings company has already been established, with a view to establishing six new regional electricity distributors (REDs) by mid-2005. Meanwhile, concerns have been raised about the impacts on social and environmental public benefits (Clark & Mavhungu 2000; Winkler & Mavhungu 2001). There is also the possibility that investment in energy efficiency may decline if private investors show less inclination to invest in measures that reduce revenue than in utilities with a public mandate.

3.4 Emerging gaps

Energy scenarios still tend too often to start from supply and resource constraints, and from the perspective of energy services. More work needs to be done in back-casting energy scenarios systematically from development objectives. Assuming that energy demand will increase from the current baseline, and taking into account government’s stated objective of 100% access to modern energy services by 2012 (Mlambo-Ngcuka 2003), future energy demand needs to be met on a least-cost basis, given specified resources and technologies.

Two significant changes in approach need further development – clear identification of the energy services required, and the analysis of future scenarios in relation to multiple objectives such as cost, environment, and social criteria. In order to analyse energy needs for sustainable development it is essential to take a balanced view of the economic, social and environmental objectives.

Other emerging gaps include:

- The understanding of drivers of energy development could be refined, based on both international and local dimensions:
    - A review of drivers identified in the World Energy Assessment (UNDP et al. 2000) and by Working Group III of the Intergovernmental Panel on Climate Change (IPCC 2001) could provide lessons for South Africa, with due care to our national circumstances.
    - A more detailed study of industrial strategy and policy would provide a more nuanced indication of areas of future development and their impact on energy demand.
- Searching the literature on coal and oil more thoroughly so as to improve the projections for future demand for hydrocarbons.

4

Energy supply in South Africa

Andrew Kenny

Energy supply can be divided into two parts, primary supply and energy transformation. Primary energy is obtained by extraction or collection. This could be mining of coal or uranium, drilling for oil or gas, damming rivers, gathering fuelwood or collecting solar radiation. Sometimes the primary energy can be used directly, as when we use coal for cooking or solar radiation for heating water. But most primary energy has to be converted into final energy to be suitable for human use, such as the burning of coal in a power station to make electricity, or the refining of crude oil to make petrol and diesel.

4.1 Energy reserves and primary production

South Africa has large coal reserves, which supply over 70% of its primary energy, large reserves of uranium, and small reserves of crude oil and natural gas. The country's renewable energy reserves are smaller but nonetheless significant. Biomass is an important source of energy, both as firewood for poor households and to supply the sugar refining and pulp and paper industries. Conditions for solar power are good, especially in the Northern Cape. Wind power conditions are fairly good, mainly in the coastal regions. For hydropower, there is very limited potential as most of the country consists of arid terrain.

Figure 4.1 gives an estimate of South Africa's non-renewable energy reserves (and also indicates the annual primary energy demand). These reserves are stock resources, unlike annual flows of renewable energy resources. The uranium reserves estimate is for the quality needed in conventional nuclear reactors. If the uranium were to be used in fast breeders, the estimate for its effective reserves would be 50 times higher.

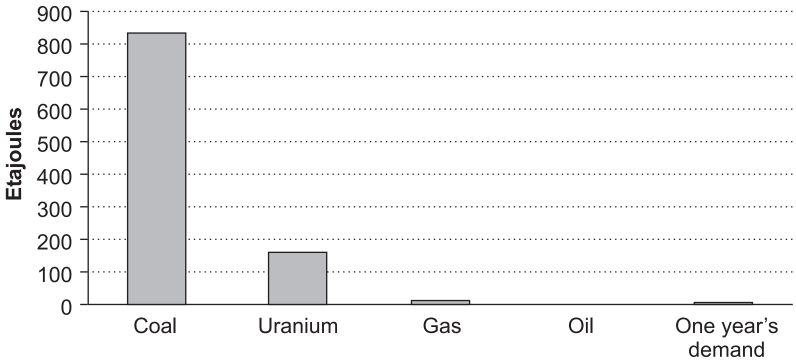


Figure 4.1: South African energy reserves (excluding renewables)
Sources - Coal: Estimate from DME (2003a); Uranium: WEC/IIASA (1995); Gas: estimate from Holliday (2003); Oil: PetroSA; One year's demand: estimate by DME and Energy Research institute

4.1.1 Coal

Coal from the southern hemisphere differs from that of the northern hemisphere in that it is rich in durain, contains more ash and less sulphur. Most South African coal is of a bituminous thermal grade, with only about 0.8% anthracite and about 1% sulphur. Its heating value varies from about 27 MJ/kg for export coal, to between 22 and 15 MJ/kg for steam coal. Coal from the Mpumalanga and Limpopo provinces is nearly always bituminous. It is laid down in thick shallow seams relatively free of faulting, so mining is relatively inexpensive. Coal in KwaZulu-Natal is often anthracite in relatively thin seams. Little of South Africa's coal is suitable for coking.

For many decades, the figure given for South Africa's coal reserves has been 55 billion tons, but this figure is now being questioned. The Department of Minerals and Energy (DME) is conducting a thorough study to assess the true reserves, but meanwhile an interim estimate of 38 billion tons (Prevost 2003) is probably more accurate. This means that South Africa has the world's sixth biggest coal reserves after China, the USA, India, Russia and Australia.

About 44.5% of South African coal is mined by opencast methods, 44% is mined underground by bord and pillar, and 10.6% by pillar recovery. By far the most coal (83.8%) is produced in Mpumalanga province, with 8.5% produced in the Free State, 6.1% in Limpopo and 0.8% in KwaZulu-Natal. South African mines typically produce three grades of coal: export, steam coal and discards. Many large mines process the coal to the required quality for export and local markets.

Figure 4.2 shows coal production from 1992 to 2001. In 2001, South Africa mined 290 million tons of coal, of which 221 million tons was saleable. Of this, 152 million tons went to the local market and 69 million was exported. Discards – too low in heating value and too high in ash to have commercial value – made up 69 million tons. It is likely that in the future there will be a market for discards in fluidised bed combustion (FBC) boilers. About 62% of exports go to the European Union, 29% to the Far East and Middle East, and the remainder to South America and Africa.

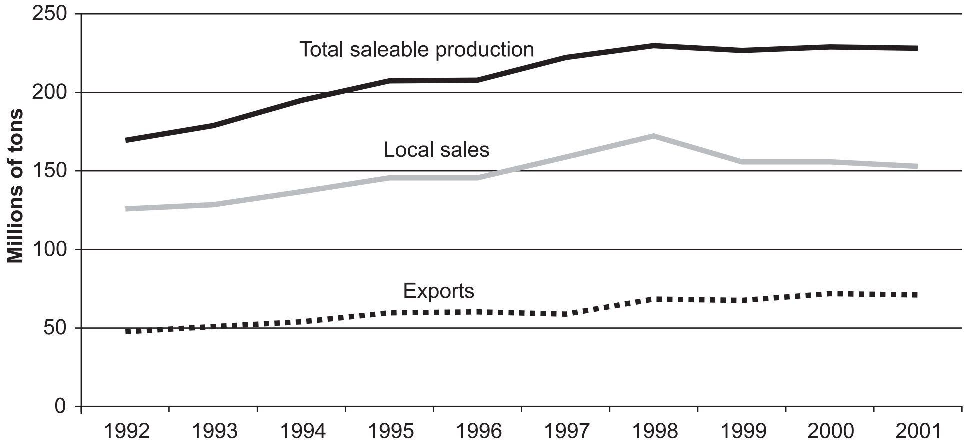


Figure 4.2: Total saleable production, local sales and exports of South African coal, 1992 to 2001
Source: DME (2003)

Table 4.1: Consumption of South African coal, 2001/2002
Source: DME (2003)

Sales category	*Million tons*
Exports	69.2
Electricity	89.0
Synthetic fuels & chemicals	48.0
Industry	6.0
Metallurgical	5.5
Merchant & domestic	3.7
Mining	0.05

4.1.2 Oil

South Africa has to import the bulk of its oil requirements. Its own reserves are limited to small fields in the Bredasdorp Basin off the southern coast – the Oribi/Oryx Fields and the Sable Field, which are owned and operated by PetroSA, Energy Africa and Pioneer. The two fields together have proven reserves of 49 million barrels. Production from the Oribi/Oryx Fields was 4.6 million barrels in 2002. Development drilling in the Sable Field began at the end of 2002 and production began in August 2003. The Sable Field will eventually produce 30 000 to 40 000 barrels a day, which will replace 7% to 10% of South Africa's imported oil.

Figure 4.3 shows imports of oil products in 2001, and Figure 4.4 shows the countries of origin of South Africa's crude oil imports in 2001.

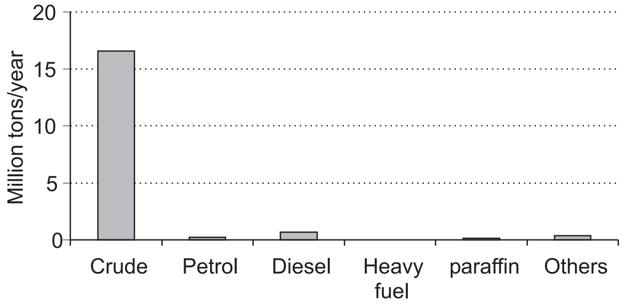


Figure 4.3: South African imports of oil products, 2001
Source: DME (2002)

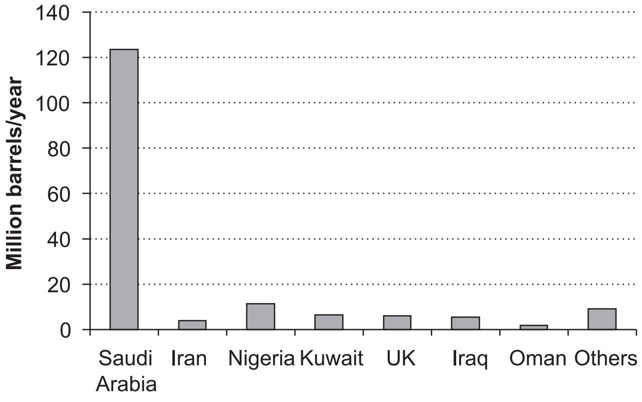


Figure 4.4: South African crude oil imports by country of origin, 2001
Source: DME (2002)

4.1.3 Natural gas and coalbed methane

South Africa has small reserves of natural gas and coalbed methane. There are no inland gas fields, but there are gas fields off the west and south coasts. In 2005, the only South African gas field in production was the F-A field off the south coast. This field, owned by PetroSA, supplies the PetroSA Mossgas plant at Mossel Bay, which makes liquid fuels from natural gas, including petrol, diesel and kerosene. The F-A field supplies about 189 mcf of gas and 7 100 barrels of condensate daily to the synfuel plant, via two 91km pipelines. The proven reserves of the field are only about 1tcf, and it is expected to run out by about 2008. PetroSA and its joint venture partners are exploring the adjacent Blocks 9 and 11a to possibly extend the production life of Mossgas.

The most promising new fields seem to be those off the Cape west coast. The Ibhubesi field, which is about 3 000 metres below the ocean bed, has proven reserves of 0.5 tcf, but there is a possibility that they might be much larger. Ibhubesi field has been studied for development by Forest Exploration International (South Africa) and the Anschutz Corporation (South Africa). Global Offshore Oil Exploration SA, Sasol Petroleum International and BHP Billiton Petroleum UK are investigating other fields off the South African west coast. The proven gas reserves of South Africa, currently estimated as about 2 tcf, could be found to be as extensive as 27 tcf after drilling and assessment.

South Africa's immediate neighbours, Namibia and Mozambique, also have small gas fields. The offshore Kudu field, about 180 km west of the Namibian coast, has reserves of about 1.5 tcf. Angola has two inland fields at Pande and Temane, with combined reserves of about 3 tcf. An 895 km pipeline is now being built which will bring gas from Temane in Angola to Secunda in South Africa, where it will join the existing pipeline system that links Gauteng province to the urban areas of Durban and Secunda. The pipeline started delivering gas in early 2004.

Coalbed methane is found in varying amounts in coalfields, and South Africa has reserves of about 3 tcf, mainly in the Waterberg and Perdekop regions. These have not yet been tapped.

4.1.4 Uranium

Nuclear energy reserves are different from those of fossil fuels because their energy is so concentrated that transport and storage costs are relatively negligible. Uranium is abundant in the earth's crust, so there has been little commercial incentive to develop new mines. Because uranium and gold are found together in mineral deposits in South Africa, uranium is produced as a by-product of gold mining. There are an estimated 261 000 tons of uranium, consisting of 205 000 tons of 'reasonably assured resources' together with 56 000 tons of 'estimated additional resources' (DME 1998). If used to generate electricity in conventional nuclear reactors, these reserves would be equivalent to 158 EJ of energy. During the apartheid era, South Africa manufactured finished fuel for the Koeberg nuclear power station near Cape Town. Today the finished fuel is imported because it is cheaper.

4.1.5 Biomass

South Africa is a dry country, with about half of its land area consisting of desert or semi-desert and only 1.2% under forest, so conditions for building up and sustaining biomass are generally poor. Nonetheless, biomass is an important source of energy, used both by industry (sugar refining plus pulp and paper) and by households for domestic energy.

South Africa's sugar cane crop is about 20 million tons a year, of which about 7 million tons is bagasse (husks) with a heating value of 6.7 MJ/kg. Some bagasse is used to make paper, but most is used in sugar refineries to raise steam for electricity generation and to process heat. The sugar refineries have an installed generation capacity of about 245 MWe (Megawatts of electrical power).

The annual production of commercial roundwood in South Africa is about 15 million cubic metres. About 10 million cubic metres of this is used to make pulp, paper and board (DWAF 1997). Bark from softwood (pine) along with 'black liquor' from pulp mills is used to fire boilers to generate electricity and process steam. The pulp mills have an installed generation capacity of about 170 MWe.

Households, mainly poor households in rural areas, use wood, dung and other vegetable matter for heating and cooking. It is estimated that about 7 million tons of wood, an energy total of about 86 PJ/year, is burned for this purpose.

The South African renewable energy database has mapped the annual biomass potential, in GJ/ha. Figure 4.5 reflects potential resources for wood (unprocessed and processed), agricultural, and grass residues, but does not show the use of residues or waste. Detailed maps with data can be downloaded from the Environmentek website – www.csir.co.za/environmentek/sarerd/contact.html. The site also includes definitions of wood, grasses and agricultural crops. It does not cover biomass sources such as animal dung or the potential of human waste.

Biodiesel, ethanol, methanol and hydrogen can be generated from biomass. Most biodiesel is produced from rape oilseed, sunflower oil and Jatropha, while bioethanol is processed from wheat, sugar beet and sweet sorghum (EDRC 2003). The main cost is feedstock, for which cheaper sources are being sought. It is predicted that cheaper feedstocks, such as wood, could reduce the costs of production quite considerably and help make biofuels more competitive in relation to fossil fuels (EC 2002). Biofuel options have the potential for generating income in rural areas through biomass plantations, which could create many jobs in the process. However the prospect of biomass plantations has raised some concerns about food supplies and about the impact of planting mono-cultural crops on biodiversity (EDRC 2003).

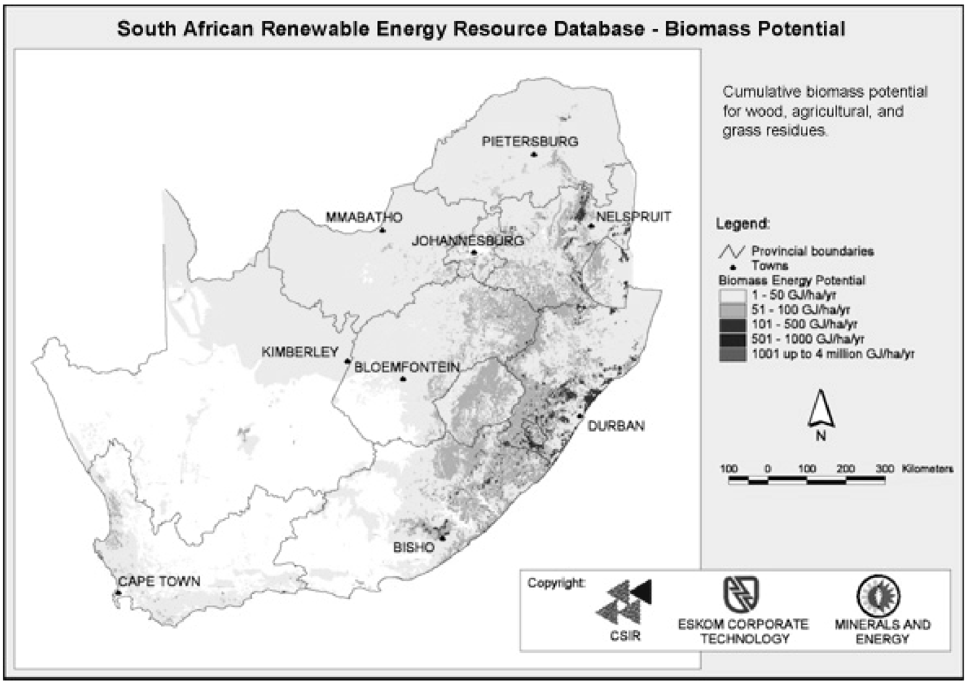


Figure 4.5: Map of biomass potential in South Africa
Source: DME et al. (2001)

4.1.6 Hydroelectric power

South Africa has few rivers suitable for generating hydroelectricity, and even these are small. They include an estimated 3 500 to 5 000 potential sites for mini-hydropower generation, mainly along the eastern escarpment. The country's existing installed capacity for hydroelectricity is 661 MWe and the potential for increasing this is limited. Other countries in southern and central Africa have enormous potential for generating hydroelectricity, some of which could be exported to South Africa. Table 4.2 gives an indication of the potential, although there are significant political constraints to developing the resource. A technical challenge would be increasing the interconnectedness of grids to distribute power within southern Africa.

Table 4.2: Hydroelectric power potential in southern Africa in addition to existing or planned hydropower

Source: Black & Veatch International (1996); Dale (1995); Dutkiewicz (1996); SAD-ELEC & MEPC (1996); World Resources Institute (1996)

Location	***Country***	***Potential (MWe)***
Zambezi River Basin		
Kariba North Extension	Zambia	300
Batoka Gorge	Zambian side only	800
Devil's Gorge	Zambia / Zimbabwe	1 240 – 1 600
Mupata Gorge	Zambia / Zimbabwe	1 000 – 1 200
Cahora Bassa North Bank Extension	Mozambique	550 – 1 240
Mepanda Uncua	Mozambique	1 600 – 1 700
Total Zambezi		approx 6 000
Other sources excluding Inga		
Angola	Including Kunene Basin	16 400
Lesotho		160
Malawi		250
Mozambique	Other than Zambezi	1 084 – 1 308
Namibia	Other than Kunene Basin	500
Swaziland		60
Tanzania		3 000
Zambia	Other than Zambezi	1 084 – 1 308
Total other sources excluding Inga		
Inga		36 000 – 100 000
Total southern Africa		70 800 – 134 800

4.1.7 Solar

The annual 24-hour solar radiation average for South Africa is 220 W/m^2, compared with 150 W/m^2 for parts of the USA and about 100 W/m^2 for Europe. Almost the whole of the interior of the country has an average insolation in excess of 5 000 Wh/m^2/day. Some parts of the Northern Cape have an average insolation of over 6 000 Wh/m^2/day. Figure 4.6 shows the distribution of solar energy falling on South Africa.

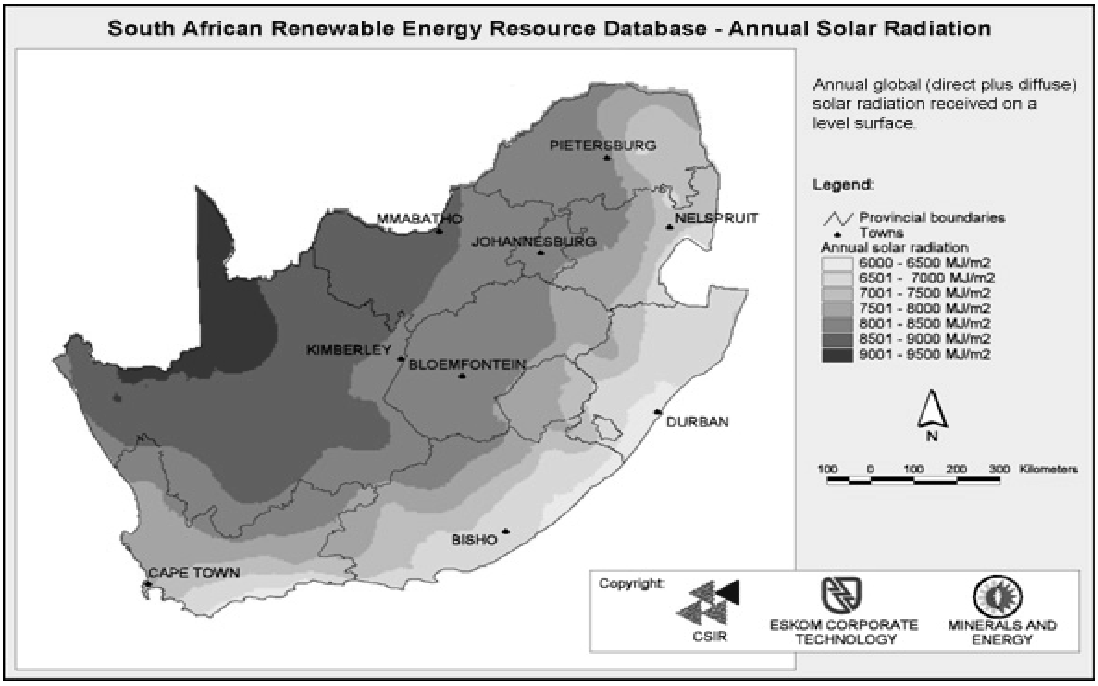


Figure 4.6: Annual solar radiation for South Africa
Source: DME et al. (2001)

4.1.8 Wind

South Africa's best wind resources are to be found mainly in the coastal regions. Figure 4.7 shows wind speeds over the country.

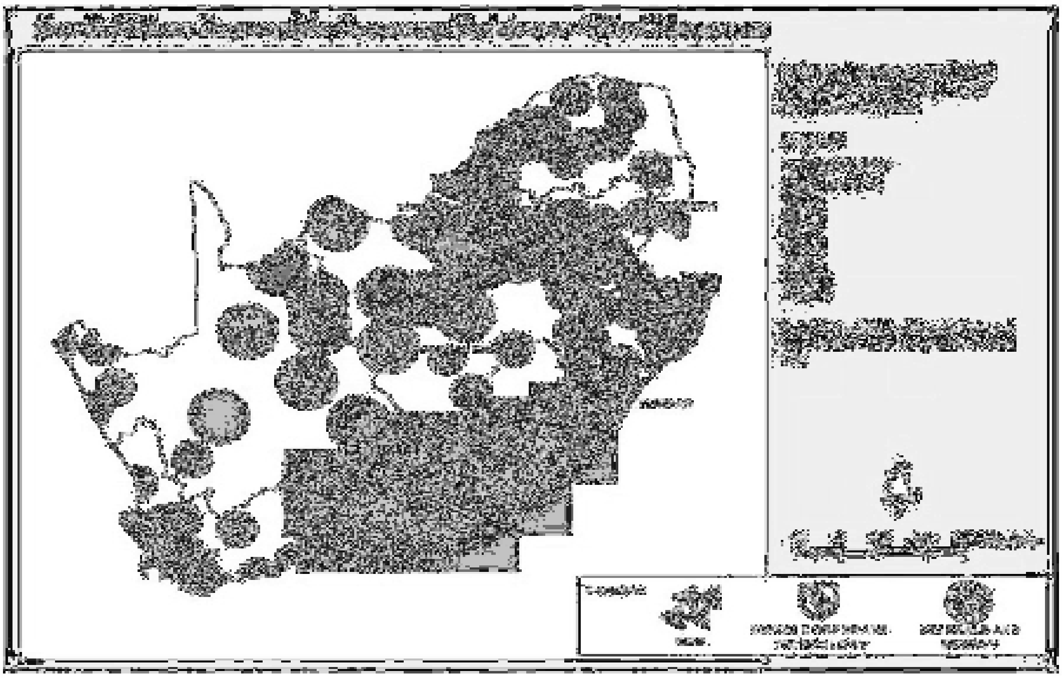
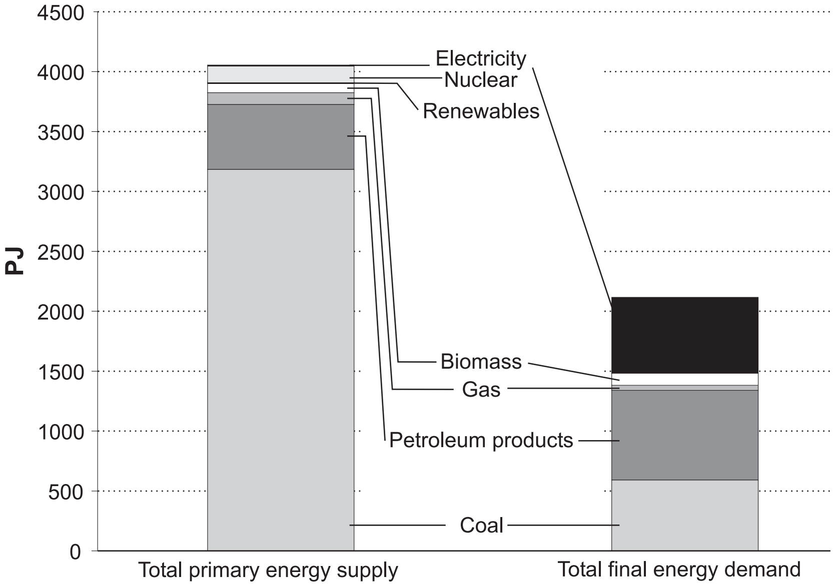


Figure 4.7: Annual average wind speeds in South Africa
Source: DME et al. (2001)

4.2 Energy transformation

The two most important conversions of primary energy in South Africa are the generation of electricity and the production of liquid fuels. Figure 4.8 shows total levels of primary and final energy.



Note: Final energy includes biomass, both as household fuels and as industrial energy, and marine bunkers. This gives a different total from Chapter 2, where these are not included.

Figure 4.8: Total primary and final energy in South Africa, 2000

4.2.1 Electricity generation

South Africa generates over half of the electricity used on the African continent. The country has three groups of electricity generators: the national public electricity utility, Eskom; municipal generators and autogenerators; and industries that generate electricity for their own use. The latter include pulp mills, sugar refineries, Sasol, Mossgas and metallurgical industries. Electricity provides 20% of South Africa's final energy.

Of these groups of electricity generators, Eskom has 91% of the total generating capacity (93.5% of the total production), the municipalities 5.6% (2.0%) and the autogenerators 3.1% (4.5%) (NER 2001). Eskom's licensed capacity is 39 870 MWe, which includes 3 550 MWe of non-operating (mothballed) coal fired power stations. The licensed capacity comprises 35 627 MWe of coal power stations, 1 840 MWe of nuclear power stations, 342 MWe of gas turbines, 661 MWe of hydro power and 1 400 MWe of pumped storage. This energy mix is shown in Figure 4.9.

In 2002, South Africa consumed 203 GWh of electricity. Eskom had a peak demand (in July) of 31 621 MWe. There are about 400 electricity distributors, including Eskom itself, large municipalities, and small town councils.

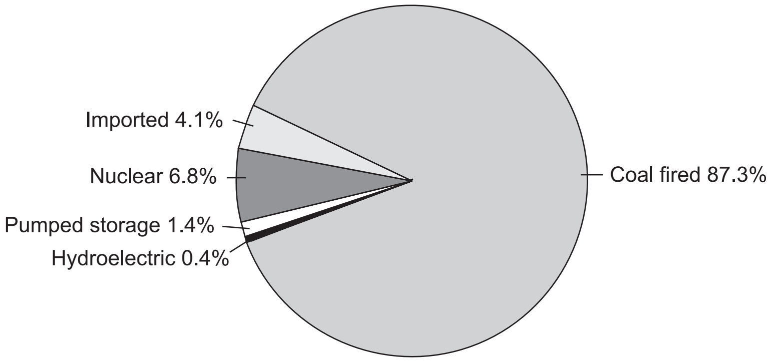


Figure 4.9: Eskom's generation mix by energy source

4.2.1.1 Coal power stations

Over 92% of the electricity currently generated in South Africa comes from conventional coal power stations (see Table 4.3), all of which are pulverised fuel power stations without flue gas desulphurisation. Future power stations will most likely include desulphurisation. From 1980 on, Eskom only built power stations with capacities of over 3 000 MWe, comprising six units each. These power stations have huge coal requirements, typically 10 million tons a year. Because it is costly to transport coal over long distances, the power stations have been built on the coalfields, with the coal transported directly from the mines on conveyor belts. The power stations are all concentrated around the coalfields in the provinces of Mpumalanga, Gauteng and Limpopo.

South African coal has a high ash and low sulphur content, and a low calorific value, some with a heating value of less than 16 MJ/kg. As a result South Africa has become a world leader in the expertise of burning poor quality coal. The combination of cheap coal and large standardised power stations without desulphurisation has allowed South Africa to produce the cheapest electricity in the world.

The power stations have certain disadvantages. Primarily, they are polluting. And because they are located at the coalfields, they are concentrated in the northern interior of the country, so power has to be transmitted long distances to coastal centres like Richards Bay, Durban and East London. This leads to problems with the quality of electricity in these areas.

Most of the coal power stations dump the heat from their condensers in conventional cooling towers, which use between 1.8 and 2.0 litres of water for every kilowatt-hour of electricity generated. Because fresh water is such a critical resource in South Africa, two of the largest stations, Kendal and Matimba, operate with dry cooling, which uses only 0.1 litres of water for every kilowatt-hour. Kendal and Matimba are by far the largest air-cooled power stations in the world. As can been seen from Table 4.3, the costs of lost efficiency for dry cooling are small.

The municipalities of Cape Town, Bloemfontein and Pretoria each have small coal power stations, which are run at low load factors. Kelvin Power Station (600 MWe) in Johannesburg is run as an independent power producer.

Eskom is investigating the future use of fluidised bed combustion coal power stations, which could burn discard coal.

Table 4.3: Eskom's coal-fired power stations

Source: National Electricity Regulator (2004b)

	Nominal capacity (Mwe)	*First unit commissioned*	*Thermal efficiency*	*MJ / kg for coal*	*Cooling*	*Operating status*
Arnot	2 100	1971	33.3	22.35	Wet	Partly operating
Camden	1 600	1966			Wet	Mothballed
Duhva	3 600	1980	34.5	21.25	Wet	Operating
Grootvlei	1 200	1969			Wet	Mothballed
Hendrina	2 000	1970	32.34	21.57	Wet	Operating
Kendal	4 116	1988	34.31	19.96	Dry	Operating
Komati	1 000	1961			Wet	Mothballed
Kriel	3 000	1976	35.02	20.04	Wet	Operating
Lethabo	3 708	1985	34.89	15.27	Wet	Operating
Matimba	3 990	1987	33.52	20.77	Dry	Operating
Majuba	4 100	1996			Wet/dry	Operating
Matla	3 600	1979	35.47	20.58	Wet	Operating
Tutuka	3 654	1985	35.32	21.09	Wet	Operating

4.2.1.2 Nuclear power

South Africa has one nuclear power station, Koeberg, about 30 km north of Cape Town on the west coast. It consists of two pressurised water reactor units, each with a capacity of 920 MWe, and is cooled by seawater. Its first unit was commissioned in 1984. It is the only large power station in South Africa that is not located in the north east of the country, and as such it assists grid stability in the southwest. The finished fuel for Koeberg is imported, which is more economical than manufacturing it locally.

Eskom has been developing a new type of nuclear power reactor, the pebble bed modular reactor (PBMR). This is a small, simple, inherently safe design, using helium as the coolant and graphite as the moderator. The fuel consists of pellets of uranium surrounded by multiple barriers and embedded in graphite balls ('pebbles'). If all the necessary legal, political and commercial approvals are forthcoming, the first demonstration model (165 MWe) will go into production in about 2008.

4.2.1.3 Gas turbines

South Africa has 662 MWe capacity of gas turbine generators. Half of these generators are owned by Eskom and half by municipalities. They are all are open cycle (single cycle) gas turbines which run on liquid fuels such as diesel or kerosene. At present they are used only for emergency power, but in the future they could be used to meet peak capacity.

A possible new source of electricity generation in the future is combined cycle gas turbines. These burn gas in a gas turbine and send the exhaust gases to a steam boiler that drives a steam turbine. Combined cycle gas turbines have the lowest capital costs per kWh of any power generation technology, and have the further advantages of high efficiency and quick construction time. They may well be suitable for South Africa, provided that gas supply and gas prices are acceptable.

4.2.1.4 Hydroelectric power and pumped storage

There is 665 MWe of installed hydroelectric power in South Africa, of which all but 4 MWe is owned by Eskom. Only two hydroelectric stations are over 50 MWe – Gariep (360 MWe) and Vanderkloof (240 MWe). There is 1 400 MWe capacity of pumped storage in two stations owned by Eskom – Drakensberg (1 000 MWe) and Palmiet (400 MWe), and 180 MWe in the Steenbras station which is owned by the Cape Town municipality. A new pumped storage scheme is being planned for Braamhoek on the Free State/KwaZulu-Natal border, which will consist initially of three 333 MWe units.

4.2.1.5 Electricity supply and demand

In the late 1960s, faced with high economic growth and high growth rates in electricity demand, South Africa embarked on an ambitious programme of building large coal stations. In the 1980s, economic growth slowed down, but the momentum of the long lead times for building the stations kept the building programme active. The result was large over-capacity in the mid-1990s. Figure 4.10 shows how the gap between total generation capacity and peak demand widened from the 1970s onwards. Since 1994 economic growth has gradually reduced the surplus capacity. From around 2007, South Africa will in fact face a shortfall of electricity generation. New power stations will soon be required.

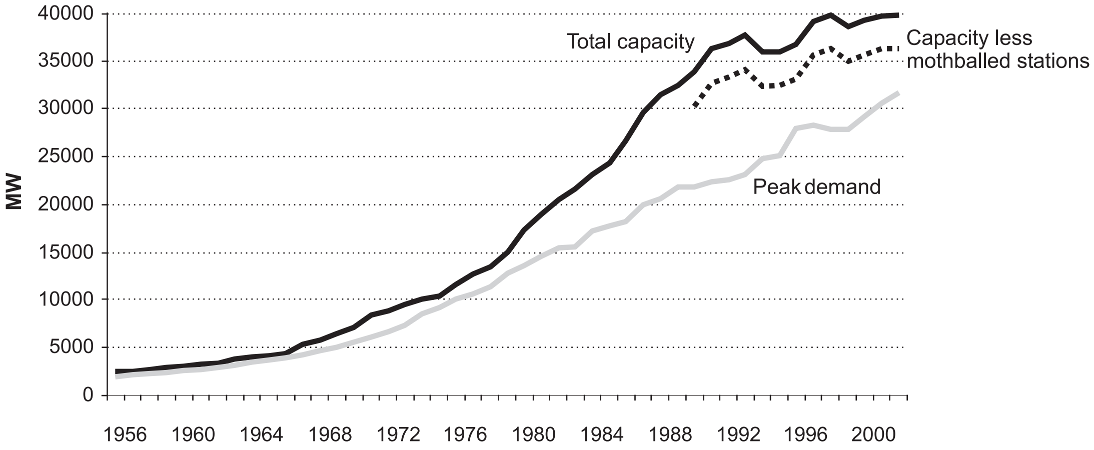


Figure 4.10: Eskom generation capacity and peak demand, 1956 to 2002

4.2.1.6 Electricity imports and exports

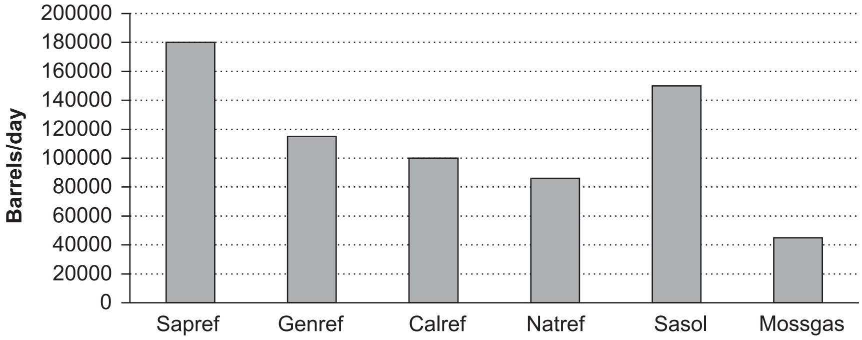
The volume of imports and exports of electricity from South Africa is roughly equivalent – about 3% of the total electricity consumed in the country. Electricity is exported to Zimbabwe, Botswana and Namibia, and imported from Zambia and Mozambique. Table 4.3 shows South Africa's total electricity consumption, together with its imports and exports, from 1998 to 2003.

Table 4.4: South African electricity consumption, imports and exports (GW-hours)

Year	*SA consumption*	*Imports*	*Exports*
1998	187 516	2 375	4 532
1999	190 120	6 673	4 266
2000	195 660	4 719	4 007
2001	196 063	7 247	6 519
2002	203 348	7 873	6 950
2003	211 023	6 739	10 136

4.2.2 Production of liquid fuels

South Africa makes liquid fuels by three different processes: refining of crude oil, conversion of coal, and conversion of natural gas. Liquid fuels come from four refineries: Sapref, Genref, Calref and Natref; from Sasol's two coal-to-liquid plants at Secunda; and from the Mossgas natural gas-to-liquid plant at Mossel Bay. Figure 4.11 shows their capacities.



Note: The units of production in this figure are given as barrels of crude oil equivalent per day. For the synfuel plants, fuel production is converted into production that would have come from a conventional refinery using crude oil.

Figure 4.11: Capacities of South African liquid fuel production plants
Source: SAPIA (2003)

4.2.2.1 Oil refineries

South Africa has three coastal oil refineries: Genref (Engen) and Sapref (BP/Shell) in Durban; and Calref (Caltex) in Cape Town; and one inland refinery in Sasolburg (Sasol/Total). Because the Sasolburg refinery does not have a market for the heavy residual oil used for marine bunkers at the coast, the refinery process is modified to produce less heavy oil, which somewhat increases costs.

4.2.2.2 Coal-to-liquid fuel plants

Sasol has by far the largest plants in the world for making liquid fuels from coal. The first was built in Sasolburg in 1955, and is now used only for making other chemicals. Two larger plants were built at Secunda in the 1970s and produce about 150 000 barrels of crude oil equivalent a day. They consume 40 million tons of coal a year, mined from Sasol's own coalfields. The coal is first converted into 'syngas', a mixture of hydrogen and carbon monoxide. Then, using the Fischer-Tropsch process, it is built up into hydrocarbons, making petrol, diesel and other fuels and chemicals. These fuels are very clean and contain no sulphur.

The synfuel plant at Secunda also includes the world's biggest oxygen plant, which will soon have a capacity of 3 550 tons of oxygen a day. A by-product of the synfuel process is methane-rich gas with a heating value of about 35 MJ/kg. This is sent by pipeline to industrial and commercial markets in Gauteng, Durban and Richards Bay. The Sasolburg plant produces hydrogen-rich gas, which has a heating value of about 18 MJ/kg and is used by steel makers and other industries.

4.2.2.3 Natural gas-to-liquid fuels

It is cleaner, easier and more efficient to make liquid fuels from natural gas than from coal, and South Africa has become a world leader in this process. The PetroSA plant at Mossel Bay (Mossgas) makes liquid fuels from natural gas piped from the offshore F-A field, producing about 45 000 barrels a day of crude oil equivalent. The field will run out of gas in about 2008, so new gas will have to be found to keep it in operation. Gas will have to come either from developing the neighbouring fields or by importing gas in the form of LNG.

Sasol has developed a new process, known as Sasol Slurry Phase Distillate technology, for making very clean liquid fuels from natural gas. Because these fuels are free of sulphur, they will be attractive for the fuel markets of Europe, Japan and the USA, which have stringent legislation on emissions and air pollution. Sasol is building similar production plants in Qatar in the Middle East and at Escravos in Nigeria.

4.2.2.4 Liquid fuel consumption, imports and exports

The tables below show South Africa's liquid fuel consumption, imports and exports.

Table 4.5: South African liquid fuel consumption, 1988 to 2001

Year	*Petrol*	*Diesel*	*Kerosene*	*Jet fuel*	*Fuel oil*	*LPG*	*Total*
1988	7 995	5409	641	784	524	406	15 759
1989	8 395	5 350	678	835	546	432	16 236
1990	8 612	5 273	723	866	576	434	16 484
1991	8 906	5 130	725	861	526	464	16 612
1992	9 171	4 950	743	1 009	549	465	16 887
1993	9 202	4 940	834	1 095	595	454	17 120
1994	9 630	5 110	875	1 193	633	485	17 926
1995	10 153	5 432	850	1 368	616	472	18 891
1996	10 566	5 759	917	1 601	704	450	19 997
1997	10 798	5 875	970	1 777	635	502	20 557
1998	10 883	5 959	1 052	1 877	574	523	20 868
1999	10 861	5 993	1 054	1 995	561	540	21 004
2000	10 396	6 254	857	2 020	555	567	20 649
2001	10 340	6 488	786	1 924	555	599	20 692

Table 4.6: South African liquid fuel imports, 2001

Product	*Quantity (tons)*	*Value (R million)*
Crude	16 563 625	23 503
Petrol	220 361	487
Diesel	653 926	139
Heavy fuel	8 974	56
Kerosene	114 224	232
Others	347 525	873
Total	17 908 635	25 290

Table 4.7: South African liquid fuel exports, 2001

Product	*Quantity (tons)*	*Value (R million)*
Crude	184 169	407
Petrol	990 989	1 075
Diesel	2 174 699	2 249
Heavy fuel	8 974	172
Aviation& kerosene	243 525	140
Others	470 094	1 027
Total	4 072 450	5 070

4.2.3 Renewable energy

4.2.3.1 Biomass

The historical trend, both worldwide and in South Africa, is a progression from traditional fuels like wood and dung, through transitional fuels like coal, kerosene, LPG and candles, to modern fuels, like electricity and piped gas. Within South Africa there is a demographic trend for people to migrate from the countryside to the urban areas. Taken together, these trends suggest a declining use of biomass for household energy in the future, although widespread poverty might well counter this decline. It is estimated that about 87 PJ of wood is used for household energy, mainly in the rural areas.

The industrial use of biomass is small but significant. Annually South Africa's sugar industry produces about 2 million tons of sugar from about 20 million tons of cane. About seven million tons of bagasse is burnt in boilers to make steam for electricity generation and to process heat.

South African pulp mills use biomass to generate electricity, with an estimated capacity of 170 MWe. The mills burn sawdust and bark (from softwoods) in their boilers to make steam for electricity generation and to process heat. In the chemical pulp mills, 'black liquor' is separated from the wood fibres after passing through digesters. The black liquor is burnt in recovery boilers to make steam. The pulp and paper industry is thriving, and timber yields in the forest are growing, so there are good prospects for expansion. The big pulp mills can generate more electricity than they need at present, and if the price was right, they could add their surplus electricity to the national grid.

4.2.3.2 Solar

So far no electricity from solar power is generated for the national grid, but solar photovoltaic electricity is used widely in rural areas. It is estimated that about 70 000 households, 250 clinics and 2 100 schools have photovoltaic panels. Rural area supply companies have been contracted under concession agreements to supply households in more remote areas with photovoltaic units, sometimes combined with LPG supply. About 1 000 households are being added to this system each month. There is also a steady increase in solar water heating for middle-income households.

Eskom is exploring the potential of grid electricity from solar and wind power. It initiated the South African Bulk Renewable Energy Generation (SABRE) programme in 1998, and in 2002, installed a 25kW solar dish with a Stirling engine at the Development Bank of Southern Africa premises in Midrand.

Eskom is studying the feasibility of building a 300 MWe solar thermal power station near Upington in Northern Cape. If built, this station would have three 100 MWe units, concentrating sunlight in reflecting troughs onto pipes carrying a coolant of molten salt. The salt would store heat so that the station would be able to deliver electricity 24 hours a day.

4.2.3.3 Wind

So far no electricity in the national grid is generated from wind. Wind was important traditionally, and continues to be, for water pumping on farms. There are about 500 wind turbines on farms that generate direct current electricity, usually at 36V.

In 2003, Eskom installed two 660 kWh wind turbines and a 1.7 MWe one at Klipheuvel in the Western Cape as part of its SABRE programme of demonstration and research. An independent group, Darling Independent Power Producer (Darlipp), proposes to develop the 5 MWe Darling Wind Farm, also in the Western Cape. It has been licensed by the National Electricity Regulator, but is still awaiting approval of its environmental impact assessment (EIA).

4.2.3.4 Municipal waste

It has been estimated that South Africa's total domestic and industrial refuse disposed in landfill sites has an energy content of about 11 000 GWh per annum. This could be directly incinerated or converted into biogas and methane to produce electricity. Various proposals for this undertaking have been made.

4.3 Issues for future energy supply

4.3.1 Energy reserves and prices

Coal is by far the largest source of primary energy for South Africa, and it is likely to remain so for decades. The country's coal reserves are now being re-assessed by the DME, and the result will be of great importance of energy planners. In view of the rising demand for coal worldwide, especially because of demand from China, coal prices are likely to rise markedly in the medium term, which will have significant effects for South Africa's energy economy, particularly in electricity generation. For gas, even if the most favourable estimates are confirmed, the indigenous gas reserves remain small.

4.3.2 Electricity supply

South Africa is rapidly running out of generation capacity and must build new stations soon. Two problems immediately arise: Who is going to build and run the new stations? What energy sources are they going to use?

At the moment Eskom, the state-owned utility, is the only national supplier of electricity. The government has stated that Eskom should not build any more power stations, but at the same time it has stated that Eskom has an obligation to supply power. Independent power producers (IPPs) would need a return on investment of about 15%, which would require electricity prices to be much higher than they are at present. New stations could possibly be built using loans, with lower returns and smaller electricity price increases. But in the circumstances it seems likely that Eskom will be asked to build new stations, or at least to build them in partnership with others.

Since gas reserves are small, and renewable sources have limited potential, the only two indigenous sources of energy for bulk electricity are coal and nuclear power. Future coal stations would probably be similar to the existing pulverised fuel stations but with the addition of desulphurisation and dry cooling. Fluidised bed combustion stations using discard coal have become a strong possibility. Of the nuclear options, the pebble bed modular reactor seems the most promising, but it will first be necessary to build a full-sized commercial prototype at Koeberg in order to make a proper evaluation of the technology.

Importing hydroelectricity from new schemes in central Africa is a further possibility. The problem here is security of supply, given the history of political instability in the region. South African power stations could also be run on imported natural gas, either piped from Angola or shipped in as LNG.

4.3.3 Liquid fuels

An unresolved question concerning liquid fuels in the future is whether South Africa will build any more production capacity, either in the form of oil refineries or synfuel plants, or whether it will simply import finished liquid fuels to meet extra demand.

4.3.4 Renewables

Renewable energy on a large scale could come from pulp mills, sugar refineries and solar water heating, with wind turbo-generators making a smaller contribution. The government's 2003 White Paper on Renewable Energy requires that from 2013 onwards, 10 000 GWh per year of final energy demand should be met by renewable energy. Of biomass, wind, solar and small hydro, biomass is currently by far the largest potential contributor.

5

Social issues

Gisela Prasad

Contributing authors: Bill Cowan and Eugene Visagie

5.1 Analysis of the current situation

5.1.1 Introduction

The social issues of sustainable development are strongly linked to economic issues. This is particularly so for very wealthy and very poor countries, because both over-consumption and poverty are threats to sustainable development. Social sustainability is strongly affected by local, national and international economic relationships, which affect access to resources, employment and social power.

As is well known, South Africa's level of income inequality, measured by the Gini coefficient, is one of the highest in the world (SSA 2000).

Access to electricity is generally seen as an important step in socio-economic development. Many countries, including South Africa, are aiming for universal access to electricity. In South Africa, prior to the 1994 democratic elections, black people (meaning all 'people of colour') were largely excluded from access to services, including electricity. The government has embarked on an electrification programme which seeks to address the electrification backlog by 2014.

Adequate energy is in itself a basic survival need, and energy is also required to meet other basic needs, such as water supply. The fuels that are commonly used by poor communities for cooking and heating (fuelwood, kerosene, coal) may be adequate to meet immediate basic energy needs, provided that these fuels are affordable and available. Where there is extreme energy poverty, the direct effects can be malnutrition, exposure to disease, and even death.

Levels of energy poverty are difficult to quantify in South Africa since they are tied up with other factors threatening the survival of the poorest people, such as food shortages, inadequate water supplies, and limited access to health care. However, there is little doubt that extreme energy poverty contributes to the plight of vulnerable households, and within these households to the survival prospects of the most vulnerable family members, such as the elderly, the infirm and the very young. Economic inequities are clearly a major cause of extreme energy poverty in South Africa, given the fact that there are no shortages in national energy supply capability.

5.1.2 Household energy access

In the early 1990s, Eskom planners, working under the slogan of 'Electricity for All', aimed to reach as many people as possible. The National Electrification Programme (NEP) Phase 1 (1994-1999) was duly launched, and provided 2.5 million electricity connections at a total cost of about R7 billion. Thousands of disadvantaged areas, rural areas, schools and clinics formerly without electricity, were connected to the national grid. Phase 2 of the

National Electrification programme was started in 2000 with a target to provide 300 000 additional households with electricity every year – a target which has been met for the past five years.

The National Electrification Coordinating Committee realised that some people in South Africa would probably not have access to grid electricity in the foreseeable future. The high costs of grid supply to households in very sparsely settled or remote places, together with the low income levels of most rural people, meant that any electrification programme would have to be non-grid. There was an acceptance that such households would have to continue using non-electric fuels for thermal energy, particularly for cooking, which is their largest energy need.

5.1.2.1 Electrification programme of the last 10 years (1995-2005)

Phase 1 of the National Electrification Programme (NEP), ambitious as it was, was an outstanding success. The national utility, Eskom, installed 1.75 million connections and municipalities installed a further 0.75 million connections. This rate of electrification was amongst the highest ever achieved in the world and was done without external funding (Borchers et al. 2001). Eskom funded the NEP out of its own resources and the municipalities' subsidies were derived from Eskom revenues through the electrification fund. This meant that connection fees for poor customers could be kept low. Valuable lessons were learned and innovative approaches and technologies were pioneered.

One of the innovations of the electrification programme was pre-payment meters. Paying for electricity before consuming it gives households better control over electricity expenditure and avoids the accumulation of household debt. Pre-payment also means that the utility supplying the service avoids the many problems associated with non-payment.

Rural settlements are generally further from the grid and more dispersed, which makes rural electrification more expensive. Table 5.1 shows that from 1997 to 2001, more urban than rural houses were electrified.

Table 5.1: Urban and rural electrification information from 1997 to 2001

Source: Based on figures from SSA 2003

Type of area	*Population*	*Houses*	*Houses electrified*	*Houses not electrified*	*% electrified*	*% Not electrified*
			2001			
Rural	20 832 416	4 267 548	2 095 229	2 172 319	49.10	50.90
Urban	23 723 327	6 503 427	5 023 186	1 480 241	77.20	22.80
Total	44 560 743	10 770 975	7 118 415	3 652 560	66.10	33.90
			2000			
Rural	19 967 564	4 267 548	1 952 494	2 315 054	45.75	54.25
Urban	23 357 452	6 503 427	4 828 103	1 675 324	74.24	25.76
Total	43 325 016	10 770 975	6 780 597	3 990 378	62.95	37.05
			1999			
Rural	20 009 245	3 873 990	1 793 193	2 080 797	46.29	53.71
Urban	23 045 062	5 745 180	4 585 185	1 159 995	79.81	20.19
Total	43 054 307	9 619 170	6 378 378	3 240 792	66.31	33.69

Type of area	*Population*	*Houses*	*Houses electrified*	*Houses not electrified*	*% electrified*	*% Not electrified*
1998						
Rural	19 550 322	3 785 454	1 612 168	2 173 286	42.59	57.41
Urban	22 580 078	5 636 392	4 322 820	1 313 572	76.69	23.31
Total	42 130 400	9 421 846	5 934 988	3 486 858	62.99	37.01
1997						
Rural	19 111 522	3 700 494	1 409 681	2 290 813	38.09	61.91
Urban	22 115 078	5 520 200	4 097 981	1 422 219	74.24	25.76
Total	41 226 600	9 220 694	5 507 662	3 713 032	59.73	40.27

Contrary to expectations, electricity consumption in low-income areas has been very low – so low that in many of these areas revenues do not cover operation costs (Borchers et al. 2001). Case studies have shown that 56% of households connected to the national grid consume less than 50kWh of electricity per month (Prasad & Ranninger 2003). A consumption level of 350kWh was initially anticipated, but the consumption for the year 2000 was 132 kWh/month/household (Borchers et al 2001). The electrification of poor and rural areas is clearly not financially sustainable, but in the long term the financial loss can be weighed against the social and developmental gains. As the NER (1998) put it:

> It was understood from the beginning that the primary motivation for the massive electrification of disadvantaged communities was not to achieve economic benefits. For socio-political reasons it made sense at the time, as it still does, to improve the quality of life of millions of South Africans while at the same time creating opportunities for jobs and prosperity.

The electrification programme contributed to the welfare of these communities by enabling improved health care in clinics and evening adult education classes in schools. It allowed computers and photocopiers to be used by those schools that could afford them. The number of fires in homes was reduced because kerosene lamps and candles were replaced by electric lights (Borchers et al 2001). Many households were only able to cover the costs of electricity for lighting and media (see Figure 5.1). Small enterprises benefited, with retailers and workshops able to open for longer hours in the evening. This has been helpful to communities, even though the provision of electricity alone is only one factor necessary for local economic development.

Although the electrification programme has been extremely successful and creditable in expanding the numbers of South African households connected to the national grid, there were some unexpected problems:

- Even after electrification, a majority of lower-income households (both rural and to a somewhat lesser extent urban) continued to use non-electric fuels for their thermal energy needs.
- The wider socio-economic development benefits of electrification seemed disappointing, partly because the improved energy supply was not integrated with other necessary improvements in infrastructure, services and economic development initiatives.
- Some groups of poor people, like backyard dwellers and people living on land not approved for settlement, remain excluded from electrification.

As a result of these challenges to expectations, there was a growing awareness that:

- An energy development strategy which seeks to benefit the poor must not be restricted to electrification, but needs to include improved access to complementary non-electric fuels, appliances, and safe/efficient practices – whether in grid-electrified or non-grid areas of the country.
- Electrification investments would achieve greater development benefits if they were not solely driven by targets related to the number of households connected, but instead were integrated into more detailed, cross-sectoral local development plans and implementation.

5.1.2.2 Non-grid electrification programme

The DME realised that certain rural areas would not be connected to the national grid in the near future. In 1999 it adopted a scheme of contracting concessionaires to deliver non-grid electricity to specific rural communities. The scheme aimed to provide 350 000 households with access to SHSs over several years. Designated rural areas were allocated to approved utilities which were to provide non-grid electricity services for an agreed fee to be paid by the customer – the fee-for-service model. Under the scheme, the concessionaires own the solar home systems that they have installed, and service them regularly for a monthly fee of R58. Most of the SHSs are small photovoltaic systems with 50 Wp (Watt peak) panels. By the end of 2005, some 7 000 SHSs had been installed in four concession areas in this way. A capital subsidy of R3 500 for each installed and certified system was paid by the government directly to the service provider.

The non-grid programme is a new initiative, and implementation has been slow. An initial evaluation of the concessionaire model indicates that very poor households cannot afford to participate. The current selection criteria are proof of employment, and the ability to make regular monthly payments of R58. The government has promised to pay a monthly service subsidy of R48 directly to the service provide – the equivalent of the basic electricity support service tariff (BESST) for grid-connected poor customers. The promise of a monthly subsidy of R48 would certainly help poor households, as they would have to find only the remaining R10 to meet the service fee.

Even so, solar electricity is not cheap. A solar panel provides on average 62 kWh/year, so that even after the capital subsidy and the poverty tariff, customers will still be paying 193c/kWh. This is five times the amount that an unsubsidised grid-connected customer pays (Spalding-Fecher 2002).

It was initially intended that the concessionaires who were operating in rural areas would also provide fuels like kerosene and gas for cooking, space heating and water heating, but this has only been partially implemented.

5.1.3 Household energy use

5.1.3.1 Provision of electricity and multiple fuel use

Multiple fuel use is commonplace in developed and developing countries worldwide, both within industrial and residential sectors, and among richer and poorer households. Some households that can afford to cook with electricity may choose alternative energy sources for a variety of reasons – convenience, tradition, or in order to prepare food in a specific way. However most households in low-income groups do not have a choice – they use wood or kerosene because they cannot afford electrical appliances or electricity bills.

In 2001, seven years after the electrification programme started, census data showed that many households were still using multiple fuels. A comparison of energy sources used for cooking in households in 1996 with those of households in 2001 (Table 5.2 below) shows that the number of households cooking with electricity increased by only 4.3%. The use of gas slightly declined, kerosene use remained approximately the same, and the use of wood declined by 2.4%.

Table 5.2: Comparing energy sources for cooking in 1996 and 2001

Source: Based on Census 1996 and 2001 data from SSA (2003)

Fuel	*1996 (%)*	*2001 (%)*
Electricity	47.1	51.4
Gas	3.2	2.5
Kerosene	21.5	21.4
Wood	22.8	20.5
Coal	3.5	2.8
Other	1.9	1.4
Total	100	100

Of the households in South Africa, 69% now have access to electricity and use it for lighting (Figure 5.1a), while 23% light their homes with candles and 7% use kerosene. Comparing electricity use for lighting and cooking (Figure 5.1a and b) it becomes clear that 18% of households, although connected to electricity, cannot afford to use it for cooking. Wood and kerosene are used as substitutes for the more convenient but unaffordable electricity. The difference in the number of households that use electricity for lighting only and the number that use it for both lighting and cooking is thus an indicator of how poverty affects energy use.[9]

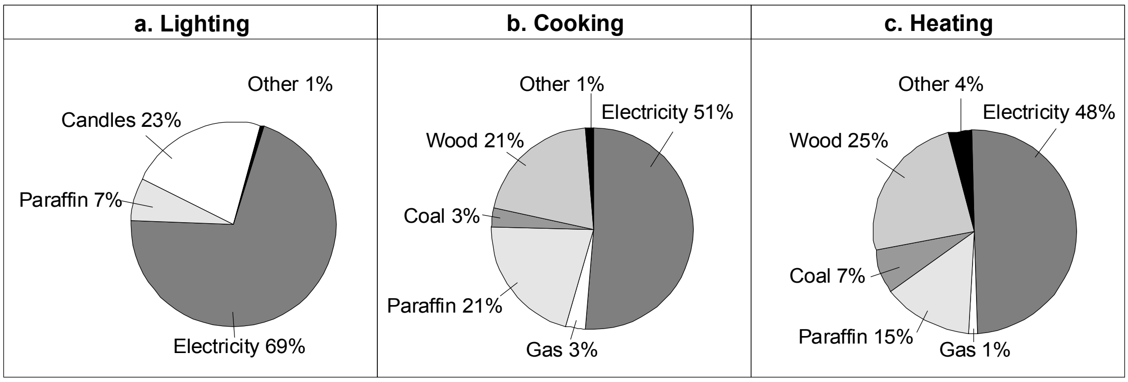


Figure 5.1: Distribution of South African households by main energy source used for lighting, cooking and heating

Source: Based on Census 2001 figures from SSA (2003)

The pattern of electricity-use for heating (Figure 5.1c) follows the same trend as the pattern of electricity-use for cooking. Wood, coal and kerosene are widely used for heating rather than electricity. These fuels appeal to poor people because they are cheaper, or are perceived as cheaper, and they can be used with inexpensive appliances or with no appliances at all.

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[9] The census data probably over-represents the extent to which electricity is used for cooking. Numerous studies have shown that lower-income households using electricity for cooking, use it for only a part of their cooking activities.

Figure 5.2 shows an analysis by province and income of the number of people who use electricity for lighting only, compared to those who use electricity for both lighting and cooking. It shows that in poor provinces such as Limpopo and Mpumalanga, a larger proportion of users consume electricity for lighting purposes only, compared to provinces with relatively high incomes such as Gauteng and Western Cape. This supports the findings of case studies which show that poor households cannot afford to buy electrical appliances or to use electricity for cooking (UCT 2002), and so tend to use electricity only for lighting and media. In very poor households there may not be enough money to buy electricity for the whole month, so towards the end of the month people either remain in darkness or use candles (Prasad & Ranninger 2003).

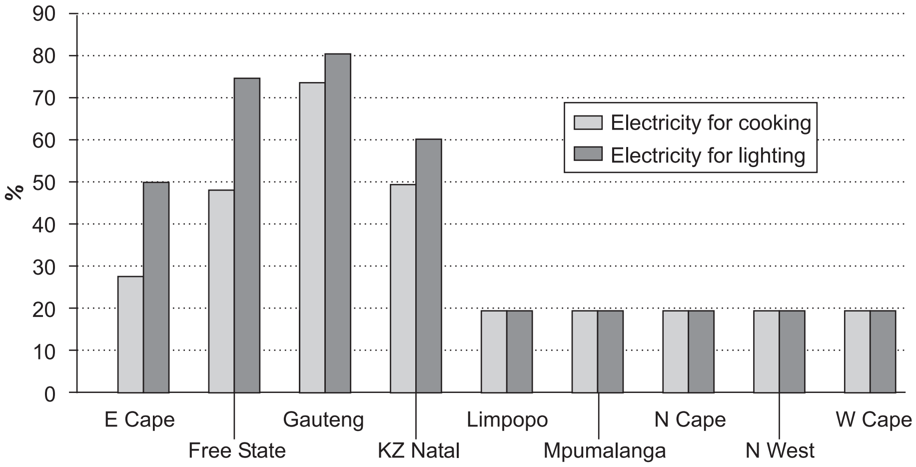

Figure 5.2: Households using electricity for cooking and lighting by province in percentages

Source: Based on Census 2001 figures from SSA (2003)

In urban areas, case studies (Mehlwana & Qase 1998) show that while electricity is considered the most desirable fuel, many households could neither afford the monthly electricity bill nor the most basic electric appliances. A comparison of income group and fuel source for cooking (Table 5.3) shows that just over 30% of households in the two poorest income groups cook with electricity while at the same time using more kerosene (25–31.4%) and wood (31–33%) than higher income categories. Wealthier households cook primarily with electricity. The income group R154 000–R307 000, cooks almost 96% with electricity, which is in fact more than in the two highest income groups.

Table 5.3: Percentage share of fuels used for cooking by households in different income groups

Source: Based on Census 2001 figures from SSA (2003)

Income group	*Electricity*	*Gas*	*Kerosene*	*Wood*	*Coal*	*Others*	*Total*
0 – R4 800	30.0	2.3	31.4	31.0	3.3	2.0	100
R4 801 – R9 600	33.8	2.3	25.0	33.0	3.8	2.0	100
R9 601 – R19 200	47.7	2.8	25.2	19.4	3.4	1.4	100
R19 201 – R38 400	67.1	3.2	17.0	9.3	2.6	0.8	100
R38 401 – R 76 800	85.8	3.0	6.1	3.3	1.2	0.5	100

Income group	*Electricity*	*Gas*	*Kerosene*	*Wood*	*Coal*	*Others*	*Total*
R76 801 – R153 600	93.3	2.2	1.9	1.7	0.5	0.5	100
R153 601 – R307 200	95.9	1.9	0.8	0.8	0.2	0.4	100
R307 201 – R614 400	94.7	2.2	1.1	1.3	0.3	0.5	100
R614 400 – R1 228 800	92.3	3.0	1.7	2.1	0.4	0.5	100
R1 228 801 – R2 457 600	76.2	2.8	7.7	10.6	1.4	1.2	100
R2 457 601 and more	85.7	2.7	3.6	6.5	0.8	0.7	100
Total	51.4	2.5	21.4	20.5	2.8	1.4	100

Compared to other countries, South Africa's relatively widespread use of electricity and its demographic patterns of electricity use are exceptional. The relatively low electricity prices mean that middle income and higher income households are more likely to use electricity for their domestic energy needs, if compared with middle income consumers in other countries. Only the lower income households can be said to use multiple fuels.

Non-commercial fuels

Much of the biomass used as fuel by low-income households is gathered 'free of charge' by householders rather than purchased, which of course has important money-saving benefits for the poor, and may be a matter of no choice for very poor households. Enforced dependence on non-commercial fuels is one the most intractable energy problems in the country, bringing with it a number of sustainability issues – including health impacts, environmental degradation, decreased productivity and energy poverty.

In some parts of the country there is an increasing commercialisation of biomass fuels, firewood in particular. Sometimes households purchase firewood because they can afford to do so. For others firewood may be an enforced purchase, because of a local scarcity of wood, or an inability to collect sufficient quantities – this in turn could be as a result of infirmity or shortage of able people in the household, or compounded by the HIV/Aids pandemic. In such cases, the commercialisation of firewood means further energy poverty and deteriorating livelihoods.

Factors affecting the use of commercial fuels among low-income households

Cost and availability are the most important determinants of poorer people's choice of commercial fuels. Cost involves not only the cost of the fuel itself, but also the appliances needed to use it. Transport is an important factor too, which affects both the cost and availability of fuel. Rural householders often have to travel significant distances to purchase fuels like kerosene, which adds to the cost of obtaining the fuel; or else they may buy small quantities from local traders, at a considerably higher cost per litre. Where there are several steps in the distribution chain (as is the case for kerosene and liquid petroleum gas) the mark-ups at each step raise the final price, increasing the energy burden on the poor. Close to mining areas, coal is a 'cheap' fuel, but it becomes more expensive the further it is transported. Thus coal is widely used by low-income households, but only in some areas of the country.[10]

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[10] These unfortunately include areas with high settlement densities, cold winters, and adverse climatic conditions for dissipating the pollutants from coal fires and stoves, leading to extremely unhealthy local indoor and outdoor pollution levels.

An important factor is the cost and availability of suitable appliances. Very cheap kerosene wick stoves are widely available, but these have poor safety, performance and durability characteristics. The use of kerosene pressure stoves, which are somewhat more efficient than the wick stoves, is also common, but these are also often of poor quality and are as expensive to purchase as a two-plate electric stove. Liquid petroleum gas appliances tend to be expensive for poor families. The cost of appliances, and the fact that they are not very durable, constrains people's fuel choices and their flexibility in switching between fuels. Among households with low and irregular income streams, the ability to switch between 'superior' and 'inferior' energy practices according to their level of resources at a given time, is an important technique for improving their quality of life, or surviving periods of destitution. However the cost of owning several appliances for multiple fuel use can be an obstacle.

5.1.3.2 Urban-rural divide

Very poor households (income quintile 1) in rural areas have the lowest electrification rates (see Table 5.1) in the country. Only 41% of these households have access to electricity. The largest difference between rural and urban households is found among the poorer households (income quintile 2). Forty-five percent of rural q2 households have electricity while 78% of urban q2 households have access to electricity.

Table 5.4: Estimated electrification levels of rural and urban household by income quintile

Source: UCT (2002); data from October Household Survey (1999)

Rural households					*Urban households*				
Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*
41%	45%	59%	68%	76%	63%	78%	87%	91%	98%

5.2 Sustainability issues for energy development

5.2.1 Access, affordability and acceptability

The term 'energy burden' refers to the percentage of the total household budget spent on energy. The average energy burden of poor households in remote rural villages is 18% [11] (see Table 5.6) (Prasad & Ranninger 2003). After an allocation of 50 kWh free basic electricity, the energy burden is reduced to 12% of the total household budget.

Table 5.5: Mean expenditure by poorer households on electricity and other fuels and energy, as a percentage of total household expenditure

Expenditure on	*Before subsidy*	*After subsidy*	*Difference*	
Electricity (R/month)	38	31	7	18%
Fuels excluding electricity (R/month)	70	59	11	16%
Energy as% of household expenditure	18%	12%	6%	

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[11] In the USA the energy burden for low-income households in 2001 was 14% – twice the energy burden for all households taken as a whole, which was 7% (EIA 2003).

5.2.2 Subsidies

Since poor households cannot afford much electricity and generally do not have the resources to start economic enterprises, they cannot make full use of the opportunities that an electric connection could provide. A subsidy is therefore needed to achieve social benefits from the investment in the electrification networks (Gaunt 2003). The DME has introduced a subsidy policy designed to reduce the worst effects of poverty on communities. The policy gives free basic electricity to all poor households. The policy has been piloted and put into effect by some municipalities, which have provided differing amounts of free electricity, from 20 kWh to 100 kWh. This will soon be standardised to a uniform 50 kWh free of charge to all grid-connected poor households in the country.

Some economists believe that subsidies have a negative effect on economic efficiency. According to this view, while the removal of value added tax on illuminating kerosene is a measure designed specifically to give some relief to low-income households, it is unlikely to lead to increased efficiency in the economy. Other economists argue that reducing taxes and levies on commercial and industrial fuels, such as diesel and gasoline, might lead to more efficient economic production (since the high taxes and levies constitute a price distortion). However in the South African economy this is debatable because of the massive uncosted social and environmental externalities such as air pollution outdoors from coal and indoors from a range of fuels.

5.2.3 Energy and job creation

South Africa has high levels of joblessness – the official rate of unemployment in 2001 was 41.6% (SSA 2003), significantly higher than previous estimates of 29.5% (SSA 2001).[12] Looked at by race, the unequal employment rate starkly reflects the inequality of apartheid. According to the 2001 Census, unemployment among black African men was 43.3%, while among white men it was 6.1% (this reflecting the strict definition of the unemployment rate among those aged 15-65, i.e. as a share of the economically active population). There was an even greater gap among women, with 57.8% unemployment for black women and 6.6% for white women. Among those employed, 1.2 million black Africans were in 'elementary occupations' and only 106 000 were working as 'professionals', of a total of 2.5 million (these are only two of ten occupational categories). Out of a total of 819 000 white people employed there were more professionals (138 000) than among all employed black people, and far fewer doing elementary jobs (20 000) (SSA 2001).

Since the early 1990s, jobs have been lost in the energy and energy-related industries (Figure 5.3). From 1993 to 2002 Eskom reduced its workforce from 40 128 to 29 359 (Eskom 2002). In the coal mining industry, 100 000 people were employed in 1986 compared with 49 000 in 2001 (SANEA 2003). For both electricity and coal, production increased at the same time as the workforce decreased, due to greater mechanisation.

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[12] Among those who are included in the expanded but not the official definition of unemployment will be discouraged job seekers (those who said they were unemployed but had not taken active steps to find work in the four weeks prior to the interview). The official definition is that 'unemployed are those people within the economically active population who: (a) did not work during the seven days prior to the interview, (b) want to work and are available to start work within a week of the interview, and (c) have taken active steps to look for work or to start some form of self-employment in the four weeks prior to the interview' (SSA 2001). The expanded unemployment rate excludes criterion (c).

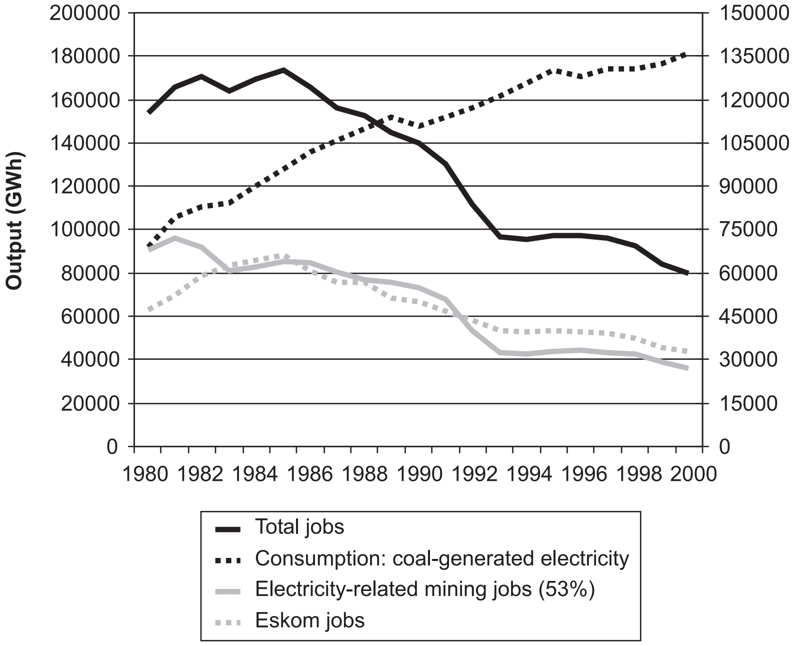

Figure 5.3: Employment in coal-based electricity generation in South Africa
Source: AGAMA (2003)

5.2.4 Economic empowerment of the historically disadvantaged

The government has made a commitment to redress the race and gender inequalities of the past. In 2003, Eskom employed 54.6% black staff and 24.5% women at managerial levels, slightly exceeding its target for 2002. Taking all levels at Eskom together, black staff members made up 68.8% of the total, and women 19.7%. As part of its procurement policy, Eskom supports black economic empowerment, and in 2002 a policy framework for the empowerment of women was implemented (Eskom 2003).

5.2.5 The need to inform and educate the poor on energy issues

The use of electricity and electrical appliances is relatively new for most poor households. Research conducted at two 'electricity basic support services tariff' (EBSST) pilot sites demonstrated that poor people did not benefit optimally from the EBSST tariff because of a lack of energy education and information. Vilakazi (2003) notes that a lack of education and information was a major barrier to the successful implementation of the EBSST programme. In fact the White Paper on Energy (DME 1998: 110) acknowledges that all levels of South African energy consumers, from low-income households to business and industry, are poorly informed about good practices and options for energy use. Lack of energy information contributes to unsustainable conditions and community underdevelopment (Visagie 2002). An energy-literate South African public is needed to make well-reasoned decisions about energy options and to use the natural resources more wisely – the key to sustainable development

5.2.6 Gender and energy

In most households women do the cooking, and in most poor rural households it is women and children who are responsible for collecting firewood. Wood collectors are vulnerable targets for attack by criminals and wild animals, and carrying heavy head-loads of up to 50 kg over many years is physically damaging. A detailed description of the effects of indoor air pollution from smoke on human health is presented in Chapter 7.

Energia News October 2003, which had a focus on women, gender and energy, highlighted the gender and energy work which began in 1994 following the national mandate for equity. The appointment in 1999 of Phumzile Mlambo-Ngcuka as Minister of Minerals and Energy was a turning point for women in the energy sector (Annecke 2003). The minister actively supports participation of women by encouraging training and allocation of resources to women.

5.3 Energy-related social issues

5.3.1 Future energy generation and job creation

About 41.6% of the population of South Africa are without jobs, which is a serious social issue. The energy sector itself has the potential to employ large numbers of people – jobs will be created as the electricity sector expands to meet demand, and in the related expansion of the coal mining industry as it increases its capacity. With one of the lowest electricity tariffs in the world, South Africa is attracting direct foreign investment and creating jobs in new energy-intensive industries. The aluminium smelter at Hillside in Richards Bay and the development at Coega near Port Elizabeth, are two examples.

Renewable energy can also create many jobs. A recent study (AGAMA 2003) evaluated the role that renewable energy could play in job creation. The projected electricity demand for the year 2020 is expected to be 267 TWh, increasing from the 2000 electricity generation figure of 181 573 GWh. Figure 5.4 indicates that if an additional 62 TWh is to be generated by renewable energy technologies (RETs) and coal capacity, around 52 000 jobs will be created, compared to 43 000 that would be created if the additional capacity were created solely by coal-fired plants. An even larger number of jobs (57 000) would be created if RETs alone were to generate the demand (AGAMA 2003).

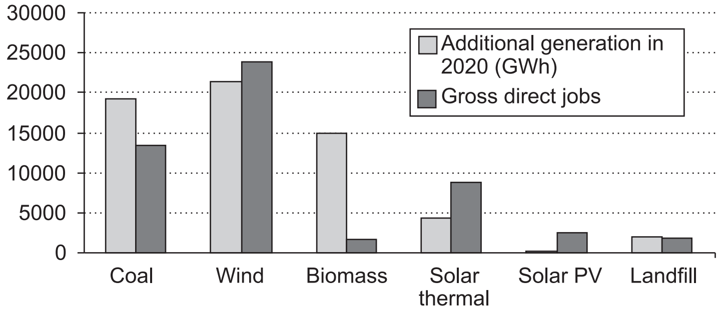

Figure 5.4: Summary of jobs against electricity generation for coal and RETs in 2020
Source: AGAMA (2003)

5.3.2 Effects of electricity prices and subsidies

As we have seen, poorer households in South Africa tend not to use electricity for their main thermal energy needs, and in any case half of rural households do not even have access to grid electricity. However if the electricity basic support services tariff (EBSST) is successfully implemented, electricity will become a cheaper cooking option than other commercial fuels, and it will make financial sense for low-income electrified households to cut down on their use of other commercial fuels and use electricity for their thermal energy requirements. This would be a profound change, requiring wide customer education/information campaigns and ongoing careful policy assessment.

The subsidies for widened access, and for electricity itself, would need to be sufficiently large to compensate for the likely higher cost of electricity expected after 2007 when new power stations will be built. It remains to be seen whether such a large national subsidisation of electricity would be sustainable. Even if subsidised grid electricity becomes an affordable cooking option for larger numbers of households, it is likely that among the very poor there will be a continuing use of non-commercial energy options. Poor people are well aware of the burden, inconvenience and health effects of cooking over smoky fires, but their economic choices are very limited.

5.3.3 Energisation approaches

The terms 'energisation' and 'integrated energy provision' have become popular in the South African energy sector in recent years. They refer to improving energy provision by using a combination of different fuels, rather than a single energy carrier such as electricity. These terms reflect a switch in thinking away from an almost exclusive focus on electrification. The term 'energisation' has also developed connotations of a more political notion of empowerment and local community activism around energy and development issues.

5.3.3.1 Agencies and actors

Energisation and integrated energy provision imply a range of fuel supplies. This requires a range of agencies and companies involved on the supply side, as well as other agencies, policy-makers and planners to support community empowerment and organisational development around energy issues.

A list of participants could include:

National government (primarily the DME)	Planning, policy, support, regulatory oversight, subsidies and taxes, etc.
Local government	Responsible for securing the delivery of basic services (including energy) in their municipal areas, and for many aspects of Integrated Development Planning. Possibly also for routing national government subsidies directed towards energy provision.
Eskom and other electricity suppliers and distributors	Mainly responsible for grid electricity supplies. A rationalisation between Eskom and municipal electricity distribution is pending.
Oil companies and distribution networks for petroleum products	Sourcing/producing and distributing petroleum-based fuels – sometimes with further diversification.
Industry associations	For example safety associations within the petroleum sector – geared more towards public interest and market-support activities.
Solar energy companies, and other energy companies/ utilities involved in the 'concessionaires programme' for non-grid service provision	Supply and maintenance of non-grid electricity services plus improved provision of complementary thermal fuels.
Retail outlets, large and small, dealing in fuels and appliances	For example retail chains selling appliances (and concerned with safety standards), or the multitude of small traders involved in the distribution of fuels like kerosene.

Community organisations	For example consumer co-operatives, community-managed ‘energy centres’, civic environmental and safety groups, local development forums.
NGOs and government/multilateral development support agencies	Generally assisting local development initiatives, organisational development, and capacity building.

The above table shows how the aims of energisation can lead to more complex involvements by many agencies – a quite different picture from an energy supply approach which focuses on electrification and where a large part of the responsibility, planning, financing and implementation would be assigned to Eskom. The combinations of different fuels and appliances in an energisation approach mean that different types of distribution and trading would be involved. For example, kerosene is widely available as a household consumable which can be purchased almost anywhere in the country from shops, petrol stations and other bulk outlets. However, its refinery-gate price is regulated, retail price mark-ups are regulated (though ineffectively), and it is exempt from VAT (also with uncertain effectiveness, when one considers the final prices paid by low-income households). Kerosene distribution and trading therefore combines elements of free market and government regulation. LPG poses different complexities, since there is supposed government regulation of refinery-gate prices, but no control over retail margins, and consumer LPG prices are unusually high in many areas.

Grid electricity is a different kind of commodity, as it involves network infrastructure. For households, electricity use is just another commodity, to be compared with alternative fuels. Electrification planners see it differently – for them it is a social rather than a commercial programme, perhaps a necessary social investment and a form of reparation for past injustices in the country. For electrification planners, the income from selling electricity units is small in proportion to the scale of subsidies required to extend the electricity infrastructure and its operation.

Thus energisation can involve a mixed bag of commercial conditions, in order to deliver a combination of energy services. The three examples below illustrate different possibilities and some dilemmas.

Extending the range of rural electrification – the weak grid approach

The costs of rural electrification tend to rise as the network is extended into remote and sparsely settled parts of the country. Cost-saving can be achieved through the use of lower-capacity medium voltage transmission and distribution lines, smaller transformers, and lower cabling costs for local reticulation. Given that typical electricity demand levels in poor rural areas tend to be very low, electrification supply projects can be designed for a very low ADMD (after diversity maximum demand)[13] thus reducing costs and increasing the number of communities and households that can be reached within the available budgets.

Such a ‘weak grid’ approach is not designed to cover community-wide cooking and heating requirements. Households depending primarily on non-commercial fuels like wood

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[13] Electricity demand is used here in the technical sense, where maximum demand is the maximum power consumed by customers. Individual consumers may require peak power at different times of day, so this ‘diversity’ effect can bring down the average peak power requirement for a community of consumers. Unfortunately, if a major electricity use occurs at the same time of day for many of the consumers (for instance, cooking meals) there is less demand diversity, and the average peak power requirement rises. The load factor then falls, indicating that the supply capacity required to cover the *peak* demand is severely under-utilised at other times of day, or seasonally. This is a familiar problem in rural electrification.

and dung are likely to continue with these to save costs, although it is hoped some of them will switch to cleaner fuels. Households using fuels like kerosene may also continue to do so. There is hope that the use of liquid petroleum gas may become more widespread through improvements in LPG supply and pricing, and appreciation of its greater convenience, cleanliness and safety compared with kerosene.

What will these households choose if grid electricity becomes cheaper than kerosene or LPG for cooking, especially households adopting the proposed electricity basic support services tariff? The demand to use electricity for cooking could then rise substantially, especially among those households presently using kerosene and LPG. The strategy of reducing electrification supply costs through a weak grid approach could then be at odds with a subsidy policy which promotes higher levels of electricity demand and use. This paradox is already apparent, according to the LPG Safety Association of Southern Africa.

Non-grid concessionaires: solar systems plus other energy services

In the non-grid 'concessionaires' programme, the primary responsibility of the concessionaire companies is to supply, install and maintain solar home systems. However, they are also expected to improve the supply of other fuels for cooking and heating. An energisation approach for the households concerned would be connection to a SHS for electric lighting and media/communications appliances, coupled with improved distribution of affordable LPG and appliances for thermal energy needs.

The first large SHS project in Eastern Cape, an Eskom-Shell joint venture, has so far not become significantly involved in improved supplies of other fuels, claiming that the challenges of SHS supply were arduous enough. However there are examples where lower-cost LPG is being supplied alongside solar electrification, reportedly with success. An example is the NuRa utility operating in northern KwaZulu-Natal. Its central strategy – which is being considered by other groups concerned with off-grid electrification in rural areas – has been to establish multi-purpose one-stop rural energy stores. These stores provide a base for the marketing, supply, maintenance and billing of solar systems, as well as providing a range of other fuels and appliances, and also conducting public awareness activities. This approach has many similarities with the idea of NGO-driven 'integrated energy centres' outlined in the next example below. It differs in having a distinctly commercial basis, which in turn depends on the government-subsidised programme for non-grid SHS electrification. NuRa reports a significant income-stream from LPG sales, a positive indication which shows that an integrated energy approach makes a good match in rural areas between energy demand and energy supply.

Integrated energy centres

Community-managed rural energy centres were piloted in the Rural SEED (Sustainable Energy, Environment and Development) project of 1998-2003 (Van Sleight et al. 2003). A number of village clusters in Eastern Cape and Limpopo provinces formed local energy committees, and subsequently energy and development co-operatives. One of these co-operatives went on to establish a multi-purpose energy centre to provide a range of fuels and appliances as well as public service activities (such as awareness and safety campaigns) to surrounding communities.

This successful example gives support to a plan by the government to establish a number of integrated energy centres across the country in areas with high needs and poor service provision. Such integrated energy centres would have a special relevance in low-income rural areas, where they would form an important component of the government's Integrated Sustainable Rural Development programme. The proposed energy centres are designed to be public-private-community partnerships, with funding assistance mainly from

Sasol and a high level of participation by local government and community groups. Two have so far been established, and more are at various stages of planning and organisation.[14]

Through bulk buying, integrated energy centres would be able obtain fuels at a lower cost and thereby reduce the cost overheads associated with transport and multiple-step distribution chains. Besides bringing energy services 'closer to the people' they could stimulate active local participation in relation to both energy issues and economic development initiatives and social services.

5.3.4 Energy and integrated development approaches

Energy is being viewed as a central crosscutting component in government policies and programmes to promote integrated development in South Africa. Important elements here are an emphasis on inter-sectoral linkages (rather than single-sector planning and implementation), the process of 'integrated development planning', and in the case of rural areas, the government's Integrated Sustainable Rural Development programme.

5.3.5 The challenge of inter-sectoral linkages

The concept of inter-sectoral linkages in relation to energy planning and provision means taking careful consideration of the links between improvements in energy supply and improvements in other services and economic activities involving energy. An inter-sectoral planning approach can encourage greater synergy and gains. However there can be drawbacks compared with a single-sector supply programme – for example, greater complexity and possibly dilution of purpose. The needs can be illustrated by some examples:

- Rural grid and non-grid electrification can contribute to improved facilities for social services like education (schools), health (clinics, hospitals) and administration – and should therefore be co-ordinated with planning in these sectors.
- Household energy supplies (electricity and other forms of energy) often take precedence in rural energisation programmes, but the links with opportunities for increased economic activity (whether in commerce, services, agriculture or manufacturing) need to be given more emphasis. Income opportunities have to be created for the poor, which would also enable them to pay for energy services.
- There are links between energy and water supplies, particularly in areas where there are critical water-pumping requirements – joint planning is necessary here.
- The transport and energy sectors are closely linked – transport requires energy, and some forms of energy distribution require transport.
- Infrastructure such as roads should be taken into account when planning energy developments.
- Special attention should be given to the close links between electricity and improved information and communications technology. Without access to affordable information and communications technology facilities, disadvantaged communities may be increasingly separated from national and world issues.

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[14] In the lead-up to national elections in 2004, it seems that there was a swing towards establishing integrated energy centres in peri-urban locations, to serve poorly serviced communities living around towns. Possibly this was because these areas have a higher voter density.

5.4 Emerging gaps

It is always useful to view energy supply from the viewpoint of social needs. An example is education. Many schools experience energy constraints, impeding some aspects of education and contributing to illness and to students' ability to concentrate – for example if there is no heating in winter, or no energy to prepare cooked meals in school feeding schemes.

Inadequate energy supplies also contribute to reduced agricultural productivity. Farmers need energy for ploughing, irrigation, food processing and preservation, and warmth and light for poultry keeping. Again, energy is not the only factor. Improved rural agricultural productivity among the poor generally requires several further inputs, such as finance and investment facilities for small-scale farmers, intensive state support for rural agriculturists, and major measures to counter inequities in access to resources, like land resettlement programmes.

Inter-sectoral linkages can make investments in electrification more effective so that poor people can use electricity and other fuels for the development of small businesses and other enterprises. Such linkages between sectors include:

- national and provincial level co-ordination among government departments;
- practical co-ordination between implementing agencies;
- local-level assessment and planning of co-ordinated development approaches which suit the prioritised local needs and opportunities, as in 'integrated development planning'.

Each of these areas presents challenges. An integrated inter-sectoral approach entails some demanding requirements, such as efficient and thorough communication between different agencies. Synchronisation of purpose and implementation is needed, together with the securing of funding and investment that would allow such synchronisation. Further complexities arise when different sectors are served by different tiers of government (e.g. national energy policies/programmes engaging with provincial departments of education) or where there are various levels of combined responsibility between government, private sector and NGOs/CBOs (as in the development of integrated energy centres).

Electrification planning should be conducted as part of the integrated development planning process. Regarding the supply of non-electric fuels, it is less clear as to how the provision of these fuels will be subjected to local-level planning, since they are usually supplied through the private sector, or if non-commercial, through informal collection. However, there is no reason why integrated energy centres supplying a range of fuels could not be incorporated as specific projects within a local integrated development plan.

The national electrification programme has begun to redress some aspects of inequality. Future social sustainability will require further redistribution combining economic growth and job creation with effective social programmes.

6

Energy and economic development

J C Nkomo

6.1 Analysis of the current situation

6.1.1 Situational analysis of the energy sector

The South African economy produces and uses a large amount of energy. It is highly energy-intensive and heavily dominated by extraction of raw materials and primary processing. The energy sector as a producer contributes 15% to GDP and employs a labour force of over 250 000. The demand for energy is expected to grow, with the energy sector remaining of central importance to the country's economic growth, especially with regard to attracting foreign investment in the industrial sector.

The South African energy sector is characterised by several important features, including the following:

- A strong natural resource base with a variety of energy options. The country has vast coal reserves, although estimates of their size vary considerably. Besides the geological quantities, the value of coal reserves is also a function of the resource price, the price of coal substitutes, improvements in technology, exploration, and the development of alternatives.
- A well-developed energy and transport and grid infrastructure.
- An electrification drive to increase access to electricity in disadvantaged communities. Most of those without access to electricity are low-income households.

To produce electricity at a cost that is among the lowest in the world, the South African economy depends heavily on coal, despite that fact that the generation and production of coal is polluting, and has a significantly negative environmental impact.

The level of competition between producers in the energy sector is low. Apart from the high cost of capital required to enter the energy industry, there are other barriers to entry. The technology is specialised and the existing structure and regulatory environment is not conducive to entry. The government seems to be reluctant to restructure the energy sector and there is lack of legislation to stimulate competition and efficiency.

6.1.2 Energy and energy-economy linkages

The relationship between energy use and economic growth is complex and affected by a number of factors. One is the volume effect, which reflects changes in economic activity; another is structural change, which leads to changes in energy technology, and hence in demand. Energy conservation also has a bearing on energy demand, mainly through the substitution of old appliances.

6.1.2.1 Economic performance

Figure 6.1 shows fluctuations in South Africa's economic growth rates over time. The economy experienced high growth rates in the 1960s, largely because of the high growth rate in the mining and raw materials sector, and also the economy was tightly controlled. In the 1970s, factors such as the world oil crises and changing gold prices slowed down the economy. From the 1970s until 1993, increased public spending, economic sanctions, and the effects of political instability stifled the economy. This period was characterised by poor growth performance, low levels of investment, rising unemployment, political instability, currency instability, widening deficits, falling living standards and growing inequalities.

Since 1994, the government has been firm about getting the macroeconomic balance right, in order to attract investors, reduce the budget deficit and fight inflation through high interest rates. The government set economic objectives to achieve economic growth to create employment, and in that way lessen inequality and poverty. Despite the government's GEAR strategy to promote growth, the economy did not achieve rates of economic growth as high as predicted (Table 6.1). Employment levels contracted substantially, and private sector investment, a driving force behind growth, grew by 2.7% instead of the predicted 12%.

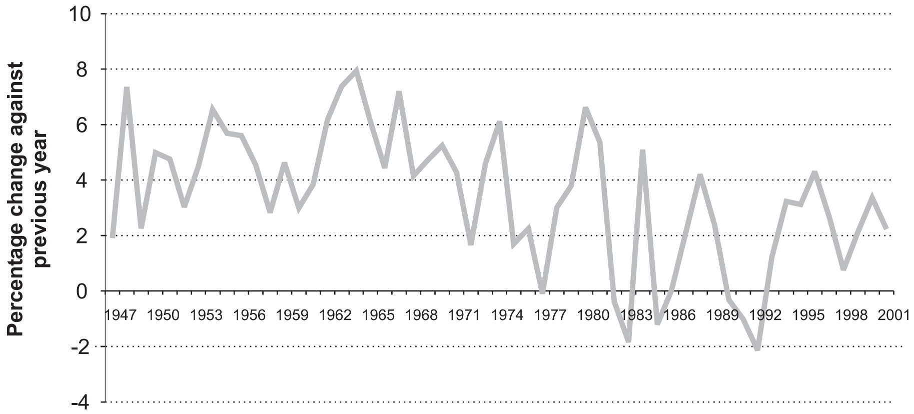


Figure 6.1: Annual real economic growth from 1947 to 2002
Source: Based on SA data, SA Reserve Bank, various years

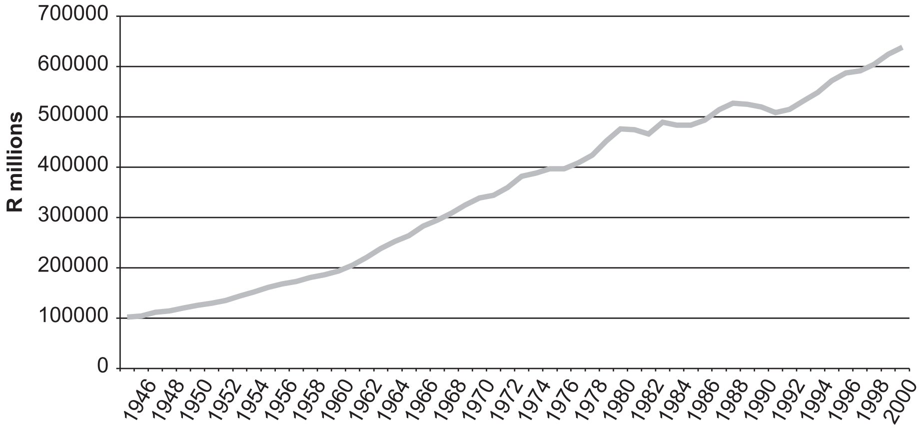


Figure 6.2: Gross domestic product at market prices (constant 1995 prices)
Source: Based on SA data, SA Reserve Bank, various years

Despite the above problems, the government has met key fiscal and monetary targets, and has been successful in reducing the fiscal deficit, inflation, and interest rates. However the rate of economic growth has been less than expected. GDP growth (Figure 6.2) averaged 2.5% between 1996 and 2000 against the predicted average of 4.2% (see Table 6.1). More recently, GDP growth has risen somewhat higher, reaching 2.8% in 2003 and 3.7% in 2004 (SARB 2005).

There has been rapid substitution of unskilled and low-skilled labour by capital equipment in almost all sectors (Bhorat et al 1998). An increase in capital intensity influences production methods and implies an increased demand for energy. As the economy has become more capital-intensive it has also become more unequal, showing increasing job losses and increased labour productivity, with no 'trickle-down effect' experienced by the poor. Because energy is cheap, the economy has become highly energy-intensive, with more energy used to produce equivalent levels of economic output than in most other countries. It is therefore not surprising that Makgetla and Meelis (2002) argue that 'the trajectory of growth must shift towards labour intensive industries, and away from the current emphasis on mining and refining and relatively high class consumer durables' so as to ensure that the poor have access to productive assets. While this may be desirable at a small-enterprise level, as a general trend, the move from high value-added industries will have low profit levels and therefore low investment potential.

Table 6.1: GEAR's predictions and actual outcomes for key indicators

Source: Naledi (2000)

	GEAR predicted average	*Actual average 1996 – 2000*
GDP growth (real)	4.2	2.5
Inflation	8.2	6.6
Fiscal deficit	-3.7	-2.9
Employment growth	2.9	-2.0
Private sector investment growth	11.7	2.7

6.1.2.2 Energy supply

Coal dominates the energy picture in South Africa, providing approximately 70% of the primary energy. Imported crude oil accounts for 20% of primary energy used, mainly by the transport sector. Nuclear energy, natural gas, and renewables including biomass, account for the rest of the energy needs. Eskom produces over 90% of South Africa's electricity, and it owns and operates the generation and transmission system. Eight municipalities generate the remaining electricity for their own use.

6.1.2.3 Energy consumption

The industrial sector, which includes mining, accounts for the largest proportion (45%) of energy consumed (SANEA 2003). The industries that consume large amount of electricity are gold producers, which have high energy demands because of declining ore grades and the consequent need to mine at very deep levels. Non-ferrous metal producers also need large amounts of electricity. Coal is the main energy source for the production of iron and steel, chemicals (as feedstock), non-metallic minerals (where coal is mainly burnt in clamp kilns), pulp and paper (which relies heavily on 'black liquor' to produce most energy requirements), food, tobacco, and beverages. Coal-based industries have low energy conversion efficiencies compared with oil, gas and hydro plants (Eberhard & Van Horen 1995).

In the residential sector the patterns and nature of energy demand is complex. Some writers argue that energy choice is a function of variables such as educational level, the degree of mobility and the length of time spent in urban environments (Viljoen 1990), while others contend that the main determinants of energy choice are income level and the relative availability of (or access to) fuels (Eberhard & Van Horen 1995). Whatever the determining factors, the phenomenon of multi-fuel use is widespread, with households selecting from a number of fuels in accordance with the nature of the end-use. The primary fuel sources for low-income households are kerosene and candles, and to a lesser extent LPG and woodfuel. Electricity consumption in low-income households is low despite these households stating their preference for its convenience, cleanliness and better lighting quality.

6.1.2.4 Investment

South Africa's massive investment in coal-fired power plants over time has led to excess energy capacity, with the country's licensed capacity having exceeded peak demand for at least 25 years. Figure 6.3 shows the degree of excess energy capacity (in MW) as well as energy exports and imports (in GWh) between 1996 and 2000. With little need for new investment in generation capacity over recent decades, debt has been reduced, as most of the capacity has already been paid off. The recent burgeoning of economic growth points indicates that before long there will need to be new investment in electricity generation capacity.

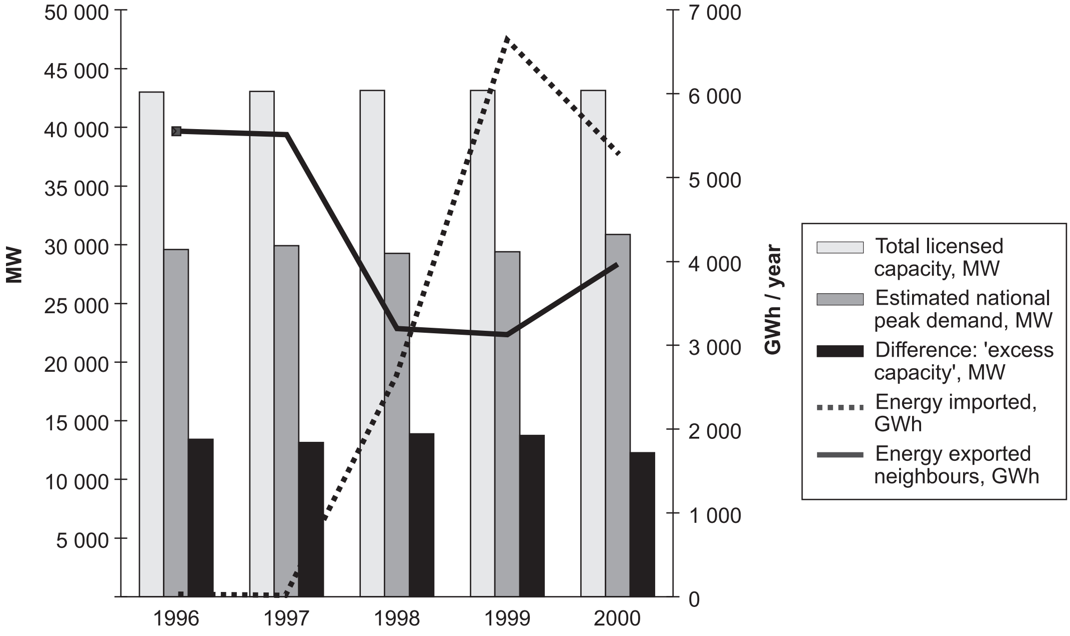


Figure 6.3: Excess capacity for all power stations 1996-2000
Source: NER (2004)

6.1.2.5 Electricity tariffs

Eskom sells electricity to distributors, who then resell it to residential consumers, commerce and industry. The average price of electricity in South Africa, per kilowatt-hour, is among the cheapest in the world. This is attributable to several factors:

- Access to large reserves of low-grade coal and the use of technologies that maximise economies of scale. Power stations are located near coalmines and have the benefits of long-term contracts.
- Overcapacity from power stations, which are already paid for. This reduces Eskom's finance costs and enables it to peg electricity prices at a low marginal cost.
- Environmental costs are not included in the price of electricity.
- Eskom's investment has been subsidised through Reserve Bank forward cover, thus protecting Eskom against exchange rate fluctuations. A financial benefit for Eskom is that it is exempted from taxation and payment of dividends.

These factors mean that, ultimately, despite the advantage of the low price of electricity, this price does not reflect the economic costs, or the long-term costs of increasing capacity, or the externality costs.

Undoubtedly, Eskom's low tariffs give local industries a competitive advantage and drive much of new investment in industry. For example, the manufacturing and mining sectors are linked through beneficiation and metals production (Spalding-Fecher 2002). These activities are energy-intensive, and rely on low prices for coal and electricity, which, in turn, have contributed to the development of an energy-intensive primary sector.

Electricity price increases have remained below inflation increases, providing sound reasons for Eskom to allow prices to rise in real terms so as to earn an acceptable rate of return on capital invested, and to ensure sufficient generation of interest. But this raises the problem of affordability by poorer households, especially given the government's commitment to making electricity accessible to all its citizens.

6.1.3 Externality costs

The reliance of poor households on wood, coal and kerosene as energy sources contributes to high levels of indoor pollution. There are serious health concerns associated with particulates, carbon monoxide, and fires – with the result that in South Africa respiratory illness is the second highest cause of death among children after gastric illness. These problems, which are essentially related to poor people's inability to afford clean fuels, persist despite the GEAR strategy that aims to bring low-income households into the modern economy through economic growth. The quantified impacts of the external cost of household fuels reveal that the greatest damage comes from candles, kerosene and the use of wood as fuel (Table 6.2).

South Africa's best quality coal is exported, earning the country its third-largest export revenues after gold and platinum. But the local use of low quality coal leads to greenhouse gas (GHG) emissions and other environmental problems such as ash emissions and pollution of water sources. South Africa's carbon emissions are higher than those of most developed countries partly because of its energy-intensive sectors (such as mining, iron and steel, aluminium, ferrochrome, and chemicals), which rely heavily on low-quality coal. This illustrates a classical conflict in resource use. While the exploitation of cheap and low-quality coal is seen to fuel growth (accompanied by arguments that this leads to social upliftment), ultimately the environmental effects have to be minimised, especially pollution and climate change.

In considering the externality cost estimates associated with coal generation, Blignaut and King (2002) estimated the potential GHG damage costs across all industries. According to their findings, the two major consumers of coal, Eskom and Sasol, are responsible for approximately 90% of all coal combusted, contributing 65% (approximately R7.2 billion) and 24% (R2.8 billion), respectively to the costs in 2001. Van Horen (1996) and Spalding-Fecher and Matibe (2003) evaluate potential costs of coal-fired power generation on health and climate change damages caused by GHG emissions for the South African economy.

The findings expressed in Table 6.3 indicate that estimated damages resulting from GHG emissions and climate change are significantly higher than those from local air pollution. The negative values are estimated benefits, and represent the total avoided health costs for 1999 for all electrified low-income households. The damage costs from GHG emissions range from R1.6 to R16.3 billion, with the total global damage per ton of coal ranging from R18 to R186. Because of lack of data, these estimates are not plant-specific, nor do they include coal-fired power stations owned by municipalities. If the municipal power stations are taken into account, the impact on health would be even greater, given that the municipal power stations are older, used during the peak period, have lower stack heights and are in major urban areas.

Table 6.2: Summary of external costs of household fuels (1999 rands/GJ)

Source: Spalding-Fecher and Matibe (2003)

Energy type	*Low*	*Central*	*High*
Coal	2.37	5.32	9.51
Kerosene[a]	10.31	60.84	151.48
Candles[b]	12.04	93.16	174.68
Wood[c]	10.46	38.20	92.60

Notes

a) Includes kerosene poisoning and 30% of costs of fires and burns.

b) Includes 70% of the costs of fires and burns.

c) Includes indoor air pollution and the social cost of fuel wood scarcity.

Table 6.3: Summary of external costs of Eskom electricity generation, 1999 (per unit of coal-fired power produced/delivered, c/kWh))

Source: Spalding-Fecher and Matibe (2003).

(1999R m)	*Low*	*Central*	*High*
Air pollution and health	852 (0.5/0.5)	1 177 (0.7/0.7)	1 450 (0.9/0.8)
Electrification	-173 (-0.1/-0.1)	-958 (-0.6/-0.5)	-2 324 (-1.4/-1.3)
Climate change	1 625 (1.0/0.9)	7 043 (4.3/4.1)	16 258 (9.8/9.4)

6.2 Energy for sustainable development – critical issues

Table 6.4 summarises the key issues for energy development as spelled out in the 1998 White Paper on Energy. We categorise these by their sustainable development dimension, showing the progress made. The objectives listed show a clear shift from a pre-1994 policy that was dominated by the need to secure energy supplies (a period dominated by international boycotts and oil sanctions) to post-1994 policies that strive for social equity and economic efficiency within the context of sustainable development.

Table 6.4: Sustainable energy development priorities and progress

Sustainable developmen t dimension	***Energy object-ives (White Paper on Energy 1998)***	***Priorities (DACS Foresight, Energy 1999)***	***Progress (Spalding-Fecher 2002)***
Economic	Secure supply through diversity	Develop Southern African Power Pool Develop gas markets Stimulate use of new and renewable energy sources Stimulate energy research	SAPP regional co-ordination centre established Mozambique gas to Sasol and Namibia discussed Renewable Energy White Paper drawn up in 2002 Declining research fund
Social	Increase access to affordable energy	Electrification policy and implementation Addressing off-grid electrification Facilitate management of woodlands for rural households Establishing thermal housing guidelines	Second phase of electrification programme, including renewables initiated Pilots of free electricity initiated No progress made Voluntary guidelines only
Environ-mental	Managing energy related environmental impacts	Improve residential air quality Monitor reduction of candle/kerosene resulting from electrification Introduce safely standards for kerosene stoves Develop policy on nuclear waste management Investigate environmental levy	Proposal of ambient air quality standards under debate Hazards still a significant challenge Safety standards under discussion Nuclear waste policy under discussion Environmental levy was not investigated
Interlinkages	Improve energy governance	Promulgate electricity regulatory bill Manage deregulation of oil industry Implement new regulation of nuclear energy Restructuring of state assets Establish information systems and research strategy	No petroleum regulator, petroleum Products and Pipelines Bills existed in 2002 Nuclear regulator established Eskom conversion bill passed PetroSA formed iGas formed Limited activity took place

Crucial issues for sustainability stand out as follows:

- The one key issue that seems to be missing in discussions on the economics of the energy sector is *added value.* Growth in economic output, measured by GDP, is not necessarily a good measure of the benefit to ordinary citizens. The more an economy is structured towards value-added sectors, rather than simply the exporting of raw materials, the greater the local benefits. Clearly such a restructuring involves changes that go far beyond the energy sector, however there are important implications for the energy sector. An example is the aluminium smelters at Coega, which makes use of cheap electricity to process raw material for export. How could such a facility go a step further into manufacturing products from aluminium?
- Another important concern relating to sustainability is the creation of local manufacturing capacity. Growth potential in energy supply, and services that can assist

in setting up industry locally (rather than elsewhere) assist in local economic development and job creation.

- Increasing access to affordable energy services (as discussed in Chapter 5) is another vital aspect to consider. Much residential energy use is characterised by poor access and the use of inefficient and hazardous energy sources. The national electrification programme is central to the development of the country and is increasing the number of people connected to the national grid. The proportion of households with grid electricity increased from 45% in 1995 to 66% in 2001, and the number of people using electricity (including non-grid electricity) increased from 58% in 1996 to 70% in 2001 (SANEA 2003). The main problem is that poorer households cannot afford enough electricity to render connection economically viable for Eskom and they cannot afford to pay for the necessary electrical appliances. Davidson et al (2003) argue that the existing system of electricity financing and implementation, while successful in meeting RDP targets, is not sustainable. Lack of access to electricity makes fighting poverty more difficult, as it hampers individual efforts to advance social and economic development goals.
- The economy exhibits high carbon-intensity due to the heavy use of inexpensive coal. Emissions per unit of economic output are high because the specific energy efficiencies of many sectors are lower than average, making emissions control a viable option. To realise the potential for emissions reductions, a clear policy framework is needed, as well as mechanisms for funding the additional investment in cleaner technology. Participation in emerging instruments like the Clean Development Mechanism will give South Africa practical experience in mitigation.
- Energy efficiency standards are generally lacking. Those standards that do exist have not been implemented because of the low cost of coal, the lack of public awareness, the unaffordability of appliances, and inadequate long-term policies. Codes and standards are urgently needed.
- Energy pricing, particularly electricity pricing, deserves more attention. The electricity price does not account for the environmental externality. The full cost of producing electricity is higher than that borne by Eskom, and the external costs are borne by society. Low energy prices have a number of advantages – they benefit the poor, give South Africa a comparative advantage, are an incentive for energy-intensive mainly export-oriented industries, and provide a subsidy to foreign markets. On the other hand, the low price of coal has not promoted incentives for investments in either energy-efficient technologies or renewable energy.
- Also related to sustainability and externality costs is the fact that South Africa's four refineries are major contributors to air pollution, emitting high levels of sulphur dioxide and other harmful chemicals that cause health problems. There are no legally binding air pollution regulations in existence, only non-binding guidelines with no enforcement authority.
- Energy governance can and should be improved by clarifying the roles of various government institutions. These institutions should be made to be accountable, transparent, and representative of the population – particularly previously disadvantaged groups. Economic and social losses from poor governance in the energy sector manifest themselves in a variety of ways – misdirection of growth (through subsidies) and losses of growth; continued economic, social and gender inequalities; negative environmental impacts and high direct consumption subsidies.
- Security of supply needs to be maintained through diversity and integrated planning of future supply options. While coal will remain the most important energy source, other

primary energy carriers should be considered. Research and development partnerships should be encouraged, as well as the facilitation of regional co-operation on energy

- Access to cleaner energy should be promoted so as to minimise the negative health effects arising from the use of certain types of fuels.
- Macroeconomic stability is a prerequisite for sustainable growth. Sustainable development cannot be expected in an economy exposed to macroeconomic shocks stemming from energy price increases and supply disruptions. Fortunately, this has not happened to South Africa.

6.3 Future outlook

The government is well aware of the critical issues raised above and will address the issue of the externalities associated with energy supply and use. As the economy develops, energy supply and use should not only be sustainable but should also lead to an improved standard of living for all South Africans. More attention has to be given to internalising the adverse impacts of energy usage. Understanding energy can better serve development, promoting growth through exports and investments, and creating jobs.

6.3.1 Some issues on energy demand

The Energy White Paper (1998) commits the government to improving the plight of low-income and rural populations and addressing the fact that the poor generally only have access to the less convenient and less healthy fuels. The success of this drive will depend on the response by stakeholders to issues such as pricing and financing of energy services, appropriate appliance/fuel combinations, and availability of efficient appliances. The benefits of small but effective improvements can be illustrated by the retrofit housing project in Kuyasa, Cape Town. This project installed solar water heaters, ceilings, ceiling insulation, and compact fluorescent light bulbs in existing RDP houses. The benefits per household were found to be a reduction in CO_2 emissions, contributing to health and energy cost savings. The monetary value of the benefits ranged from R626 to R685 per annum per household. Building thermally efficient low-cost housing can therefore be expected to promote energy efficiency and conservation.

Greater energy efficiency will also yield potential financial and environmental benefits, allowing industry to become more internationally competitive. Although the current cheap energy results in foreign exchange earnings, harmful environmental and health factors have not been included in energy pricing. Energy pricing needs to be balanced against sustainable environmental standards. The South African National Energy Association (SANEA) (2003) estimates that greater energy efficiency could save between 10% and 20% of current consumption and in turn lead to an increase of between 1.5% and 3% in the GDP. But to achieve this, a solution has to be sought to the critical barriers that hinder the uptake of such technologies, such as inappropriate economic signals, lack of public and official awareness, and the high capital costs involved.

6.3.2 Restructuring and energy diversification

Following new policy, the electricity industry is to be restructured into independent regional distributors, and Eskom is to be restructured into separate generation and transmission companies. The policy aims to promote universal household access to electricity and to make the industry more competitive.

The restructuring of electricity generation towards greater regional autonomy is likely to result in some of Eskom's power stations being sold, as well as the opening up of opportunities for independent power producers to enter the generation market. The current price of electricity, however, is unrealistically low and is therefore a deterrent to new competitors wishing to enter the market. Proper regulation of this market is therefore important. The coal industry, on the other hand, will remain deregulated, with coal remaining a dominant energy source and still the least expensive option on the planning horizon. It thus becomes all the more important to pursue clean coal technologies.

Notwithstanding the dominance of coal, it remains important to diversify the energy market by developing and promoting other energy forms, such as natural gas and renewable energies. This is in line with policy objectives of improving both supply security and environmental performance. Power stations in future will run not only on coal, but on nuclear, gas and hydropower. The viability of nuclear energy as a future source of electricity generation depends very much on the environmental and economic merits of other energy sources. The next generation of nuclear power stations is expected to make use of simpler and safer reactors. The main concern with gas is its price, given the limited reserves in the country, but the importation of gas from other countries is a strong possibility. South Africa's limited potential for hydropower implies that there will be some reliance on imported hydropower. Finally, liquid fuels are to be subjected to minimum government intervention and regulation, with the emphasis on environmental and safety standards, investment and the promotion of black economic empowerment.

6.3.3 Realising the potential benefits of energy efficiency

With the prevailing low costs of energy there has been very little incentive for either industry or households to adopt energy efficiency measures. The increase in GHG emissions is a source of growing concern for the promotion of energy efficiency standards.

Demand-side management can be used to limit the growth of residential demand, or to mitigate the impacts of residential usage, by providing incentives for industry/commerce to move the load out of peak periods. Managing demand by ironing out the load to reduce peak demand is likely to mean that price increases will not be as steep or as sudden because the construction of more generation capacity will not need to happen so quickly.

The residential electrification programme, with a final target of five million additional connections by 2007, raises various issues of public policy interest. The electrification connection of poor households (where coal, wood, kerosene and LPG are the primary household energy sources), promotes the use of a clean, versatile and convenient form of energy that connects this group of households to the modern economy. This raises the proportion of energy sales, but leads to a rise in peak demand, with the residential sector contributing more than 30% because of its 'peaky' nature (Africa 2003). Eskom will have to construct new plant to meet this load type. For the residential sector, various energy efficiency interventions could defer the building of a new plant – energy efficiency lighting, thermal insulation, energy management and the use of energy saving appliances.

There is substantial scope for energy saving in the commercial and industrial sectors. For the commercial sector, the energy savings opportunities lie in better design of buildings and improved management of energy use. In the industrial sector, the opportunities are in energy management and good housekeeping, providing incentives to adopt specific technologies, conducting energy assessments to identify areas for energy savings, and implementing standards for electrical equipment. The main challenge is the adoption and promotion of economically efficient energy measures, which would guarantee the achievement of market transformation and demand-side management sustainability.

6.3 Emerging gaps and challenges

Some challenges facing the energy sector which are crucial to economic development are:

- Dealing with the problem of negative externalities. Use of low quality coals is the main contributor of GHG emission. Eskom is thus vulnerable to any international response measures that may be taken to reduce GHG emissions (Davidson et al 2002), for which South Africa has no commitments. An even bigger problem is that poor communities use energy sources that contribute to high levels of indoor air pollution, with negative health effects.
- Adoption and promotion of energy-efficient measures. While such measures are being pursued in the residential sector, there is an even higher potential for energy savings in the industrial and commercial sectors, which has yet to be realised.
- Achieving social equity and economic efficiency within the context of sustainable development within the energy sector. The White Paper on Energy (1998) focuses on the security of supply through diversity, increasing access to affordable energy, managing the energy-related environmental impacts, and improving energy governance.
- Choosing appropriate policy instruments to minimise the negative impact of externalities. Such instruments should provide incentives for carbon intensity reduction, encourage investment in energy saving measures, and generate revenue for the economy. A most effective way is to encourage the adoption of improved technologies, which may be much more efficient and more economically accessible than technology switching, and which may improve society's well-being.

The linkages between these challenges and suggested solutions may seem clear, since all of them endeavour to contribute to economic development and to improve social well-being. But there remain sharp conflicts over the meaning of sustainable development and its implications for policy. If, for example, economic efficiency is the prime objective of sustainable development, then energy subsidisation to alleviate poverty will receive limited attention. However this would limit the role of energy as an essential precursor to redressing the challenges of social and economic inequities. Thus a trade-off is necessary between addressing the energy requirements of the poor and promoting the efficiency and competitiveness of the whole economy by providing low-cost and high-quality energy inputs (Eberhard & Van Horne 1995). Obviously, South Africa's economy will not be able to develop without its abundant, easily mined and low-cost coal. But we have to include the environmental equation, which means, apart from addressing short-term environmental problems, there has to be serious planning for a long-term transition to include renewable energy sources with fewer negative externalities. There does not seem to be any comprehensive policy position on environmental taxes in South Africa.

Finally, data limitation poses a serious problem for the assessment of policy instruments. A lack of meaningful data limits effective decision-making on which areas should be subsidised, the number of qualifying households, and how to assess the cost and impact of subsidies to the economy. Furthermore, there is no established network for the delivery of information on the consequences of industrial pollution and available technological options, nor are there training and awareness programmes for industrial managers on the consequences of pollution and the options for energy efficiency.

7

Energy and the environment

Debbie Sparks
Contributing author: Stanford Mwakasonda

7.1 Analysis of the current situation

7.1.1 Broad overview

South Africa placed itself firmly on the environmental world map when it hosted the World Summit on Sustainable Development in Johannesburg in 2002. The primary outcome of the summit was a global Plan of Implementation. The summit also put sustainable development firmly on the international agenda and encouraged world leaders to recommit themselves to sustainable development goals (Bigg 2003).

Environmental issues for South Africa's energy sector relate largely to bulk energy supply, the household sector, and the transport sector. In the energy supply sector, the long-term feasibility of the resource base is the main concern (Spalding-Fecher et al. 2000). For households, the primary concern is indoor air pollution and the negative health effects of burning coal and woodfuel. In the transport sector, the main concern is the emissions of noxious gases.

South Africa is party to a number of international conventions and protocols, some of which are particularly relevant to the sustainable use of energy and the environment. The UNFCCC, ratified by the South African government in 1997, addresses the climate change threat, compelling governments to reduce and control their sources of GHG emissions. Linked to this is the Kyoto Protocol. South Africa has ratified the 1990 Montreal Protocol on substances that deplete the ozone layer, which is designed to restrict the use of chlorofluorocarbons and halons.

As discussed in Chapter 3, energy demand in South Africa is dominated by coal, liquid fuels and electricity. Each of these energy types has environmental advantages and disadvantages, which need to be weighed up in the context of economic growth and development.

7.1.2 Legislation and policy

Some of the environmental impacts of energy in South Africa are governed by legislation. Important laws in this regard are the National Environmental Management Act (NEMA) (No. 107 of 1998) and the Atmospheric Pollution Prevention Act (No. 45 of 1965). NEMA should be seen as a framework for integrating good environmental management practice into government activities (DEAT 1998). Some of its principles have been open to interpretation, and some obligations are difficult to determine unambiguously. Nevertheless NEMA has important implications for the energy sector, especially with respect to renewable energy and energy efficiency. Provincial government and to some extent national government, are now required to prepare environmental implementation plans or management plans (EDRC 2003).

The Atmospheric Pollution Prevention Act is managed by the Department of Environmental Affairs and Tourism (DEAT) and is responsible among other things for the control of noxious gases, smoke, dust, and vehicle emissions. Noxious or offensive gases are controlled by the granting of registration certificates to any party engaged in one of 72 listed processes, which include power generation processes, and gas, charcoal and coke processes (DEAT 1965). This act, promulgated in 1965, does not focus on current issues of concern such as energy efficiency and renewable energy.

The new Air Quality Act (No. 39 of 2004) provides a regulatory framework that can address both local air pollutants and global pollutants such as greenhouse gases. The Act includes mechanisms in domestic legislation that can be used to implement international obligations, by listing priority pollutants and activities, by requiring pollution prevention plans to be submitted, and by controlling the use of certain fuels.

Two policies guide the government's environmental management framework. The White Paper on Environmental Management Policy for South Africa (1997) is based on sustainable development and shows an alignment with international trends. The White Paper on Integrated Pollution and Waste Management (2000) aims to develop an integrated pollution and waste management system which takes into consideration sustainable social and economic development with respect to air, water and land resources protection (EDRC 2003).

7.2 Critical local issues

7.2.1 Petroleum

When considering the environmental issues related to petroleum in South Africa we need to look at the five areas of production, refining, distribution, storage, and use. A number of different initiatives to ensure environmental conformity have been undertaken by stakeholders in the country, including the formation of the South African Oil Industry Environmental Committee more than 20 years ago. The Committee was formed with the objective of managing potential environmental impacts that may arise anywhere between production and use. The issues include (SAPIA 2002):

- oil spills at sea during importation;
- air and water emissions and waste management at refineries;
- spillage of product during transport to depots;
- leaks from underground storage; and
- inappropriate disposal of used petroleum products.

7.2.1.1 Upstream petroleum activities

Given the relatively active exploration, development and production of oil in the South African marine environment, there is a need to evaluate the environmental effects of these activities. Measures have to be put in place to ensure that regular environmental monitoring is undertaken; that sampling techniques which show the changing contaminant profiles are set up, and that reliable measurements of pollutant concentration levels are provided. Samples need to be drawn from areas suspected of having, or about to have, elevated levels of contaminants, and these need to be compared with areas with no contamination. Parameters to be measured include seismic noises, levels of hydrocarbons and metals in the water, impacts on breeding habitats, and movement of species. The potential effects of offshore petroleum activities have to be monitored in the context of the marine environment. Social and economic aspects would also have to be monitored, including the effects on people living in coastal communities.

Decommissioning of offshore production facilities also calls for appropriate planning so as to avoid environmental and safety problems. Options should be considered well in advance for the removal and disposal of redundant facilities, and the government needs to have a clear regulatory framework on decommissioning of facilities, even though the responsibility of removing the facilities lies with the companies concerned. Depending on circumstances, decommissioning may mean complete removal, partial removal or alternative use.

The environmental issues relating to the refining of petroleum include emissions, spills, discharges, and sludge handling. Currently South Africa has four crude oil refineries, located in Durban, Cape Town and Sasolburg, and two refineries producing liquid fuel from gas, located in Mossel Bay and Secunda. One refinery-related environmental issue has been a lack of nationally regulated ambient air quality standards. While the Atmospheric Pollution Prevention Act (1965) sets out guidelines and some standards on air quality, this is applied on a rather arbitrary basis and with specific objectives, such community health. To address existing gaps in the refinery sector, oil companies in South Africa, through the Refinery Managers' Environmental Forum, have taken the initiative to tackle some of these issues, and have been drawing up an Environmental Management Cooperation Agreement with government (SAPIA 2003).

The Atmospheric Pollution Prevention Act of 1965 includes guidelines and standards for sulphur dioxide emission levels for refinery plants, average sulphur content in fuels used by refineries, efficiency standards for sulphur recovery units, particulate emissions, and control of oxides of nitrogen (NO_x). The guidelines also cover issues of incineration, odours, spills and fugitive emissions.

7.2.1.2 Oil spills

Environmental safety is an important issue for oil drilling and transportation. During offshore drilling, uncontrolled oil spillage into the ocean is a potential hazard. Within the vicinity of South African ports oil spills may be the result of the damage or loss of a shipping vessel at sea, inaccurate navigation into the port, or the transfer of oil from oil tankers (CSIR 1997). Most oil spills are due to transfers, and are generally small, less than seven tons, and considered to be part of routine oil transfer operations. Larger oil spills pose a serious threat to the physical and socio-economic environments in the vicinity of the spill, through damage to beaches, mariculture, and sea birds. An oil spill in 2000, from a ship called The Treasure off the Western Cape coast, will be particularly remembered for its effect on the African penguin colonies, and the resultant volunteer-driven effort to clean oil off thousands of penguins.

There are two international compensation mechanisms which cover damage and recovery costs associated with a marine oil spill:

- The International Convention on Civil Liability for Oil Pollution (1969), which makes provision for compensation from damages associated with oil spills.
- The International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1971), which subsidises the International Convention on Civil Liability for Oil Pollution on the basis that there has been compliance with the convention.

The South African oil industry has equipment, such as booms and skimmers, lodged in Cape Town, Mossel Bay, Port Elizabeth, East London, Durban and Richards Bay to respond to oil spills in the marine environment. Land-based oil spills are dealt with via 42 trailers, which clean up road and rail tanker accidents along major transport routes (World Energy Council 2003).

7.2.2 Transport pollution

The transport sector has a notable effect on the environment, primarily due to the fact that it produces 'brown haze' (especially in Cape Town and Pretoria), with road transport being the main source of emissions. The sector also contributes to global warming through GHG emissions, and emissions of sulphur dioxide, carbon dioxide, nitrous oxides, carbon monoxide, suspended particulate matter and volatile organic carbons. The associated toxicity or carcinogenic effects of these emissions contributes to deteriorating air quality (Xhali 2002). The orientation of the transport sector towards private cars contributes to this pollution, as do the high emissions from the extensive bus and taxi commuter networks (Xhali 2002). Some of the typical transport-related environmental problems are summarised in Table 7.1.

As a result of the brown haze in the Cape Metropolitan Region, the City of Cape Town has initiated a Brown Haze Action Plan (CCT, undated). There are also government initiatives that will help curb brown haze by phasing out lead in petrol and reducing sulphur in diesel. The Cabinet has approved the phasing out of leaded petrol, and also the reduction of sulphur in diesel to 0.05% which came into effect in January 2006, with a further reduction to 0.005% due in 2010 (World Energy Council 2003). Xhali (2002) recommends the use of alternative fuels such as natural gas and electricity in addition to petrol- and diesel-burning vehicles for public road transport in the longer term.

Table 7.1: Transport-related environmental problems

Source: Davidson (1993)

Scope	***Environmental issue***	***Impacts***
Global	Global warming (GHG emissions)	Impacts on: - ecosystems - hydrology and water - food and fibre production - coastal systems - human health
Regional	Air pollution (emissions of NO_x etc.)	May affect nearby nations
	Marine pollution (emissions of NO_x, SO_x etc.)	Run-off to water resource
National	Air pollution (emissions of CO, HCs, NO_x, SO_2, SPM etc)	Health
	Water pollution	Surface and groundwater runoff
	Land disturbance	Land destruction and waste disposal
	Solid waste	Waste disposal from vehicles and machinery
	Noise and vibrations	Acoustic pollution and vibration effects
	Accidents	Injury and death and / or damage to property from transporting waste
	Socio-cultural	Social and cultural disturbance

7.2.3 Impacts of kerosene as a fuel

Kerosene is a primary energy source used to meet the cooking, lighting and heating needs of some six million households. It is also one of the main causes of death and injury in the 0-4 age group in South Africa (Pasasa, undated), with children often subject to kerosene burns and poisoning. Since informal housing is often high density, kerosene-related fires spread easily, multiplying the consequences. Residential fires accounted for 75% of the deaths of children recorded at the Salt River State Mortuary in Cape Town between 1990 and 1996 (Van Horen 1994). Ingestion of kerosene by children frequently leads to hospitalisation and/or death. Kerosene is also emerging as the cause of health problems as a result of indoor air pollution. It causes respiratory-related diseases, especially in poorly ventilated dwellings (Sparks et al. 2002). Carbon monoxide emissions are also a major concern.

A fuel which has emerged as a good alternative to kerosene, is LPG. Its health and safety risks are an order of magnitude lower than either kerosene or coal (Lloyd & Rukarto 2001) but the cost of LP gas and it's the associated appliances are the main obstacles to its widespread use. A government directive promoting LPG use could help stimulate the mass production necessary to reduce appliance costs. A reduction of the fiscal burden would help with on-the-ground fuel costs (Lloyd & Rukarto 2001).

7.2.4 Coal production and use

7.2.4.1 Water consumption by coal-based electricity production

There are three primary environmental concerns about water use by power stations. The first is degradation of the water quality of associated water sources – for example coal mining affecting the ground water quality in coalfields. The second is the excessive amount of water required by power stations. The third relates to the price paid by Eskom for water, and whether this reflects the actual opportunity cost of water. Eskom has, in fact, paid for the construction of water infrastructure in a number of cases, rather than the Department of Water Affairs and Forestry, as one would expect, so the cost calculations are somewhat complex (Spalding-Fecher & Matibe 2000).

Water consumption depends on various factors, such as the age of the power plant (the newer generation of water-cooled plants improve efficiency), weather conditions (evapotranspiration losses are greater under hot and windy conditions), and water quality (wet-cooled power stations require more water if the water is of a poorer quality) (Eberhard 2000). A large proportion of the generation of coal-fired power is provided by water from three river systems. Dry-cooled power stations incur an efficiency loss of about a percentage point.

With the push towards a stablisation in water pricing (DWAF 1998) it is likely that the costs of water supply to power stations will increase over the coming years. However, based on modelling done by Eberhard (2000), it is unlikely that this will significantly affect the cost of electricity. Nevertheless, sustainable use of water resources should be encouraged.

7.2.4.2 Air pollution and health

Electricity, through coal combustion, is the major contributor to air pollution in South Africa (Van Horen 1994). Most of the country's power stations are situated in the coalfields of Mpumalanga province, with about 90% of the scheduled emissions of dust, nitrous oxide and sulphur dioxide are accounted for by eastern Mpumalanga (Held et al. 1996). Climatological conditions in this region are unfavourable for low-level dispersion because of stable atmospheric conditions (Preston-Whyte & Tyson 1993).

Most of South Africa's higher-grade coal is exported, so the coal used within the country is of a poor quality, with a low energy content and a low economic value (Van Horen 1996a, 1996b). Eskom has therefore invested in particulate matter control rather than reduction of sulphur dioxide and nitrous oxide emissions (Sparks et al. 2002). Bag filters or electrostatic precipitators have been fitted to coal-fired power stations in the Mpumalanga region, removing the smaller remaining particles (Van Horen 1994). Precipitator performance is being improved further by installing flue gas conditioning plants at some power stations (Eskom 2003).

Between 1994 and 1998 particulate emissions were reduced by approximately 50%, while power generation increased by almost 10% (Eskom 2003). Figure 7.1 shows ash emitted per 1kWh of power, with a marked decrease evident between 1992 and 2001. In addition, chimneystacks (up to 220m) have been fitted in areas where low-level dispersal conditions are unfavourable. These have proved effective in penetrating the lower inversion layer (Van Horen 1994).

Air pollution has been reduced over the last 20 years, due to these and other measures. Surveys done since 1994 have shown that low-level sources (burning waste dumps and domestic coal use) are in fact one of the major sources of air pollution (Held et al. 1996). The mining process itself has had important environmental consequences, since land which has been mined needs to be rehabilitated afterwards, and also because miners are also exposed to occupational health hazards associated with coal dust (Van Horen 1996a).

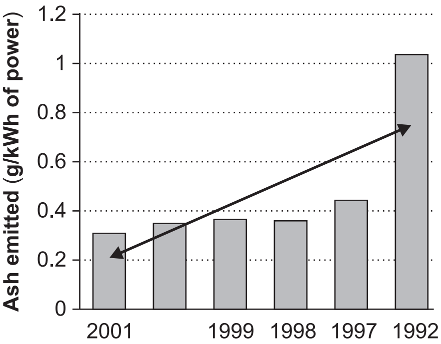


Figure 7.1: Ash emitted per 1 kWh of power
(data provided by Eskom)

In rural areas, where approximately 40% of the South African population lives, wood and coal are used to meet most of poor households' energy needs, which means that people in these households are exposed to high levels of indoor air pollution. Many of these communities are either not grid-electrified or they continue to opt for coal despite being electrified. A coal stove can provide for cooking, space heating and water heating (Williams 1994), and also form a social focal point. To provide the equivalent range of benefits with electricity would mean considerable expense including at least three different appliances – a stove, a heater and a geyser.

Indoor air pollution increases the risks of chronic obstructive pulmonary disease in adults (primarily women) and acute respiratory infections in children, in some cases leading to death. It is also associated with certain cancers (lung cancer, for example), infant mortality, low birth weight, cataracts and tuberculosis (Sparks et al. 2003).

From a sustainability perspective it would be useful in the longer term to consider renewable energy sources in addition to coal (Sparks et al. 2002). Households should also be encouraged, or provided with incentives or opportunities, to move away from using coal to meet their space heating and cooking needs, especially considering the health problems and costs associated with this fuel. At the very least, as much as affordability allows, there needs to be better ventilation in coal-burning households.

7.2.5 Gas-fired power generation

South Africa has two power stations fired by natural gas, with a total maximum capacity of 171MW. The gas brought in from Mozambique has initially been used for Sasol, but the Kudu natural gas field in Namibia is likely to provide fuel for an 800 MW power station, with South Africa importing most of the electricity. While natural gas is considered a better fuel alternative to coal or liquid fuels for electricity generation, its production, processing and transportation by pipeline can also be a major contributor to greenhouse gases through fugitive emissions. Efficiency measures through good housekeeping and prevention of leaks are necessary to bring fugitive emissions down to acceptable levels.

Combined cycle power plants, as opposed to simple cycle gas turbines, would also contribute to reducing GHG emissions because of the relatively high efficiencies of combined cycle plants – of the order of 52%, compared to 30%-35% for the simple cycle. Combined cycle power plants have the added advantages of short installation periods and very low emission levels of NOx. The exhaust gases consist of, typically, 3-3.5% CO_2 (by volume), corresponding to emission level of approximately 0.4kg CO_2/kWh.

7.2.6 Nuclear energy – potential impacts

Koeberg, the only nuclear power station in South Africa, generates 60 tons of high-level radioactive waste annually in the form of spent fuel. Ninety percent of its radioactivity is lost while being stored ten years underwater in spent pools (World Energy Council 2003). Thereafter the 10%-radioactive waste needs to be stored safely so that there is no seepage into groundwater or human exposure to the risks of radiation. Nuclear power creates no air pollution, but the disposal of hazardous waste and other aspects of nuclear plant safety have been much-debated environmental concerns worldwide.

The Pebble Bed Modular Reactor (PBMR), a new type of nuclear power unit, is now being investigated by Eskom Enterprises and will in all likelihood be built at Koeberg. The PBMR technology also has the potential to be exported. An EIA was conducted on the PBMR. The Record of Decision on the EIA for the PBMR was initially approved by the Department of Environmental Affairs and Tourism in 2004.

The NGO Earthlife Africa brought a court case appealing against the Record of Decision, with the assistance of the Legal Resources Centre. The high court ordered a re-consideration of the decision, taking account of the objections by Earthlife. One of the conditions of approval of the EIA was the completion of a Radioactive Waste Management Policy and Strategy by the DME. While the court battle over the EIA continued, such a policy was approved by the Cabinet in 2005. The first principle adopted in that policy was the ‘polluter pays principle’, which states that generators shall bear the financial burden for management of radioactive waste (DME 2005c).

The nuclear energy sector needs to be able to survive economically without the state support which it received in the apartheid years, which means pricing itself low enough so that South Africa can continue in its drive as a competitive manufacturing exporter (Eberhard 1994). The environmental sustainability of nuclear energy in the future depends on how its economic costs balance against its environmental costs and benefits.

7.2.7 Biomass fuel impacts

About 16 million South Africans rely on wood for space heating and cooking (Van Horen 1996a; 1996b). While wood collection is ‘free’, the time needed to collect wood may be lengthy, up to three hours per load several times a week, making it burdensome on the households concerned (CSIR 2000). The indoor air pollution health impacts associated with wood as a fuel are similar to those of coal. There are also vegetation impacts linked to the use of wood as a fuel source with denuding of indigenous vegetation in many areas. On the other hand, in the Cape Flats area of the Western Cape much fuelwood is derived from alien vegetation, particularly Port Jackson willow, so collection of firewood may be of indirect advantage to the environment through the clearing of invasive aliens (Sparks et al. 2003).

Biogas and landfill gas, both derived from organic waste, are two other sources of biomass energy for space heating and lighting. Biogas requires a reliable and appropriate supply of animal and plant material, while landfill gas is generally obtained from landfill sites. General application of either of these gases is therefore limited. However, there are two notable landfill gas sites: the Grahamstown landfill project, which supplies a nearby brick kiln, and the Johannesburg landfills, which provide methane to the chemical industry (CSIR 2000). Landfill gas is produced as a matter of course in landfills, through the decomposition of organic matter. However, it can be an environmental hazard, since it may explode if incorrectly managed, so sealed landfill compartments and extraction wells need to be created (CSIR 2000).

A 1985 study by Williams considered the potential for obtaining biomass energy from crops, since the agricultural sector is capable of converting agricultural land to such uses. However, crops as an energy source have generally not yet taken off, perhaps because this type of production would use up scarce land and water resources that could be used to produce food crops. Bagasse co-generation stations are already used in the sugar and paper and pulp industries, as described in Chapter 4.

7.2.8 Environmental issues related to renewable energies

7.2.8.1 Wind

While the use of wind turbines for the production of electricity is expanding rapidly throughout the world, studies have highlighted three main environmental concerns related to this technology – sight pollution, bird strikes and turbine noise. Some of these studies relate to perceptions rather than realities, and therefore it is important that studies be conducted to determine the effects or potential effects in a particular locality before making any conclusive decisions. While, for example, there has been concern about bird strikes from wind turbines, studies have indicated that migratory birds can fly in large numbers in close proximity to turbines without any mortalities, and that bird collisions with wind turbines are rare events (Toronto Hydro undated). Noise has also been cited as an environmental problem associated with wind turbines, although, at a 350m distance, a car going at 64km/hr emits more noise (55dB) and a heavy-duty truck quite a lot more (65dB) than a wind turbine (35-45dB).

7.2.8.2 Solar

While the production of solar panels can be highly toxic and result in a substantial amount of GHG emission, SHSs in use do not produce any emissions or waste products that adversely affect the environment. However, disposal of SHSs at the end of their lifetime can pose health, safety and environmental problems if not addressed appropriately. This is especially so in cases of extensive deployment of the systems, such as in South African rural areas, where people may not be well informed about some of the hazards of improper handling of the discarded components. Concerns associated with SHS components relate to the disposal of light fixtures, batteries and the solar panels. Some associated aspects of these components, which are largely a ‘product disposal’ rather than ‘use’ concern, are listed in Table 7.2.

Table 7.2: Environmental concerns linked to SHS components

SHS component	*Environmental concern*	*Problems associated with the concern*
Light fixtures	Mercury in fluorescent lamps, broken glass	Mercury contents in the lamps, injury due to broken lamps
Lead-acid batteries	Sulphuric acid in batteries, pure lead, and other heavy metals	Water, food contamination by heavy metals
Solar panels	Crystalline or amorphous silicon	Heavy metals, injury

Light fixtures

Fluorescent lamps are the most common light facilities in SHSs because they are more energy-efficient than incandescent lamps. Their biggest disadvantage, however, is that they contain mercury, a highly persistent and toxic chemical that can build up to dangerous concentrations in fish, wildlife, and human beings. Mercury is essential to the operation of fluorescent lamps. The mercury vapour inside a fluorescent lamp is electrically energised to emit ultra-violet (UV) light. Phosphor, a luminescent material, is coated on the inside of fluorescent lamps. It absorbs this UV energy, which causes it to fluoresce, re-emitting visible light.

Inhaling mercury vapours or indirect ingestion is toxic to the nervous system. Even very low mercury doses can significantly affect a foetus or young child. Depending on the level of mercury in the mother, it can have varying effects on foetal development and health. It can cause physical deformity and affect the brain, spinal cord, and other nervous system functions of the child. Adults who have been exposed to too much mercury might begin to experience trembling hands and numbness, or tingling in their lips, tongues, fingers or toes. These effects can begin long after the exposure occurred. At higher exposures, walking could be affected, as well as vision, speech and hearing (MPCA 1998).

It is therefore important for standards to be set on the mercury content of fluorescent lights. While measures for the disposal of spent lamps might be difficult to administer, a special case could be made for rural areas that are electrified with SHSs, by offering an incentive when a spent fluorescent lamp is delivered for recycling. Education on disposal is vitally important.

Batteries

Heavy metals in the batteries that are used for recharging SHSs are a major concern. These batteries last for an average of three years, so in a community with many SHSs, disposal of batteries at the end of their lifetime can be a serious problem. The major material constituents in lead-acid batteries include lead, lead oxide, lead sulphate, water, sulphuric acid and some traces of antimony and arsenic. To prevent any of the material components from contaminating the food chain, it is important that attention be given to educating rural communities in appropriate handling of scrapped batteries. Service providers should be given the responsibility of disposing of the batteries.

Solar panels

Studies have been done to assess the risks associated with solar panels, for example in cases of fire or broken modules. It has been accepted generally that such risks are negligible or small, but there may be long-term risks that should not be ignored (Alsema et al. 2003). While certain panel materials might be potentially damaging to the environment if exposed, their glass encapsulation reduces the chances of their leaching out of the cell. Double glass encapsulation helps significantly to prevent this. Amorphous silicon panels, however, are known to have little or no toxic materials and thus pose no significant health concerns in terms of their disposal; apart from those associated with disposal of glass material.

There is currently very limited recycling of solar panels. Conventional glass recycling can be applied for glass panels. Consideration should be given, or standards set, for the choice of materials of module encapsulation for panels used in South Africa.

7.2.8.3 Hydroelectric power – environmental aspects

Being a relatively dry country, South Africa does not have much to offer in terms of hydropower generation. There are currently six hydroelectric schemes in South Africa, most of which are operated by Eskom (see Table 7.3). It is generally considered that large hydropower schemes are an environmental concern, however large schemes have no applicability in South Africa. South Africa's unique biodiversity endowment and ecological sensitivity necessitates stringent environmental measures even in the case of small hydroelectric projects, especially given the limited number of fresh water sources in the country.

Table 7.3: Hydroelectricity in South Africa

Station	*Maximum capacity (MW)*	*Location*
Gariep	360	Orange River
Vanderkloof	240	Orange River
Colly Wobbles	42	Mbashe River
Second Falls	11	Umtata River
First Falls	6	Umtata River
Friedenheim	3	
Lydenburg	2	Ncora River
Ncora	2	Ncora River
Piet Retief	1	
Ceres	1	
Total hydro capacity	668	

South Africa has two pumped storage electricity generation schemes, which pump water to an elevated dam from which it is released to generate electricity when needed. One advantage attributed to such schemes is the fact that they re-use water. However, even for what might be seen as a low-environmental-profile scheme, construction of the Palmiet station was subjected to acute environmental scrutiny because of the ecological and biodiversity sensitivity of the project location.

7.3 Critical global issues

7.3.1 Greenhouse gas emissions and climate change

The highly energy-intensive South African economy makes the country one of the highest emitters of GHGs in Africa, and it stands above the OECD region average in energy sector emissions. South Africa was ranked as the world's 14th-highest carbon dioxide emitter from fuel combustion in 2000, and was the 19th most carbon-intensive economy, measuring kg CO_2 / 95$ PPP (IEA 2002). South African per capita emissions are higher than those of many European countries, and more than 3.5 times the average for developing countries (see Table 7.4).

Table 7.4: Fuel combustion CO_2 emissions by intensity and per capita, 2000

Source: IEA (2002)

	CO_2/cap (tons/capita)	***CO_2/GDP (kg/1995 US$)***	***CO_2/GDP PPP (kg/1995 PPP$)***
South Africa	6.91	1.73	0.79
Africa	0.86	1.16	0.43
Non-OECD	2.24	1.73	0.64
OECD	11.10	0.45	0.51
World	3.89	0.69	0.56

Key: PPP = purchasing power parity, GDP = Gross domestic product

Reliance on coal energy sources is the main reason behind South Africa's high emissions profile. Coal-related sources of GHGs in South Africa include electricity generation and the production of synthetic liquid fuels, and energy-intensive industries such as mining, iron and steel, aluminium, ferrochrome and chemicals – the same sectors that make up a large share of South African exports. Other major emission sources include oil refining, coal mining and gas extraction, wood burning, and the burning of coal and oil to produce heat. A summary of South Africa's total emissions in 1994 for major GHGs is shown in Table 7.5.

Table 7.5: Sector emissions, 1990 and 1994

Source: RSA (2000)

Category	***Mt CO_2 Equivalent***							
	CO_2		***CH_4***		***N_2O***		***Aggregated***	
	1990	***1994***	***1990***	***1994***	***1990***	***1994***	***1990***	***1994***
Energy	252.02	287.85	7.29	7.89	1.58	1.82	260.89	297.56
Industrial process	28.91	28.11	69.0	26.0	1.81	2.25	30.79	30.39
Agriculture			21.30	19.69	19.17	15.78	40.47	35.46
Waste			14.46	15.61	0.74	0.83	15.19	16.43
Total							347.35	379.84

Because the specific energy efficiency of many sectors is lower than average (see Chapter 2), the emissions per unit of economic output are high – 45% higher than those of developing countries and 70% higher than the industrialised OECD countries (IEA 2001). Table 7.5 shows that the energy sector contributed about 78% of South Africa's total GHG emissions in 1994, and more than 90% of CO_2 emissions.

The government has been supportive of regional and global initiatives to reduce GHGs and other air pollutants. South Africa ratified the UNFCCC in 1997, thereby accepting the obligation to prepare a national GHG emission inventory by 2000. The latest official published estimate of South Africa's total GHG emissions is for 1994.

In 1998 the government developed a climate change policy discussion document and circulated a national response strategy for public comment. In 2002 South Africa ratified the Kyoto Protocol. In 2000 the South African government compiled the first Initial National Communication to UNFCCC, and after cabinet approval this was submitted to UNFCCC at COP-9 in 2003.

7.3.1.1 Emissions from the synfuel process

Most of the GHG emissions at Secunda are in the form of CO_2, with much smaller amounts in nitrous oxide and methane. This is consistent with both SASOL's reporting and the GHG inventory. Indirect emissions, i.e. those related to electricity generation at Sasol, are not included here, because they are captured under electricity in GHG inventories. Indirect emissions are smaller than direct, less than 10% of total GHG emissions. The emissions from the chemical process at Sasolburg are not included here. Emissions from South African operations of Sasol are the only ones considered, not the Sasol group internationally.

The best available data for direct CO_2 emissions from Fischer-Tropsch process at Secunda indicates that total direct emissions are approximately 50 Mt CO_2 for 2003.

- The 50 Mt CO_2 is a round number, in between the values for SA operations only in 2002/3 (49.1 MtCO_2) and 2003/4 (52.2 MtCO_2) (Kornelius 2005). It also corresponds to a figure of 49.6 Mt CO_2 which was verified with Sasol (Lloyd 2005; Mako & Samuel 1984).
- A higher level of emissions is consistent with more recent reporting of 32 Mt CO_2 at Secunda at 90-98% concentration in a study for carbon capture and storage (Engelbrecht et al. 2004).
- The emissions are significantly higher than the 10.7 Mt CO_2 reported in the 1994 inventory (Van der Merwe & Scholes 1998). While there is a gap of almost ten years in the reporting year, it does seem that this number was too low, probably attributable to using an emission factor of 9.03 t CO_2 / TJ in that study.
- These emissions represent 78% of the direct CO_2 emissions reported for Sasol as a group, including its international operations (Sasol 2004b).

The emission factor for this process is 56 t CO_2/TJ. The energy contained in the coal fed into the Fischer-Tropsch process at Secunda is 894 PJ (energy output at 35% efficiency is 313 PJ)(DME 2003a). Of the total carbon in the coal input to the process, some 64% is emitted as CO_2 to the atmosphere (27% in concentrations around 10-15%, 37% in high concentrations of 90-98%), 32% goes into products and 4% is 'lost' as tars or phenols (Lloyd 2005).

7.3.2 Other global agreements or protocols

South Africa has been active in the environmental sphere, culminating in its hosting of the WSSD in 2002 in Johannesburg. The government has signed and ratified a number of conventions and treaties that address energy and environment conservation for sustainable development. It has signed the UNFCCC and the Montreal Protocol, and some other conventions linked to sustainable development including:

- Convention to Combat Desertification (Paris, 1994);
- Convention Relative to Preservation of Fauna and Flora in their Natural State (London, 1993);
- Convention on Biological Diversity (1992);
- Convention on the Prevention of Marine Pollution from Ships (1973);
- Convention on International Trade of Endangered Species of Wild Fauna and Flora (1973);
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (1972);
- Convention Concerning the Protection of World Cultural and Natural Heritage (1972);

- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971); and
- the African Convention on the Conservation of Nature and Natural Resources (1968)

7.4 Outlook for the future

7.4.1 Future environmental policy goals

Energy and economic development in the context of sustainable development requires a sound framework for environmental performance. Any environmental policy framework should be set up on a three-part basis: voluntary, regulatory, and market-based.

5.4.1.1 Voluntary mechanisms

Voluntary mechanisms refer to non-obligatory agreements or statements of corporate responsibility that commit organisations to appropriate environmental performance. Such initiatives are usually made on the understanding that the parties concerned will contribute positively to environmental conservation and avoid any form of degradation. Such initiatives are becoming more and more popular worldwide, often linked to the sense of social responsibility that companies or organisations feel they have towards communities. The government can play a pivotal role here, in appealing to communities in different sectors to become more active in environmental management. While voluntary initiatives are not binding in nature, they can be very effective.

5.4.1.2 Regulatory mechanisms

These are basically command-and-control measures, whereby the government decides to set standards on issues such as emissions, discharges and noise. Regulatory mechanisms require a legislative framework which makes non-compliance a criminal offence. For such mechanisms to be successful, efficient enforcement is necessary. Such measures can be effective forms of environmental management, but their administration is usually difficult and expensive, as they require institutions for monitoring, regulation and enforcement.

5.4.1.3 Market-based mechanisms

Market-based instruments work by instituting fiscal instruments (taxes and charges) so that the polluter or offender pays in monetary terms. The assumption is that the taxes and charges will prompt a change in behaviour through market signals, as certain undertakings, lifestyles and acquisitions become very expensive. This mechanism is usually considered the least-cost option for controlling environmental degradation, and its use has grown significantly in many countries, as it helps control the environment and act as a source of revenue to the government. Depending on the government budget system, the revenue generated can be marked for specific environmental programmes.

Of the three mechanisms described, no single mechanism can be said to be the most suitable. A combination of the three mechanisms in the appropriate proportions is the best approach. The government can decide on the mix of the three mechanisms, based on the specific circumstances. Further policy decisions may involve shifting a particular mechanism from one category to the other, for example a voluntary mechanism aspect could evolve into a regulatory mechanism at some stage.

7.4.2 Future commitments on GHG reductions

Being a non-Annex I country, South Africa does not have emission reduction targets for the first commitment period, which runs from 2008-2012. However, with one of the highest

GHG emission profiles among developing countries, the South African government recognises that adequate measures will have to be taken as the effort against escalating GHG emissions becomes more urgent.

Participation by South Africa and other developing countries could take many forms, the extreme case being the taking on of quantified emission reduction targets. One approach, which has been the cause of considerable debate amongst developing countries, has been that of implementing policies for sustainable development. It is based on the premise that some developing countries already have policies and measures that have been taken in relation to development, which have the co-benefits of also reducing GHG emissions reduction. 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 individual country's national development objectives and priorities, and on streamlining these to meet sustainable development economic, environmental and social criteria. This can be achieved either by putting in place more stringent policies or by implementing new measures. Together, such policies and measures could shift the country's development path to become more sustainable (Winkler et al. 2002).

This approach would not only lead to reduction of GHG emissions, it would also acknowledge each country's unique circumstances and development objectives. For South Africa, the SD-PAMs approach would focus on development objectives of economic growth, job creation and access to key services, such as housing, water, transport, and access to modern energy services.

Part II

SCENARIOS OF FUTURE ENERGY POLICIES AND INDICATORS OF SUSTAINABLE DEVELOPMENT

Part II of this report identifies and models scenarios for future energy policies for both demand- and supply-side interventions. Chapter 8 identifies policy options for the scenario modelling, analysing in greater detail a selection of policies from Part I. Chapter 9 describes the modelling framework and the key drivers of the reference case. The base reference case is close to the government's Integrated Energy Plan (DME 2003a) and the second National Integrated Resource Plan (NIRP) (NER 2004a). A set of energy policy cases is modelled and compared to the base case.

Chapter 10 models results for each of the policy options. Nine policies are analysed:

- *Higher energy efficiency in industry.* Industrial energy efficiency meets the national target of 12%, less final energy consumption (compared to business-as-usual). This is achieved through greater use of variable speed drives, efficient motors, compressed air management, efficient lighting, HVAC system efficiency, and other thermal saving.
- *New commercial buildings designed more efficiently.* HVAC systems are retrofitted or new systems have higher efficiency; variable speed drives are employed; efficient lighting practices are introduced; water use is improved with heat pumps and solar water heaters. In addition, fuel switching for various end uses is allowed.
- *Cleaner and more efficient use of energy in the residential sector.* More use is made of water heating through solar water heaters (SWHs) and geyser blankets. The costs of SWHs decline as new technology is accepted more widely in the South African market. Compact fluorescent lights (CFLs) spread more widely, with a further reduction in costs. The shells of houses are improved by insulation, prioritising ceilings. Households switch from electricity and other fuels to liquid petroleum gas (LPG).
- *Biodiesel production increases.* The supply of biodiesel partially displaces high dependence on petroleum. Biodiesel production increases to 35 PJ by 2025, with a maximum growth rate of 30% per year from 2010. Biodiesel crops do not displace food production, and sustainable production means the fuel is effectively zero-carbon.
- *The share of renewable electricity increases.* The share of renewables increases to meet the target of 10 000 GWh (gigawatt-hours) by 2013. The shares of energy from solar

thermal, wind, bagasse and small hydroelectric sources increase beyond the base case. New technology costs decline as global production increases.

- *Pebble bed modular reactor (PBMR) modules increase the capacity of nuclear energy production.* Nuclear capacity is increased to 4 480 MW by introducing 32 PBMR modules. Costs decline with national production and initial investments are written off.
- *An increase in imported hydroelectricity.* The share of hydroelectricity imported from the Southern African Development Community (SADC) region increases from 9.2 TWh in 2001, as more hydroelectric capacity is built in southern Africa.
- *An increase in imported gas.* Sufficient gas is imported to provide 5 850 MW of combined cycle gas turbines, compared to 1 950 MW in the base case.
- *Tax on coal for electricity generation.* The use of economic instruments for environmental fiscal reform is being considered by the national Treasury. The option of a fuel input tax on coal used for electricity generation is modelled.

Chapter 11 consolidates the assessment of the policy options against indicators of sustainable development. Chapter 12 presents conclusions.

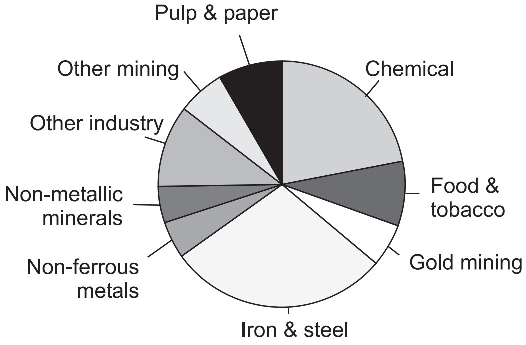
8

Identifying and modelling policy options

Harald Winkler, Mark Howells and Thomas Alfstad

8.1 Industry and energy efficiency

Industry is the biggest consumer of final energy, using 42% of final energy in the country. The industrial sector is split into eight divisions: mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco, and other. In this chapter we consider the output of each of these eight divisions relative to GDP, as well as changes in the energy intensity of each division. Combining output and energy intensity, we develop a simple forecasting model and determine estimates that are useful in assessing energy requirements. Throughout the discussion we refer to the year 2000, which we have taken as the 'start year' of our modelling.



Total: 1335 PJ

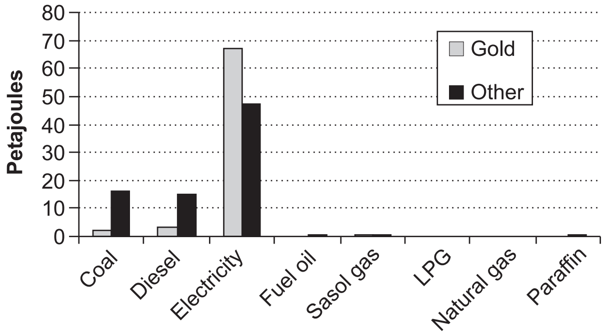
Figure 8.1: Energy in industrial divisions, 2000

8.1.1 Mining

The industrialisation of South Africa began with the discovery of diamonds and gold in the 1870s. South Africa has since been found to have the world's biggest reserves of chrome, gold, manganese, platinum-group metals and vanadium, and vast reserves of several other minerals. Historically, gold has been an important driver of South Africa's economy, so that mining in South Africa may be logically divided into 'gold' and 'other metals and minerals'.

Because of declining ore grades, gold production has been dropping steadily, from 1 000 tons in 1970 to 395 tons in 2001. The energy required to mine a unit of gold has increased fourfold in this period, because the mines are going deeper and have to process more ore for each ton of gold produced.

Within South Africa, the gold mines are the single greatest users of electricity across all sectors, and the amount of energy used for gold mining is only slightly less than the total energy used by all the other mining sectors combined. Electricity constitutes over 90% of the energy use on the gold mines. Unlike the gold sector, the other mining sectors are growing and have good prospects – these sectors get about 75% of their energy from electricity.

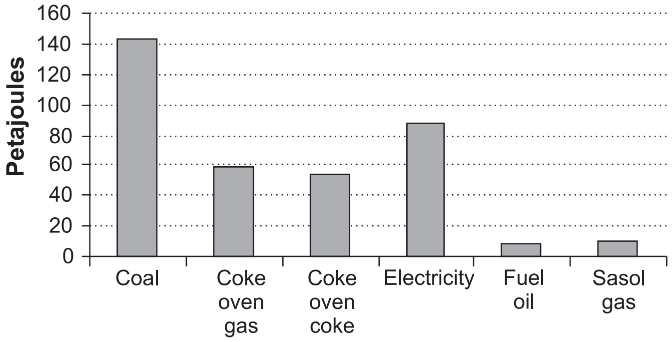


Total: 153 PJ

Figure 8.2: Energy in gold mining and other mining, 2000

8.1.2 Iron and steel

South Africa has all the resources required for steel making except coking coal (coke). In 1996 South Africa produced 6.5 million tons of steel, and since that time the industry has modernised towards specialist mills and mills using new technologies that do not require coke. An example is Saldanha Steel, which uses the new Corex and Midrex processes to make hot-rolled steel. There has also been considerable investment in stainless steel capacity.



Total: 361 PJ

Figure 8.3: Energy used in iron and steel production, 2000

8.1.3 Chemicals

South Africa's chemical and petrochemical industry is well developed and produces plastics, fertilisers, explosives, agrochemicals and pharmaceuticals. South Africa's special expertise and experience in making chemicals from coal gives it a unique advantage in this field. Coal has been the main feedstock in the past but natural gas will replace some of this in future.

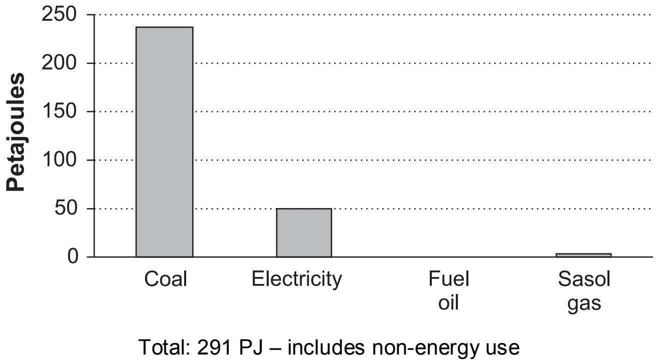


Figure 8.4: Energy used in the production of chemicals, 2000

8.1.4 Non-ferrous metals

The biggest energy users in the non-ferrous metals division are aluminium and titanium smelting. South Africa is the world's second largest producer of titanium minerals, manufacturing over 662 000 tons of aluminium in 2001. An expansion of the aluminium smelting capacity is expected, with investment in a new smelter at Coega in the Eastern Cape. Over 95% of the energy used in this division is electricity.

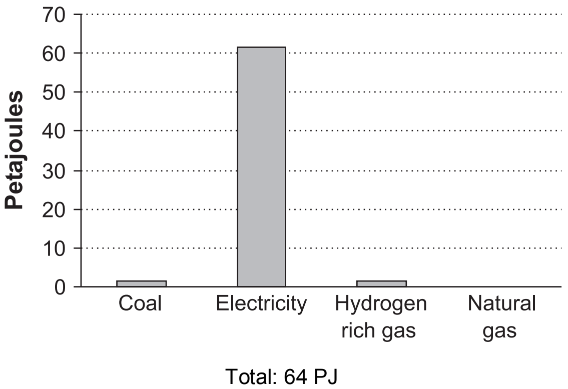


Figure 8.5: Energy used in the production of non-ferrous metals, 2000

8.1.5 Non-metallic minerals

This division makes cement, bricks and glass. Nearly all South African cement is made using the efficient dry kiln method, but some brick making still uses the inefficient 'clamp' kilns. South Africa is self-sufficient in all of these products.

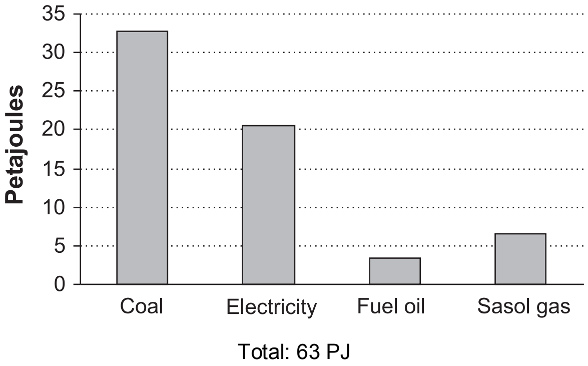
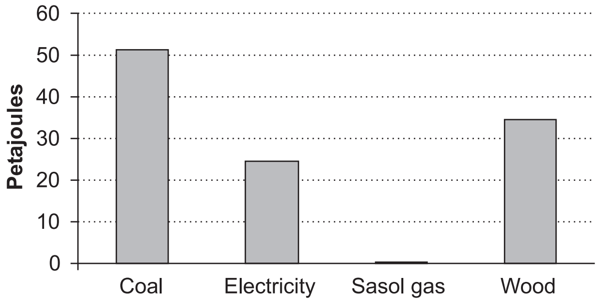


Figure 8.6: Energy used in the production of non-metallic minerals, 2000

8.1.6 Pulp and paper

Only slightly more than 1% of South Africa's land is forested; however this land provides good conditions for growing commercial softwood and hardwood species. South Africa has a highly developed pulp and paper industry, producing over 4.5 million tons a year, and marketing its products internationally. South Africa produces the cheapest pulp in the world. Modern pulp and paper mills use 'black liquor' to produce most of their energy requirements, the remainder coming from coal, gas, heavy furnace oil (HFO) and imported electricity.

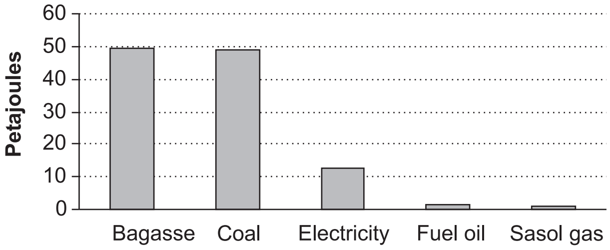


Total: 110 PJ

Figure 8.7: Energy used in the production of pulp and paper, 2000

8.1.7 Food, tobacco and beverages

The single biggest energy user in this division is the sugar refining industry, which gets much of its energy requirements from bagasse (sugarcane residue).

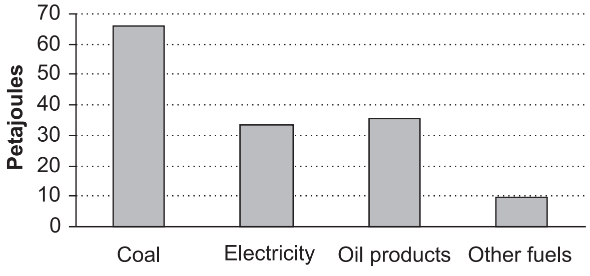


Total: 113 PJ

Figure 8.8: Energy used in manufacturing food, tobacco and beverages, 2000

8.1.8 Other

This division includes other manufacturing, construction, textiles, wood products and various other activities in industrial processing and fabrication. It includes large and small industries. The division incorporates high-value economic activity and it is expected that it will grow more quickly than most other divisions.



Total: 145 PJ

Figure 8.9: Energy used in 'other' industry, 2000

8.1.9 Energy intensity changes

Let us now consider changes in energy intensity. To do this we consider energy consumption per unit output for each division. For modelling purposes we need to choose a relevant indicator of output, this is generally either a physical indicator or an indicator of value added. The choice depends primarily on the consistency and convenience of the indicator chosen. Generally, where value added was more a function of market volatility than of local production quantities, we used physical output as a preferred indicator. However, in cases where there was little consistency in physical output (e.g. in the wide array of foodstuffs produced) value added was preferred. (For an in-depth discussion of local indicator options, see Hughes et. al. 2002.)

Except for electricity, the record of historical disaggregated energy consumption for South Africa is sketchy. Nevertheless it is known that fuel substitution has been limited (Dutkiewicz and Stoffberg 1991). In the absence of physical limitations, extreme price hikes, or big policy interventions, we can expect minimal fuel switching (DME 2003).

Table 8.1 summarises our findings. In general, energy intensity relative to that of 2000 decreases over time with process and efficiency improvements. The exceptions are changes within an industry, or increased beneficiation. For example in gold mining, as gold has had to be mined from greater depths, more energy is used. In the iron and steel industry, on the other hand, the level of local beneficiation is expected to increase, resulting in a drop in energy intensity per unit of value added, as opposed to the gold mining sector, where there is an increase in energy intensity per ton of gold produced.

Table 8.1: Energy intensity data and projections

Source: Howells (2004)

Sector/sub-sector	***Year***	***1990***	***1995***	***2000***	***2005***	***2010***	***2015***	***2020***
	Activity measure	***Intensity data with 2000=100***						
Mining								
Gold	Energy / Physical output	75	88	100	112	125	137	150
Platinum	Physical output	107	102	100	99	98	97	96
Coal	Physical output	105	102	100	99	98	98	97
Iron ore	Physical output	104	102	100	99	99	98	98
Copper	Physical output	87	95	100	103	105	106	107
Diamond	Physical output	169	126	100	86	76	69	63
Chrome	Physical output	126	110	100	95	91	88	86

Sector/sub-sector	***Year***	***1990***	***1995***	***2000***	***2005***	***2010***	***2015***	***2020***
	Activity measure	***Intensity data with 2000=100***						
Asbestos	Physical output	58	84	100	109	114	119	123
Manganese	Physical output	102	101	100	100	99	99	99
Rest of mining	Value added	103	101	100	99	98	98	97
Industry								
Food, beverages & tobacco	Value added	79	92	100	104	107	110	111
Textile, cloth & leather	Value added	10	67	100	118	131	140	148
Pulp and paper	Physical output	92	96	100	102	103	104	105
Chemicals	Energy / value added	109	103	100	98	97	96	95
Non-metallic minerals	Physical output	82	92	100	104	107	109	111
Iron & steel	Physical output	81	91	100	105	108	110	112
Precious & non-ferrous metals	Physical output	94	97	100	101	102	103	104
Rest of basic metals	Physical output	54	78	100	111	118	123	128
Rest of manufacture	Value Added	97	99	100	101	101	101	102

8.1.10 Structural change in industry

Next, let us consider structural change within the economy. Typically, as economies develop they move from heavy industry to service-based businesses. That is not to say that heavy industry declines, but rather that there is a decline in its relative contribution. Historically, this has been the case in South Africa. Table 8.2 below shows an index of sector output divided by economic growth, normalised so that 2000 has a value of 100% for illustrative purposes. This trend is projected into the future in the last four columns.

Table 8.2: Index of output to GDP for various manufacturing and mining sectors (%)

	1990	***1995***	***2000***	***2005***	***2010***	***2015***	***2020***
			Mining sector				
Gold	203	155	100	76	57	43	33
Platinum	74	90	100	104	103	100	96
Coal	94	102	100	99	92	85	79
Iron ore	106	109	100	99	94	89	84
Copper	170	127	100	87	73	61	52
Diamond	90	87	100	104	103	100	96
Chrome	82	80	100	104	102	97	93
Asbestos	1461	478	100	82	67	56	47
Manganese	114	98	100	96	90	83	77
Rest of mining	99	102	100	106	96	87	79

			Manufacturing sector				
Food beverages & tobacco	109	110	100	97	94	90	87
Textile, cloth & leather	477	90	100	85	74	66	60
Pulp and paper	97	108	100	99	97	94	91
Chemicals	90	113	100	103	104	102	101
Non-metallic minerals	117	116	100	97	94	90	87
Iron & steel	104	100	100	95	93	89	86
Precious & non-ferrous	57	66	100	113	106	95	87
Rest of basic metals	129	82	100	95	88	83	79
Rest of manufacture	89	102	100	101	100	97	94

8.1.11 Demand projections

Following the United Nations Development Programme's econometric approach (UNDP 1997), an electricity forecast was then derived using the projection of energy intensity change (see section 8.1.9) and the projections of structural change in Table 8.2 above. The forecast assumes that shares of fossil fuels remain constant in the reference case, which is consistent with the IEP (DME 2003a) and past trends (Dutkiewicz and Stoffberg 1991). The resulting projections of industrial electricity demand are shown in Figure 8.10 below. These projections assume a GDP growth rate of 2.8% – the rate chosen for the most recent electricity expansion plan (NER 2004a).

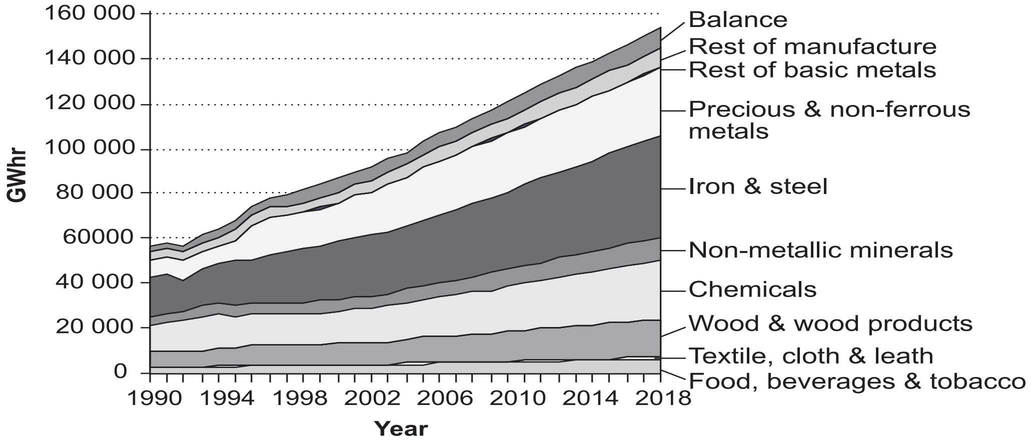


Figure 8.10: Electricity forecast for the industrial sector

8.1.12 Implementing policy options

On the demand side, industry is a major energy user. For the industrial sector we examined the policy objective of meeting the target stated in the government's energy efficiency strategy (DME 2004a). This target is a 12% reduction in final energy consumption by 2014, relative to business-as-usual projections for energy consumption. The model was constrained to meet this overall target, giving insight into which energy efficient interventions had to be chosen to implement the policy. We examined the penetration rates of individual technologies or behavioral changes, taking into account that there may be regulatory, technical and other barriers to actually achieving such rates.

The energy efficiency strategy's 12% energy-savings target was expressed in relation to the forecast national energy demand at that time. It was based on the business-as-usual baseline scenario for South Africa modelled as part of the National Integrated Energy Plan (2003), which uses energy consumption data for the year 2000. The target also assumed that the energy efficiency interventions outlined in this strategy would be undertaken – most of them low cost interventions that could be achieved with minimal investments. These energy efficiency improvements are achieved through a range of interventions: economic and legislative means, information activities, energy labels, energy performance standards, energy audits, energy management and the promotion of efficient technologies (DME 2004a).

While the DME document covers all forms of energy, the National Electricity Regulator (NER) has approved policy for efficiency in the electricity sector in particular, with an 'energy efficiency and demand side management policy' (NER 2003b).

The rationale for adopting the energy efficiency strategy is to meet a series of development goals. The goals South Africa hopes to meet can be grouped according to the three themes of social sustainability, environmental sustainability, and economic sustainability.

Table 8.3: Goals to be met by energy efficiency

Source: DME (2004a)

Social sustainability

Goal 1: Improve the health of the nation. Energy efficiency reduces the atmospheric emission of harmful substances such as oxides of sulphur, oxides of nitrogen, and smoke. Such substances, known to have an adverse effect on health, are a primary cause of common respiratory ailments.

Goal 2: Job creation. Spin-off effects of energy efficiency implementation. Improvements in commercial economic performance, and uplifting the energy efficiency sector itself, will contribute to nationwide employment opportunities. Energy is a necessary but not sufficient condition for job creation.

Goal 3: Alleviate energy poverty. Energy efficient homes not only improve occupant health and well-being, but also enable the adequate provision of energy services to the community at an affordable cost.

Environmental sustainability

Goal 4: Reduce environmental pollution. Energy efficiency will reduce the local environmental impacts of energy production and use

Goal 5: Reduce CO_2 *emissions.* Energy efficiency is one of the most cost-effective methods of reducing GHG emissions, and thereby combating climate change. Addressing climate change opens the door to using the novel financing mechanism of the Clean Development Mechanism (CDM) to reduce CO_2 emissions.

Economic sustainability

Goal 6: Improve industrial competitiveness.

Goal 7: Enhance energy security. Energy conservation will reduce the necessary volume of imported primary energy sources, crude oil in particular. This will enhance the robustness of South Africa's energy security and increase the country's resilience against external energy supply disruptions and price fluctuations.

Goal 8: Defer the necessity for additional power-generation capacity. It is estimated that the country's existing power-generation capacity will be insufficient to meet the rising national maximum demand by 2007-2012. Energy efficiency is integral to Eskom's Demand Side Management programme, contributing 34% towards the 2015 demand reduction target of 7.3 GW.

The specific programmes that constitute the policy, which are being considered to meet the target (12% reduction in final energy consumption by 2014), include the following measures, all of which assume a high level of awareness:

- energy efficiency standards;

- appliance labelling;
- education, information and awareness;
- research and technology development;
- support of energy audits;
- monitoring and targeting;
- green accounting.

In order to determine the potential savings that may accrue as a result of any energy efficiency policy, it is necessary first to determine the demand for energy end-use. Typically, coal is used either for thermal purposes (boilers and furnaces), and oil for a mix of thermal and motive purposes (ERI 2001). The apportioning of electricity is more complex, and we estimated an end-use demand for electricity by industry (Howells 2004a), which is reported in Table 8.4.

Table 8.4: Percentage of end-use of electricity by the industrial sector

Source: Howells (2004a)

	Food & beverages	***Textiles***	***Wood & wood products***	***Chemicals***	***Iron & steel***	***Non-ferrous metals***	***Rest of basic metals***	***Rest of manufacture***	***Non-metallic minerals***
Indirect uses – boiler fuel	2	1	3	1	0	0	0	1	0
Process heating	4	5	6	3	39	1	17	10	8
Process cooling & refrigeration	24	7	0	6	1	0	0	5	0
Compressed air	8	10	38	10	8	0	11	9	14
Other machine drive	44	50	38	53	40	2	56	47	72
Electro-chemical processes	0	0	0	18	2	95	17	11	0
Other process use	0	1	1	0	1	0	0	1	0
Facility HVAC	8	15	4	4	3	1	0	8	3
FAcility lighting	3	10	7	3	4	1	0	7	3
Facility support	2	2	1	1	1	0	0	2	0
Onsite transportation	0	0	0	0	0	0	0	0	0

We combined this end-use apportioning with a detailed industry-by-industry sector energy forecast (NER 2004; Howells 2004b) in order to determine a forecast for the end-use of energy for the industrial sector as a whole. It was then possible to estimate the total potential savings by using assumptions about the savings potential of each energy efficiency measure by end-use. In doing so, we assumed that an increased proportion of the technical potential would be realised, depending on the policies implemented. Hughes et al. (2003) estimate this as a function of each specific programme. We adopted a conservative estimate that set an upper limit to the savings that could be realised. The specific measures we considered are described by Howells and Laitner (2003) and Trikam (2002). The list below itemises the measures we considered, their payback and proportion of fuel saved:

Variable speed drives: These drives reduce unnecessary power consumption in electrical motors with varying loads Typical paybacks are 3.6 years, conservatively 2.2% of industrial electricity can be saved.

Efficient motors: (ERI 2000a) These motors are available at higher cost. Efficient motors can reduce power consumption, but may require modifications because running speeds are generally higher than for inefficient motors. Typical paybacks are seven years, conservatively 2.3% of industrial electricity can be saved.

Compressed air management: (ERI 2000a) This measure is easily achieved and often results in significant savings at low cost. Typical paybacks are 0.9 years, conservatively 3.2% of industrial electricity can be saved.

Efficient lighting: (ERI 2000a) These measures take advantage of natural lighting, more efficient light bulbs and appropriate task lighting. Typical paybacks are 3.6 years, conservatively 1.9% of industrial electricity can be saved.

Heating, ventilation and cooling: ((ERI 2000b) These measures are for maintaining good air quality and temperature and can commonly be improved through better maintenance and the installation of appropriate equipment. Typical paybacks are 2.2 years, conservatively 0.6% of industrial electricity can be saved.

Thermal saving: (ERI 2000b) Thermal saving refers to more efficient use and production of heat. For steam systems in particular we consider condensate recovery and improved maintenance. Typical paybacks are 0.8 years, conservatively 1.4% of industrial electricity, 10% oil and 15% coal can be saved.

Confidence that potential energy efficiency savings can be realised in practice can be improved by measurement and verification. This depends to a large extent on the institutional capacity in the country. In the case of South Africa, institutional infrastructure already exists to measure and verify the implementation of energy efficiency interventions in industry.

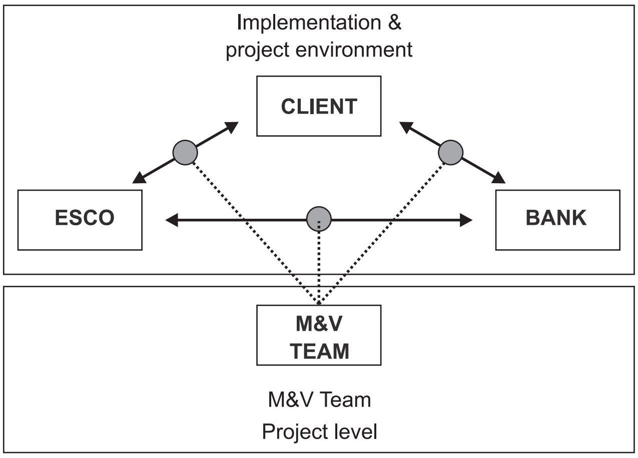


Figure 8.11: Institutions involved in measuring and verifying energy efficiency savings in South Africa
Source: Grobler & Den Heijer (2004)

Figure 8.11 shows the South African institutions involved in measuring and verifying energy savings. Eskom, the electric utility, has a demand-side management programme. The implementation of the programme is outsourced to energy service companies (ESCOs), which assist clients in industry, commerce and residential sectors. The ESCOs carry out specific interventions for companies in industry (the clients in Figure 8.11). Four universities in South Africa are involved in measurement and verification (M&V). These

M&V teams are employed by Eskom to measure the savings against an energy baseline established prior to the intervention. After the intervention, the teams measure energy consumption by once-off use of instrumentation, or long-term data recording. Taking a conservative approach to energy savings, the M&V teams report only energy savings that can be verified, and submitting these reports to the National Electricity Regulator (not shown in the figure) and to the client. Table 8.5 gives estimates of electricity savings potential by end use (rather than the totals).

Table 8.5: DSM interventions and their potential (stand alone) savings by end use

Source: Howells (2004a)

Use of electricity / measure considered	*Steam system*	*Other thermal measures*	*Efficient motors*	*VSDs*	*Efficient lighting*	*Compres-sed air saving*	*HVAC*	*Refriger-ation*	*Load shifting*
Indirect uses - boiler fuel	15%	5%							
Process heating		5%							
Process cooling and refrigeration				10%					20%
Machine drive (inc. compressed air)			5%	5%		15%		15%	
Electro-chemical processes									
Other process use									
Facility HVAC			5%	10%			30%		20%
Facility lighting					40%				
Facility support									
On-site transportation									

8.2 Commercial energy use

8.2.1 Definition of commercial sector and commercial sector activity

The commercial sector is an aggregation of the economic sectors defined under Standard Industrial Classification (SIC) codes 6, 8, and 9. Table 8.6 shows the breakdown of commercial sub-sectors. All public sector activities are included under SIC 9.

Table 8.6: Commercial sub-sectors by SIC code

SIC	*Description*
6	**Trade, catering and accommodation**
61	• Wholesale trade
62	• Retail trade
631	• Accommodation
632	• Catering
8	**Finance, property and business services**
81	• Financial institutions
82	• Insurance institutions
83	• Auxiliary activities
84	• Real estate

85	• Renting of equipment
86	• Computer activities
87	• Research and development
88	• Other business activities
9	**Community, social and personal services**
91	• Public administration
92	• Education
93	• Medical and health services
94-99	• Other services

The activities of the commercial sector are mainly confined to buildings such as offices, warehouses, shops, places of accommodation, restaurants, educational facilities and healthcare facilities. Energy-use in the commercial sector therefore largely constitutes energy use for buildings. For this reason, the driver of energy demand was taken as the total floor area of commercial buildings and demand was thus specified as a minimum required energy service per square metre of floor space.

8.2.2 Energy use patterns in the commercial sector

Table 8.7 shows fuel use in the commercial sector as estimated by several organisations. About 75% of the fuel used is in the form of electricity, while the remainder is mainly coal, with small amounts of methane-rich gas, liquid petroleum gas (LPG) and paraffin also being consumed.

Table 8.7: Energy use in the commercial sector (PJ)

Source	*Year*	*Electricity*	*Coal*	*Methane-rich gas*	*Paraffin*	*HFO*	*LPG*
This study	2001	64	20	1.1	0.15	3.5	12
DME	2001	66	36	0.24	0.15	3.5	12
IEA	2000	62	17	1.2	0.13	-	-
Beyond 2020	1999	64	21	1.0	0.17	-	-
NER	2001	29	-	-	-	-	-

This study identified six energy service demands for the commercial sector:

- cooling;
- lighting;
- refrigeration;
- space heating;
- water heating; and
- other (cooking, personal computers, printers etc).

Figures for the distribution and market shares of fuels for the different end uses were taken from De Villiers (2000). Total floor space in 2001 has been estimated at 77 million square metres (De Villiers 2000). Using the consumption details for the commercial sector (Table 7 above), the energy service demands per square metre were derived (see Table 8.8. All energy intensities are assumed to remain constant throughout the time period 2001-2025 except for the services grouped as ‘other’, for which the energy intensity is expected to increase by 0.5% per year.

Table 8.8: Useful energy intensity of commercial end-use demands

Demand	*Useful energy intensity [MJ/m^2/annum]*
Cooling	911
Lighting[*]	800
Refrigeration	48
Space heating	163
Water heating	116
Other	145

[*] Lighting service demand is measured in an artificial lighting unit based on efficiencies (lumens/watt) relative to that of incandescent lamps.

8.2.3 Characteristics of energy demand technologies

The energy demand technologies considered in this study are listed in Table 8.9. which also details their basic characteristics. Actual technology and appliance stocks are a lot more diverse than those reflected here, but we believe the list to be a reasonable aggregation.

Table 8.9: Basic technical and economic assumptions for commercial sector demand technologies

Fuel consumed	*Device*	*Year 2000 efficiency or COP*[a]	*Year 2025 efficiency or COP*	*Life-time (Year)*	*Residual capacity (PJ/a)*	*Investment cost (R/GJ/a)*	*O&M cost (R/GJ)*
			Cooling				
Electricity	Air-cooled chillers	2	3.1	15	3.51	200	
	Central air conditioners	3	4.1	15	42.07	123	
	Heat pumps (air)	2.2	3.1	15	14.02	322	
	Room air conditioners	2	3.2	15	10.52	168	
			Lighting				
Electricity	CFLs	400%	400%	5	3.69	37.7	14.7
	Fluorescents	450%	450%	5	43.08	74.8	8.4
	Halogen	200%	200%	2	1.23	13.6	10.4
	Incandescents	100%	100%	1	4.30	45.2	11.2
	HIDs[b]	700%	700%	6	9.23	5.5	15.4
			Refrigeration				
Electricity	Refrigerators	1	1	15	-	-	-
			Space heating				
Electricity	Heaters	100%	100%	15	5.10	230	-
Coal	Heaters	80%	80%	15	7.17	383	-
Methane rich gas	Heaters	92%	92%	15	0.306	383	-

Fuel consumed	***Device***	***Year 2000 efficiency or COP[a]***	***Year 2025 efficiency or COP***	***Life-time (Year)***	***Residual capacity (PJ/a)***	***Investment cost (R/GJ/a)***	***O&M cost (R/GJ)***
Water heating							
Electricity	Heaters	100%	100%	15	2.04	31	-
Coal	Heaters	80%	80%	15	6.02	46	-
Methane rich gas	Heaters	92%	92%	15	0.76	46	-
Paraffin	Heaters	91%	91%	15	0.14	46	-
LPG	Heaters	91%	91%	15	0.01	46	-
Other							
Electricity	Appliances	100%	100%	5	8525	-	-
Coal	Appliances	75%	75%	5	2640	-	-
LPG	Appliances	90%	90%	5	3	-	-

Notes:

a) COP: Coefficient of performance – ratio of output heat to supplied work. This coefficient is used for space cooling and refrigeration, rather than the more usual measure of efficiency.

b) High-intensity discharge lamps (includes mercury vapour and metal halides).

8.2.4 Demand projections

Service demand is linked to floor space and useful energy intensity. Two sets of assumptions are thus needed to project future service demand: time series data for total floor space (in square metres) and future changes in useful energy use per square metre. Floor space is assumed to depend on total sales in the commercial sector. This study uses the Industrial Development Corporation's projections of future sales in the sector up until the year 2015 (IDC 1999). For the remainder of the period the average growth rate from 1990 to 2015 was used to extend the time series. In doing this we assumed that the growth in floor space would be proportional to the sales growth, at a ratio of 0.7. This means that for every percent in sales growth, the total floor area would grow by 0.7%, which again reflects an assumption of a more efficient use of floor space (rather than more people per area). The resulting projection is shown in Table 8.10.

Table 8.10: Projection of total commercial floor area, 2000 to 2025

	2000	***2005***	***2010***	***2015***	***2020***	***2025***
Floor space (million m^2)	75.2	86.4	102	120.5	142.7	169.3

8.2.5 New building thermal design

HVAC systems are the biggest consumers of energy in the commercial sector. The most important influence on energy use is the design of the building. A new building envelope design can significantly reduce energy consumption. The following measures are considered to reduce energy consumption in new buildings:

- optimisation of thermal mass for local climate;
- optimal insulation;
- glazing;
- correct orientation; and
- building shape.

We assumed that a 40% reduction in final energy demand for HVAC per square metre would be achieved through these measures compared to the baseline (De Villiers 2000) with a five-year payback period. Since this aggregated value is highly uncertain, we assumed that 30% reduction is achievable for one sixth of floor space and 50% reduction is achievable for another sixth of floor space at the same cost. In other words, reductions would be possible for a third of the floor space, at two different levels of energy saving. Similar distributions were also assumed for all subsequent measures.

The barriers to improved thermal design are the increased initial cost, weakened incentives (the developer does not usually pay the energy bill, the tenants do), and lack of training of architects and consulting engineers in efficient building practices.

8.2.6 HVAC retrofit

Options for HVAC retrofit include:

- switching off of air-conditioning when there are no occupants;
- eliminating re-heat, in which pre-conditioned air is reheated in a heating coil in the duct system;
- preventing the mixing of hot and cold air;
- new air-conditioning set-points;
- ventilation by outside air and night cooling;
- use of evaporative cooling; and
- use of computerised energy management systems.

It is assumed that 35% of energy consumption is achievable for 50% of existing buildings through a combination of these measures (De Villiers 2000). The overall payback period is estimated at three years. Barriers include lack of awareness by building owners, and a general perception that energy services are not an integrated part of the commercial activity, with the result that not enough attention is given to energy services in cost analysis.

8.2.7 Efficient HVAC systems for new buildings

The same options listed in section 8.2.6 above apply to new buildings. We assumed that a further 25% reduction in energy consumption could be achieved, with an average payback period of five years (De Villiers 2000).

8.2.8 Variable speed drives for fans

Roughly half of HVAC energy demand was assumed to be used by fans. Fitting variable speed drives (VSDs) on fans can reduce energy consumption by 15% per square metre (De Villiers 2000). Only variable volume air handling units can be operated with VSDs and these units account for 25% of all currently installed air handling units. VSDs were assumed to have a technical lifetime of 15 years and a cost of R0.56 per kWh of electricity saved.

8.2.9 Efficient lighting systems for new buildings

We estimated that 20% of lighting energy requirements could be reduced with a three-year payback, through efficient design and management of the lighting system by:

- introducing more switches, photo-electric sensors and occupancy sensors;
- reducing lighting levels in areas where illumination is higher than necessary;
- introducing skylights and other building design features.

The barriers to efficient lighting systems are the increased initial costs, split incentives and lack of training of architects and consulting engineers in efficient building energy practice.

We further assumed that in both new and existing buildings, energy demand would be reduced by replacing both incandescent and standard fluorescent lamps with more efficient lamps, such as high-pressure sodium and metal halide lamps and more efficient fluorescent lighting. The relative costs, efficiencies and market shares for various lamp technologies are given in Table 8.9.

8.2.10 Heat pumps for water heating

The cost of a 50 kW heat pump is roughly R50 000 and the annual maintenance is R2 500 (Graham 1999). A heat pump will reduce energy consumption by 67%, compared to an electrical resistance heater. Barriers to the installation of heat pumps are the high investment costs and the possibility of operational problems.

8.2.11 Solar water heating

We assumed that in South Africa, on average, 90% of hot water could be generated by solar energy, while the remainder could be heated by a back-up source when solar irradiation is insufficient. Solar water heaters have a lifetime of about 20 years and the installation costs are about R35 000 for a 1000-litre system, which translates into roughly R475 per GJ. Barriers to installation of solar water heaters are the high investment costs and the possibility of operational problems.

8.2.12 Fuel switching

In addition to the specific measures mentioned above, general fuel switching through substitution between the technologies listed in Table 8.9: was assumed, to ensure a more cost effective provision of energy services.

8.3 Residential energy policies

8.3.1 Defining the sector – six household types

In the residential sector, energy is mostly related to households rather than to individuals. For example, electricity grid connections are made to households, and monthly expenditure is recorded ‘per household’ rather than ‘per person’. Six household types are defined here, differentiated according to urban/rural, high/low-income and electrified/non-electrified. We have coded them as follows:

UHE	urban higher income electrified household
ULE	urban lower income electrified household
ULN	urban lower income non-electrified household
RHE	rural higher income electrified household
RLE	rural lower income electrified household
RLN	rural lower income non-electrified household

The three categories – rich/poor, urban/rural, electrified/not electrified – should actually yield eight household types. However, rich urban households are all electrified, and most rural rich households are as well, so these are omitted.

The energy use patterns of rich and poor households differ quite markedly from one another, as do those of rural and urban households. Given the policy drive to universal electrification since the 1990s, the distinction between electrified and non-electrified households has become significant, with lack of electricity being seen as similar to energy poverty.

For this sector, activity levels are defined by the number of households, of which there were 11 205 705 according to the 2001 Census (SSA 2003a). Definitions of 'urban' and 'rural' are technically difficult to make in South Africa, given the existence of 'dense rural settlements' like Bushbuckridge or Winterveld. In fact the Census no longer reports this distinction. Other statistical publications continue to report different patterns of 'urban' and 'non-urban' (e.g. SSA 2000, 2002). For the purposes of evaluating electrification, the National Electricity Regulator distinguishes between urban and rural connections (NER 2001, 2002a), and for this study we assumed a 60:40 split of urban to rural households. (The percentages used in the modelling are 59.61% urban households, 40.39% rural, but reporting them with two decimals would give a false sense of accuracy.)

There is no single source that breaks down these household types by income group. However, the income and expenditure statistics are reported for urban and non-urban households (SSA 2002: Fig 4.9), dividing each group into quintiles.

Table 8.11: Income and expenditure in urban and non-urban areas by 1995 quintile (in 2000 market values), 2000

Source: SSA (2002)

	Income	
	Urban	***Non-Urban***
Quintile 1 (top)	18%	4%
Quintile 2	20%	9%
Quintile 3	23%	18%
Quintile 4	20%	29%
Quintile 5 (bottom)	19%	40%

It seems reasonable to define energy poverty for the purposes of this analysis by treating the bottom two quintiles as 'poor', so that the poor are those with an annual per capita income of less than R4 033, and annual expenditure of less than R3 703 (at exchange rates of R6/$1 and given SA household size, this works out to less than $2 per person per day). This being so, 61% of urban households could be considered neither poor nor rich (i.e. medium to high income), while in rural areas only 31% would fall into this category. By these assumptions, in other words, almost seven out of ten rural households are poor.

The proportion of poor to rich households varies across urban and rural areas, with urban areas having a much higher share of medium and high-income households. Similarly, the share of electrified households is lower in rural areas, as shown in Table 8.12.

Table 8.12: Numbers and shares of rural and urban households, electrified and not electrified

Source: Own calculations, based on NER (2002a)and (2002)

	Electrified	***Not electrified***	***Rich***	***Poor***
Urban households	5 330 166	1 349 240	4 074 438	2 604 968
Share	79.8%	20.2%	61%	39%
Rural households	2 276 729	2 249 571	31%	69%
Share	50.3%	49.7%	1 403 153	3 123 146

Although there is no comprehensive statistical survey available, it is clear that access to electricity still differs by population group. In 2000 almost all 'African' (99%) and 'coloured' (>99%) households in the highest expenditure category in urban areas had access to electricity for lighting, as against proportionately fewer households in this expenditure category in non-urban areas (79% of 'African' and 93%of 'coloured' households) (SSA 2000:70). These percentages refer only to the highest income group, and if weighted by population group would give approximately 84% of rich rural households as electrified. With this information it is possible to derive the number of households in each of six household types. This is shown in Table 8.13. Further calculations reveal that 33% of the rural poor are electrified, while not quite half (48%) of the urban low-income households have access to electricity.

Table 8.13: Six household types (2000)

Source: Own calculations, based on assumptions and data given in text

Household	*Number of households*	*Share of all households*	*Notes and assumptions*
Urban rich electrified (UHE)	4 074 438	36.4%	Virtually 100% of rich urban households are electrified
Urban poor electrified (ULE)	1 255 728	11.2%	Remainder of urban electrified households must be poor
Urban poor unelectrified (ULN)	1 349 240	12.0%	Rest of urban must be non-electrified
Rural rich electrified (RHE)	1 181 279	10.5%	Assume 84% of rich rural households are electrified
Rural poor unelectrified (RLE)	1 095 449	9.8%	Remainder of rural electrified must be poor
Rural poor unelectrified (RLN)	2 249 571	20.1%	Rest of rural households must be non-electrified; number of households includes the few rich rural not electrified

Of course, reducing all households in the country to six types abstracts enormously from the diversity of different energy patterns. However, for purposes of national-level scenarios it provides some distinctions between the major residential energy-use patterns. Perhaps the biggest omission with this method of categorization is geographical disaggregation – poor urban unelectrified households in Cape Town, for example, would use paraffin extensively for cooking, heating and lighting; while households in the same category in Gauteng are likely to use coal which is locally more available. Apart from the reality that households respond to differences in fuel availability, there are also regional climatic differences that affect fuel usage.

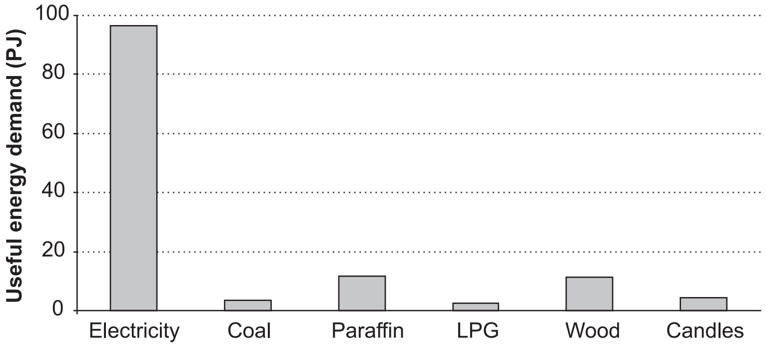
Affordability – in the sense of consumers being able to use the electricity that is available – is emerging as a central policy challenge. The issue is not simply one of getting the physical supply out to households, policy measures are needed to ensure that the use of energy is affordable to households, given their specific living conditions and income. The electricity 'poverty tariff' does not address other energy needs. Further work is needed in understanding how the 'energy burden' can be relieved. Creative approaches to modelling may need to be found, since current approaches do not include households as real entities, nor do they incorporate average income levels.

Since each additional household type requires additional data in the modelling, the number of household types needs to be limited. Further disaggregation could be achieved in future work, but is constrained by our currently limited knowledge of distinctive energy use patterns. For example, there is relatively little research on rich rural unelectrified households, compared to their urban counter-parts.

8.3.2 Energy use patterns in the residential sector

Energy use patterns in the residential sector show the continued use of multiple fuels. Five major end uses were considered – cooking, space heating, water heating, lighting and electrical appliances for other uses.

Multiple fuels are used in the residential sector, with electricity clearly dominating useful energy demand (see Figure 8.12). This is reflected both in the increased use of energy, but also in the relatively high efficiencies of electrical appliances. Patterns of household energy demand differ significantly in rich and poor, urban and rural households (Mehlwana 1999; Mehlwana & Qase 1998; Simmonds & Mammon 1996). Electricity contributes a larger share of household energy use in urban areas than in rural areas, while the inverse is true for fuelwood. About 5% of the total electricity is sold to the domestic sector, so that the bar for electricity in the figure below represents 34.6 TWh of final energy (NER 2001).



Note: 2001 total: 130 PJ

Figure 8.12: Demand for useful energy in the residential sector, by energy carrier

It is much more difficult to attribute the consumption of other fuels to specific end uses. Survey results typically report only the monthly consumption of fuel types. For example, household members may be able to give an indication of the number of litres of paraffin used per month, but are unlikely to know how much is used to heat the house, boil water, cook or produce light.[15]

Household energy use patterns vary across the six household types. Table 8.14 shows the consumption for each end use for the base year 2001 (see Table A3 in Appendix) for projections into the future). The energy services related to each end use are delivered by multiple technologies for most end uses, as can be seen from Table 8.15.

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[15] Note that in Table 8.14, lighting is also reported in energy units (PJ) to facilitate comparison to other end uses, rather than lighting units. In other analyses, we adjust for the relative efficiencies of different lighting technologies, so that the same level of lighting service is delivered. For example, a CFL produces four times as much lighting as an incandescent light, for the same amount of energy input. The energy is converted to light, not thermal heat – at least the useful part of it. The units take incandescents as the norm, so that for them 1 LU = 1 PJ, but for CFLs, 1PJ = 4 LU. The relative efficiencies of non-electric lighting technologies, including paraffin wick lights, gas pressure lamps and candles, are low.

Table 8.14: Useful energy demand by household type for each end use (PJ , 2001)

	UHE	*ULE*	*ULN*	*RHE*	*RLE*	*RLN*
Cooking	15.8	1.4	1.8	1.8	0.6	3.1
Water heating	23.2	4.3	1.2	2.8	0.7	5.3
Space heating	16.3	2.4	2.0	1.7	0.5	6.1
Lighting	7.4	2.7	2.3	4.1	2.0	4.2
Other electricity	12.6	0.1	-	3.3	0.1	-

The fuel use patterns in this study have been determined endogenously in the model, given appropriate technology-specific discount rates. A future study may wish to compare the optimised results with a simulated future, based on expected fuel use patterns.

8.3.3 Characteristics of energy technologies

The key characteristics of technologies relevant to the residential sector are shown in Table 8.15. In reality there are many more technologies that apply to this sector, but only the major energy-consuming ones have been included here. The information is organised according to the services that households required – the end uses of cooking, space heating, water heating, lighting and electrical appliances. Appliance costs were collected for this study in early 2005; they were deflated from the end of 2004 to provide costs in the year 2000 in rands. 'Residual capacity' refers to the capacity available in the base year, without any further investment.

Lifetimes and efficiencies are taken from previous studies (De Villiers & Matibe 2000; DME 2003a), updated in some cases by expert input (Cowan 2005; Lloyd 2005). For all end uses other than lighting, the efficiencies relate to the amount of useful energy delivered by the appliance for each unit of final energy delivered to the household. For lighting, however, relative efficiencies reflect the amount of lighting service produced, not thermal outputs.

Table 8.15: Key characteristics of energy technologies in the residential sector

Fuel consumed	*Device*	*Effic-iency (%)*	*Capital cost – nominal (2005 R)*	*Adjusted cost (2000 R)*	*Life-time (Yrs)*	*Residual capacity (PJ)*	*Investment cost (R/GJ)*
				Cooking			
Electricity	Hot plate	65	229	178	5	0.6559	230.1160
	Oven	65	2 349	1 823	9	16.2011	435.8943
	Microwave	60	874	678	5	0.1004	2 556.3243
Paraffin	Wick	40	107	83	3	0.1657	77.6743
	Primus	42	37	29	6	2.4558	29.8504
Gas	Ring	53	249	193	5	0.7088	45.6038
	Stove	57	4 995	3 877	9	1.1136	293.2659
Wood	Stove	25	848	687	9	2.7729	366.1427
Coal	Stove	13	5 231	4 060	11	–	
	Brazier	8	0	0	1	–	–

Fuel consumed	***Device***	***Efficiency (%)***	***Capital cost – nominal (2005 R)***	***Adjusted cost (2000 R)***	***Lifetime (Yrs)***	***Residual capacity (PJ)***	***Investment cost (R/GJ)***
Water heating							
Electricity	Geyser	70	2 172	1 686	22	29.7663	255.5052
Paraffin	Wick/ kerosene/ pot	35	37	29	3	1.8019	34.8500
Gas	Geyser	84	4 298	3 479	22	0.2936	2 813.7125
Solar	SWH (integral)	100	7 150	5 549	17	0.1922	588.1703
Coal/wood/ wastes	Stove jacket/pot)	40	0	0	1	5.4846	–
Space heating							
Electricity	Radiant heater	100	100	78	6	11.8984	18.2595
	Rib/fin/ radiator	100	968	751	9	7.3770	176.4690
Paraffin	Heater	73	59	46	9	3.4390	26.3508
Gas	Heater	75	993	771	5	0.3012	166.3370
Wood	Open fire/stove	40	0	0	–	–	–
Coal	Stove	59	5 231	4 060	11	–	
	Brazier	8	0	0	1	–	–
Lighting							
Electricity	Incandescent	100	3	2	1	14.2820	7.9843
	Fluorescent	290	13	10	4	–	
	CFLs	400	17	14	10	0.0989	245.0688
Paraffin	Wick	1.71	5	4	4	3.8536	4.3635
	Pressure	7.43	192	155	4	–	
Gas	Pressure	5.71	250	194	4	–	
Candles		0.05	1	1	0.01	–	40.6078
Other electrical appliances							
Electricity	Appliances	80			5	16.0407	

8.3.4 Projections of future residential energy demand

Projecting future energy demand in the residential sector depends on the changing number of households in each group, as well as the changes in the amount of energy services consumed by each household. Future household numbers depend on population growth rates, the impact of HIV/Aids, and migration patterns, whereas changes in useful energy intensity depend on changing fuel use (notably electrification) and income levels. We have assumed that the pattern of household/population growth will continue, but that population growth rates will be lower due to the impact of Aids. This important assumption is a driver of future energy patterns, not just those of the residential sector, and it is discussed further with other key assumptions about the future in section 9.2.2.

8.3.4.1 Future urban-rural shares

Given the definition of household types in this study, the distinction between urban and rural households is important. Rates of electrification are much higher in urban areas, and other fuel use patterns differ too. Urban population growth rates for earlier periods were substantially higher, e.g. population growth from 1946-1970 was 3.45% per year, 3.09% for 1970-1996 (SACN 2004). Overall, this gives a picture of a growing urban population, but also of growth slowing down to lower rates. Will South Africa's population continue to urbanise? There have been some suggestions that rural populations have peaked and will stabilise or even decline (Calitz 1996). We assume that virtually all the household growth – moderate as it is projected to be – will occur in the broadly defined urban category, and that rural household numbers will remain stable. Under these assumptions, 64% of the population will be urbanised by 2030.

8.3.4.2 Households and household size

A notable trend in South African cities is that the number of households (dwelling units) has been growing faster than the population. Across South Africa's nine largest cities, the population grew by 2.8% per year between 1996 and 2001, but the number of households increased at 4.9% per year (SACN 2004:179). Possible reasons include people establishing new households, particularly when incomes increase; migration from rural areas to the cities and associated cultural changes; and increased household formation. Such trends are consistent with demographic experience elsewhere in the world, where increasing income levels are negatively correlated with fertility and population growth rates (UN Population Division 2000). The average number of people per urban household dropped from 3.98 in 1996 to 3.58 in 2001 (SACN 2004). Nationally, it dropped from 4.5 to 4.0 over the same time (SSA 1996, 2003b), although these trends are probably partly the result of reconsideration of earlier census data. Given demographic trends elsewhere in the world, it seemed plausible to assume that household size would continue to decline a little further, reaching 3.8 by 2030.

8.3.4.3 Trends in energy consumption

One of the key developments since 1990 has been the national electrification programme, which has gradually moved energy use patterns to a greater reliance on electricity – although the affordability of using electricity remains an issue. We can assume that universal access to affordable electricity will remain a cornerstone of policy, since the government's commitment to achieving universal access to electricity has been reiterated in many policy speeches (Mbeki 2004; Mlambo-Ngcuka 2002b, 2003, 2004). For the purposes of this study, we have assumed that by the end of the period (2001-2030), 99% of urban and 90% of rural households will be electrified. Taken with other projections, this implies that 17% of poor rural households will still be non-electrified by 2030, as will 3% of urban low-income households.

As highlighted in Chapter 5, access needs to be complemented by policies to promote affordable use. Or, put another way, electricity should be promoted not only for lighting or entertainment, but also for cooking and productive uses. A supplementary study on the poverty tariff found that a 'weak access' approach was feasible – a self-targeted tariff with a limit on the level of current supplied (UCT 2003). The proposal in the original report (UCT 2002) was that customers who wished to receive the free electricity should agree to limit supply to 8A (compared to 20A or 60A household connections). However, supplementary work found that many households already owned appliances with ratings above 1.8 kW, which would be unuseable with an 8A supply. A 10A supply was found to be more socially acceptable. That would require an estimated further R150 million for network reinforcement over several years.

8.3.4.4 Changing patterns of energy consumption

The concept of energy transition has been described by some as a 'universal trend' whereby households move from traditional fuel, consisting of wood, dung and bagasse, through transitional energy sources (coal, paraffin and LPG) to 'modern energy services' (electricity) (ERI 2001). While some shifts in fuel consumption have occurred, questions have been asked about whether this process is happening in a linear fashion, and whether it adequately accounts for the persistent use of non-commercial fuels (Yamba et al. 2002). Non-commercial fuel-use patterns generally continue for several years after households receive electricity services (Mehlwana 1998). Proposals have been made to more effectively represent multiple fuel use and the use of a single appliance for multiple end uses in modelling (Howells et al. 2005), focusing more on the energy services than on the fuel used. In reality, a single appliance such as an LPG stove might be used for cooking, water heating and space heating.

Overall, residential energy demand shows an increase over the period 2000-2030. Most of the increase derives from increasing incomes – more households move from poor to rich categories, where more energy is used per household. For electrical appliances, the intensity of energy use shows increases.

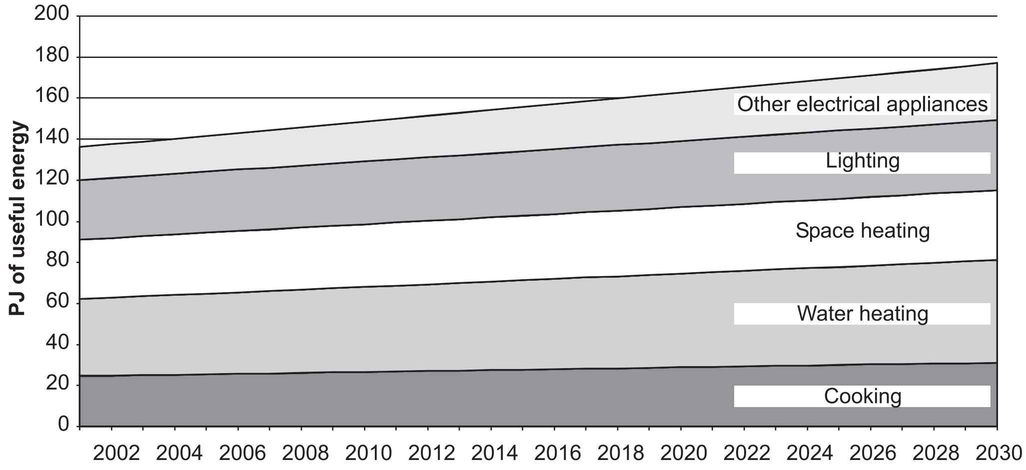

Figure 8.13: Projected energy demand by end use

8.3.4.5 Poverty

Perhaps one of the most difficult assumptions we have had to make concerns estimates of future poverty. We chose a middle path between assuming that poverty would be reduced dramatically and assuming that the proportion of poor households would be unchanged. In absolute terms, we assumed that overall income levels would increase so that 70% of urban households would be 'non-poor' by 2030 compared to 61% in 2001. The proportion of low-income households declines to 60% in the reference scenario by 2030, from 69% in 2001. These assumptions do not claim to address 'relative poverty', the phenomenon whereby households may still consider themselves poor in comparison with high-income households that have grown wealthier.

8.3.4.6 Future activity levels

Given the data for the starting year of 2001 and the assumed changes as described above, the changes in the numbers and shares of the six different household types in this study are shown in Table 8.16.

Table 8.16: Number and share of households, estimated for 2001 and projected for 2030

Source: See text for underlying data and assumptions

	2001		*2030*	
	No. of households	*Share of households*	*No. of households*	*Share of households*
UHE	4 074 438	36.4%	6 050 063	45.9%
ULE	1 255 728	11.2%	2 506 455	19.0%
ULN	1 349 240	12.0%	86 429	0.7%
RHE	1 181 279	10.5%	1 810 520	13.7%
RLE	1 095 449	9.8%	2 263 150	17.2%
RLN	2 249 571	20.1%	452 630	3.4%
Total	11 205 705		13 169 247	

More detail is provided in the Appendix, with Table A3 showing the energy demands by end use and household type, and providing household numbers as projected for selected intermediate years. Table 12.4 also provides the total demands for each end use, as well as the grand total of residential energy demand for the years 2001 to 2025.

8.3.5 Solar water heaters and geyser blankets

Energy policies for the residential sector should start with water heating, one of the major end uses in the sector. However, given the high capital costs of solar water heaters (SWHs), such an approach would more suitable for middle- and upper-income households, primarily those in urban areas. Estimates of penetration rates for SWHs vary quite widely, from 20% over 15 years (De Villiers & Matibe 2000) to 60% of electricity for water heating avoided, amounting to 2 PJ per year (DME 2003b). A simpler intervention, with lower initial costs, is the installation of geyser blankets, which provide a substantial energy saving.

For SWHs, it makes sense to separate out new from existing buildings, requiring all new urban middle- and upper-income households to install hybrid solar-electric water heaters instead of electric storage geysers (according to the DME, virtually no SWHs are encountered in low-cost housing areas) (DME 2004b). SWHs would save 60% of electricity use (Karekezi & Ranja 1997; Spalding-Fecher et al. 2002b). Existing homes could be encouraged to insulate existing electric storage geysers, saving 12% of electricity use (EDRC 2003; Mathews et al. 1998), and could be required to do so when existing electric geysers are replaced. Currently 1%-3% of households have geyser blankets (Borchers 2005), and we have assumed 2% for this study.

The typical cost of an electric geyser was R1 500 in 2005 (cost survey done for this study). SWHs currently are more expensive, around R8 000 to R12 000 installed; however with the introduction of new vacuum tube technology these costs are likely to decline to between R4 000 and R6 000 (Borchers 2005). A reasonable figure for a hybrid solar and electric system would be R6 500 installed (EDRC 2003); a study for Cabeere gives R6 000 for ‘machinery’ plus R1 500 for ‘other’ costs (DME 2004b: 93). Vacuum tube technology is already available (www.solardome.co.za) in South Africa, so it can be expected that the prices will decline from R6 000 in 2005 to R4 000 by 2010, in real terms. Since the vacuum tubes themselves are imported, economies of scale in importing will be important in reducing the price, which would imply a step change in relation to the introduction of a new technology. Future research is needed to quantify the point at which this step change is likely to occur in terms of levels of output, imports or cumulative production. Informal enquiries with local distributors indicate an expectation that by 2010 all SWHs will use vacuum tube technology.

8.3.6 Energy-efficient housing

The Department of Housing commissioned a study early in 2003 to set up a framework for the regulation of environmentally sound building. The policy here would be to revise the South African Energy and Demand Efficiency Standard guidelines in order to specify which measures should be included in the energy-efficient housing package, plus any technical details required for these interventions, and to make these standards mandatory for all new subsidy-supported housing.

Since most of the thermal energy in a house escapes through the roof (Holm 2000), the single most effective intervention in the building shell is the installation of a ceiling (Spalding-Fecher et al. 2002a). A layer of low-cost insulation above the ceiling and on the walls can significantly improve the thermal performance of the building shell (Holm 2000; Winkler et al. 2002).

Housing built under what was originally called RDP housing does not typically include ceilings. Costs of ceilings are therefore included here, at R1 278 for a 30 m^2 RDP house in 2001 (Holm 2000; Thorne 2005). Middle- and upper-income houses already have ceilings, so only insulation needs to be installed, at a cost of R2 031 for a 90 m^2 three-bedroomed house in 2001. These interventions can be combined with passive solar techniques (correct orientation, north-facing windows and optimised roof overhang) to make for a more efficient building shell.

Although it is technically possible to eliminate the need for space heating through proper insulation, orientation and ceilings, i.e. achieve 100% savings (Holm 2000), many households will choose to use some of those potential savings on additional space heating. This ‘take-back’ effect will reduce the actual savings achieved, although it still provides development benefits because it means that people who previously had homes that were too cold in winter and too hot in summer can be more comfortable (see Schipper & Grubb 2000; Scott 1980; Spalding-Fecher et al. 2002a) and have an improved quality of life.

The savings achievable through ceilings and insulation alone are estimated in the range of 34% to 50%; together with zero-cost passive solar design, we have assumed the average of this range, i.e. 42%. This is a conservative estimate if compared to previous studies which assume higher savings for passive solar design of houses + ceilings + insulation (especially in low-cost housing) – up to 60%-70% of space-heating energy according to a variety of sources (EDRC 2003; Holm 2000). This should confirm that the savings reported in this study are easily achievable.

Currently, at most 0.5% of households are efficient in their thermal design. The reference case assumes that this share will grow at 5% per year in future, so that over the period 2000-2030 the number of efficient households will double twice. The model results show how much these penetration rates are increased by policy interventions such as subsidies.

8.3.7 Subsidies for energy efficiency in low-cost housing

It is one thing to demonstrate the technical potential of energy efficiency, quite another to examine whether such interventions are affordable, particularly for low-income households. Most poor communities rely heavily on the national housing subsidy to help them build decent housing. However this subsidy is not linked in any way to the energy efficiency characteristics of the house. There is nothing comparable to the incremental subsidy that is provided for homes in the southern Cape for mitigating condensation and dampness.

An incremental housing subsidy for energy efficiency could be set to be equal to the initial incremental cost of the intervention, for the same end-uses covered under 'building codes' and 'appliance standards'. This measure could be implemented through existing housing legislation and programmes.

One could ask what subsidy would be needed to make the interventions with upfront costs affordable, given the relatively high discount rates of poor households. In this study we examined the marginal level of investment needed to make energy-efficient interventions affordable for poor households. We assumed that the discount rate of poor households is higher at 30% than the general rate of 10%. Currently, there is a subsidy for coastal areas (R1003) to which the results from the modelling can be compared. The required subsidy is reported in the results.

8.3.8 Efficient lighting

Many low-income households use less than 75 kWh of electricity per month, and hot water geysers and electric cooking appliances are not common in such households. Most of the electricity use is for lighting, which means that energy efficient bulbs can markedly reduce electricity bills. Compact fluorescent light bulbs (CFLs) use significantly less power than conventional bulbs. From the utility's perspective, CFLs can reduce expensive peak demand, because lighting demand has a high degree of coincidence with peak demand, especially in the winter when daylight fades early. Efficient lighting practices include switching off lights when a room is unoccupied, fitting lower-power light bulbs where possible, and controlling security lighting with light or movement sensors.

The relative efficiency of CFLs compared to incandescents is about 1:4, and they burn about ten times longer (10 000 hours life versus 1 000 hours). The efficient lighting initiative significantly reduced the price of CFLs between 2001 and 2003, and increased the market share of CFLs (ELI 2005). Current market shares for CFLs vary between zero for poor rural households and 8% for medium- and high-income urban households. This study assumes that penetration rates increase more rapidly in the first half of the period, and then grow more slowly towards some upper limit. Studies in the Netherlands, Germany, and Denmark have gathered detailed data on the uptake of CFLs, and show that about half the households have CFLs installed (Netherlands 56%, Germany 50%, and Denmark 46%) (Kofod 1996). These high penetration rates are probably not matched anywhere else in the world and are the upper bound for our reference case.

Table 8.17: Penetration rates for 2001 and assumptions of upper and lower bounds for the reference case

Household type	*2001 (%)*	*Bound for future*	*2013 (%)*	*2030 (%)*
UHE	8	UP	35	50
		LO	15	17
ULE	1	UP	20	40
		LO	9	17
RHE	6	UP	30	50
		LO	11	17
RLE	0	UP	20	40
		LO	9	17

8.4 Agriculture

8.4.1 Agricultural sector activity

The agricultural sector includes all users classified as agriculture, forestry and hunting, as well as ocean, coastal and inland fishing under SIC codes 11, 12 and 13. A detailed breakdown of activities included in this sector is given in Table 8.18.

Table 8.18: Agricultural sub-sectors by SIC code

SIC	*Description*
11	Agriculture, hunting and related services
111	• Growing of crops; market gardening; services
112	• Farming of animals
113	• Growing of crops combined with farming of animals (mixed farming)
114	• Agricultural and animal husbandry services, except veterinary activities
115	• Hunting, trapping and game propagation, including related services
116	• Production of organic fertilisers
12	Forestry, logging and related services
121	• Forestry and related services
122	• Logging and related services
13	Fishing, operation of fish hatcheries and fish farms
131	• Ocean, inland and coastal fishing
132	• Fish hatcheries and fish farms

In South Africa about 3 000 large commercial farmers produce 40% of the agricultural output, while another grouping of 10 000 farmers survive economically by producing a further 40%. Between 40 000 and 60 000 full-time struggling farmers produce the remaining 20% of agricultural output. The agricultural sector employed about 10% of the workforce in 2001: 960 500 employed people aged 15-65 in agriculture, hunting, forestry and fishing, out of a total national employment of 9,58 million (SSA 2004).

Since all agricultural sub-sectors have been aggregated into one group, the only common measure of activity is value added, and this has therefore been the indicator used in this study. Other alternatives for measuring activity variables, such as hectares or livestock population, are only appropriate when working with a greater sub-division of sectors. Due to the poor data availability, further disaggregation was not feasible for this study.

8.4.2 Energy use in the agricultural sector

Table 8.19 shows energy consumption in the agricultural sector. An estimated 73 PJ of energy was consumed in the sector in 2001. Approximately 58% of this was diesel, 10% was other liquid fuels, 30% was in the form of electricity, and the remaining 2% was coal.

Table 8.19: Energy use in the agricultural sector (PJ)

Source	*Year*	*Electricity*	*Coal*	*Petrol*	*Paraffin*	*LPG*	*Diesel*	*HFO*	*Total*
This study	2001	22	1.5	2.8	2.4	0.13	43	1.6	73
DME	2001	15	2.7	3.8	3.0	0.13	43	1.6	69
IEA	2000	14	1.6	2.6	2.3	0.14	40	-	61
Beyond 2020 REF	1999	-	2.7	-	-	-	-	-	-
Eskom	2001	22	-	-	-	-	-	-	-

Energy use in agriculture is primarily for the purposes of:

- preparing the land;
- irrigating the land;
- applying nutrients, pesticides and herbicides;
- harvesting; and
- primary processing.

Based on this, the following set of end-use demands were considered for this study:

- traction (tractors, harvesters and on-site transport);
- irrigation (electricity, diesel and petrol driven pumps);
- primary processing (electric equipment);
- heat (hot water for dairies, incubators, drying of crops); and
- other (electricity demands such as lighting and cooling).

The total value added by the agricultural sector in 2001 was R26 558 million. Based on the fuel use given in Table 8.19, a set of end-use energy intensities can be derived. These are given in Table 8.20. The allocation of fuels to various activities is based on the Integrated Energy Plan (IEP) in the case of electricity. For other fuels there are no accurate sources of information. The allocation is therefore a best guess, although there is a high confidence in attributing the majority of this to traction.

Table 8.20: Useful energy intensity of agricultural end-use demands

Demand	*2000 Useful energy intensity (GJ/R)*	*2025 Useful energy Intensity (GJ/R)*
Traction	0.564	0.564
Irrigation	0.314	0.401
Processing	0.214	0.344
Heat	0.211	0.211
Other	0.371	0.596

8.4.3 Demand projections

Value added is used as the driver for energy demand in the agricultural sector. The projections are given in Table 8.21.

Table 8.21: Forecast of value added in the agricultural sector

	2001	*2005*	*2010*	*2015*	*2020*	*2025*
Agriculture GVA (R millions)	26 558	27 510	28 098	28 538	28 912	29 200

8.5 Coal mining

Coal mining is an important upstream activity, providing fuel for electricity generation, synthetic fuels and industrial processes. No specific policy options in coal mining were modelled in this study, but some background is relevant.

For a long time the figure given for South Africa's coal reserves has been 55 billion tons. An interim estimation of 38 billion tons (Prevost 2003) is the best figure currently available. The DME is conducting a thorough study to assess the true reserves. Figure 8.14 shows coal production from 1992 to 2001.

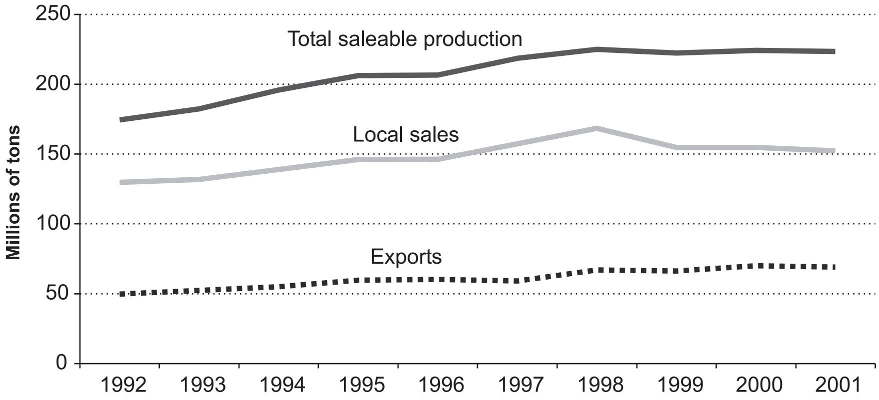

Figure 8.14: Total saleable production, local sales and exports of South African coal, 1992 to 2001
Source: DME (2003)

In 2001, South Africa mined 290 million tons of coal, of which 223.5 million tons was saleable. Supplies to the local market were 152.2 millions tons with 69.2 million tons exported. Discards, too low in heating value and too high in ash to have commercial value, amounted to 66 000 million tons. However, discards may well have commercial value in the future, as they can be burned in fluidised bed combustion (FBC) boilers. The use of coal for export, various internal uses, and discards, is shown in Figure 8.15.

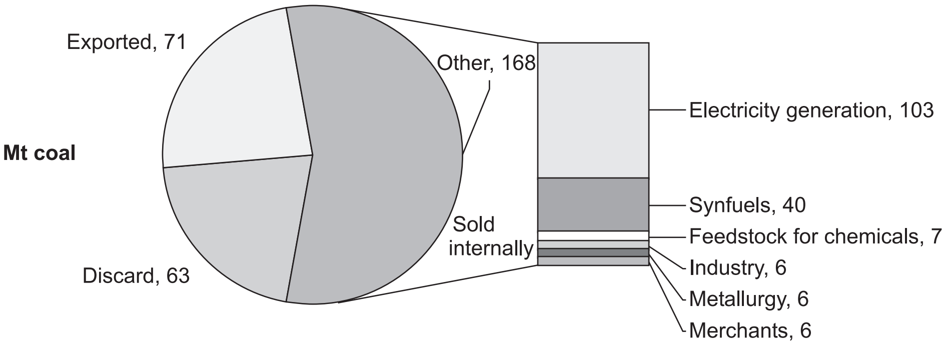

Figure 8.15: Coal used for export, domestic uses and discards, 2003
Source: (DME 2004c)

The prices of domestic coal were reported by DME as more constant over time than the prices of coal for export.

Table 8.22: Price of coal for local sales, 1994 to 2003, in rands per ton

Source: DME (2004c)

1994	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*
40	43	46	49	53	54	57	63	75	79

South African coal prices were R60.73 per ton of coal for electricity generation in 2001 (calculated in terms of the rand value for 2000). The calorific value of South Africa's sub-bituminous coal for electricity generation is 20.1 MJ / kg, which is lower than the average figures due to its relatively high ash content (Pinheiro 1999). For details of assumption about future coal prices, see section 9.2.4, which puts South African coal prices in the context of other fuel prices.

8.6 Electricity generation – gas, renewables, hydroelectricity and nuclear

For the electricity sector, we examined alternative supply options, from natural gas to renewable energy technologies, PBMR nuclear, imported hydroelectric power, and fluidised bed combustion coal-fired plants. For each source, bounds were set on the ranges of supply, within which the model optimised. We examined the implications for total energy system costs, environmental impacts, water use, job creation potential and other parameters – in other words, the major supply-side options in the sector. These were complemented by the various demand-side interventions as described for each economic sector above.

The excess capacity that the electricity sector experienced from the 1970s to the 1990s is ending. The decisions about who will supply new power stations, and what energy sources they will use (ERC 2004a) will shape South Africa's energy development path for the next few decades.

The overarching policy goal for electricity supply can be drawn from 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 doing so by pursuing all energy sources, was restated by the Energy minister in her budget vote speech of 2004, when she said that 'the state has to put security of supply above all, and above competition especially' (Mlambo-Ngcuka 2004). She made it clear that the government would examine all available energy technologies and plan for future capacity needs, based on planning to select the least-cost option. In his 2004 State of the Nation speech, the South African president acknowledged the need for new capacity by announcing a tender to deliver 'new generating capacity to provide for the growing energy needs from 2008' (Mbeki 2004). Prospective investors could tender to provide the most cost-effective means to build new capacity of a certain quality (stating reliability, availability, emissions).

For the present study, the following approaches and assumptions were made:

- The modelling approach included all existing power plants and the technology options spelled out below, using renewables, gas, nuclear power, coal, and imported hydroelectric power. The lead times for different technologies were included, as was the cost of 'unserved' energy.[16]

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[16] 'Unserved' energy occurs when load is interrupted. Attaching a cost to the lost revenues due to this energy not being provided allows comparison with the cost of increasing capacity (perhaps specific peaking capacity) to meet the demand.

- The reference case was very close to the National Integrated Resource Plan developed by the ERC modelling group and others for the NER (NER 2004b).
- Future policy cases will model departures from the reference case, as outlined below.
- Our approach to scenario modelling was first to consider using each of the energy technologies separately. The implications of using these technologies were examined in terms of: costs (capital, operations and maintenance [O&M] costs, fixed costs and variable costs), wider impact on the economy, environmental impacts (notably local air pollutants and GHGs) and social benefits (e.g. electricity prices, job creation). Policy recommendations were drawn from considering these implications. Given the large scale of the study, reporting was at the level of policies and scenarios.

Table 8.23: Characteristics of new power plants

Source: NIRP (NER 2004b)

Type	*Units of capacity (MW)*	*Investment cost, undiscounted (R/kW)*	*Fixed O&M cost (R/kW)*	*Variable O&M cost (c/kWh)*	*Life-time (Yrs)*	*Lead time (Yrs)*	*Efficiency (%)*	*Availability factor (%)*
Coal								
New pulverized fuel plant	642	9 980	101	1.1	30	4	35	88
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-generation (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	-	95

8.6.1 Switch from coal to gas

Natural gas currently only accounts for 1.5% of the country's total primary energy supply (DME 2002c). The total proven gas reserves of South Africa are about 2 tcf (Trillion cubic feet), and this figure could rise with further exploration (ERC 2004a). New fields are being explored off the South African West Coast (Ibhubesi), Namibia (Kudu) and Mozambique (Pande and Temane). All of these are relatively small, with larger fields further away in Angola (ERC 2004a). During 2004, gas from Mozambique started being delivered to Gauteng – however this was for use at Sasol and industry, rather than in electricity generation. Import of LNG by tanker was an option considered in the second National Integrated Resource Plan (NER 2004b).

Apart from the regulation of gas pipelines, gas prices are a critical factor in determining viability of gas-fired power plants. The next power station to be built will be an open cycle gas turbine (NER 2004a). 'Gas turbines' in South Africa use aeronautical diesel fuel to drive jet turbines, connected to power generators (NER 2002a). The Integrated Resource Plan includes a simple cycle of 2 400 MW: made up of 240 MW in 2008 and 2013, and 480 MW each year from 2009 to 2012 (NER 2004b).

A policy case for natural gas is investigated in this study, building three combined cycle gas turbines (CCGT) of 1950 MW each, or a total of 5 850 MW by 2020. Gas has been imported by pipeline from Mozambique since 2004, but its preferred use has been for feedstock at Sasol's chemical and synthetic fuel (synfuel) plants (Sasol 2004a). The alternative is the shipping of LNG, potentially landed at Saldanha in the Western Cape, Coega in the Eastern Cape or Richards Bay in KwaZulu Natal. Gas turbines have relatively short start-up times and play an important role in meeting peak power needs. Construction of an LNG terminal would add two years to the lead-time of a project, due to the need for environmental impact assessments and harbour modifications. This makes the total lead time five years, even under a fast-track option whereby LNG terminal construction would be done in parallel with building the plant; otherwise it would take eight years (NER 2004a: Appendix 3). Fifteen units of 390 MW each could be constructed with lead times of five years spreading them over the period. The policy case is implemented with a higher upper bound than the reference case, which, following the National Integrated Resource Plan (NIRP), included a maximum of 1 950 MW of combined cycle gas turbines.

8.6.2 Renewable energy for electricity generation

Renewable electricity sources are derived from natural flows of solar, wind, hydro, biomass, geothermal and ocean energy. The IPCC has estimated the long-term global technical potential of primary renewable energy to be at least 2800 EJ/yr (IPCC 2001: Chapter 3) – a number which exceeds the upper bound of estimates for global energy demand. Unfortunately the realisable potential is much lower, limited by the ability to capture dispersed energy, as well as markets and costs. While the installed capacity of wind and solar photovoltaic technologies grew at rates of around 30% from 1994 to 1999, they started from a low base – 10 GW and 0.5 GW respectively (UNDP et al. 2000). By comparison, South Africa's total electricity grid – of which a small part is renewable – amounts to roughly 40 GW.

South Africa's renewable energy target of 10 000 GWh per year is 4% of the estimated generation in 2013, which would require 3 805 MW capacity, assuming a 30% availability factor.

Renewable resources like wind and solar energy are intermittent by nature. Technical solutions and business and regulatory practices can reduce the levels of intermittency, for example through variable-speed turbines. Wind can be complemented with an energy technology capable of storage, such as fossil fuels, pumped storage or compressed air storage. Storage, however, imposes a cost penalty. Since utilities must supply power in close balance to demand, the share of highly intermittent resources that can be incorporated into the energy mix is limited.

The level of intermittent renewable energy sources that can be absorbed into the national energy grid requires further study. In Denmark, Spain and Germany, the penetration levels for renewable energy resources, is over 15%: for very short periods this can rise up to 50%. In some instances this has caused grid control and power quality problems, but not in other cases (IEA 2003b). With South Africa's penetration of renewables for electricity generation being very low (about 1%, from hydroelectricity and bagasse (NER 2003a)), the grid will absorb most fluctuations.

Other renewable energy technologies, like biomass and small hydroelectric schemes, are dependent on seasonal patterns. The annual load factors of these renewable sources are highly dependent on the particular site, but they are usually significantly lower than the load factors for fossil fuel technologies. The load factors for renewable energy technologies are generally higher for solar thermal and biomass installations than for wind at South African sites, e.g. the solar power tower technology with molten salt storage has an availability factor of 60% (NER 2004a).

The theoretical potential for renewable energy in South Africa lies overwhelmingly with solar energy, equivalent to about 280 000 GW (Eberhard & Williams 1988: 9). Technological and economic potentials, by various estimates, would be lower than the theoretical potentials – shown in Table 23. Other renewable energy sources – wind, bagasse, wood, hydro, and agricultural and wood waste – are much smaller than solar.

Table 8.24: Theoretical potential of renewable energy sources in South Africa

Sources: (DME 2000, 2002a; Howells 1999)

	DANCED / DME	***Howells***	***Renewable Energy White Paper***
Resource		***PJ / year***	
Wind	6	50	21
Bagasse	47	49	18
Wood	44	220	
Hydro	40	20	36
Solar		8 500 000	
Agricultural waste		20	
Wood waste			9

The most recent estimates of the potential of renewable energy were compiled for the South African Renewable Energy Resource Database (www.csir.co.za/ environmentek/ sarerd/contact.html). The costs of updating the data will be borne by selling more detailed GIS maps (Otto 2003). In estimating the economic potential of renewable energy, there is even less data available. There is not sufficient experience regarding local costs and markets to provide estimates of any great accuracy. What is available, however, is a study which shows that renewable energy sources could provide 10 000 GWh of electricity to meet the target (see Table 8.25).

Government has adopted a White Paper on Renewable Energy (DME 2003b). The Energy minister's 2003 budget speech indicated that renewable energy would be subsidised. Her speech suggested that renewable energy policy would 'lead to the subsidisation of renewable energy and develop a sustainable market share for clean energy' (Mlambo-Ngcuka 2003). Two major types of subsidies can be considered: investment subsidies, as an upfront grant, given per unit of installed capacity, and production subsidies, through a rebate per kWh of renewable electricity produced

Production subsidies, in the form of feed-in tariffs, are based on energy production and so provide an incentive to use capital efficiently. [17] The motivation for subsidising renewable electricity is to contribute to the local and global socio-economic and environmental benefits that are not captured by existing markets. The policy would be to formulate these incentives as production subsidies – as opposed to capital subsidies, which do not guarantee production. For example, the 'green electricity' tariff negotiated for the 2002 World Summit on Sustainable Development in Johannesburg, was 50c/kWh, which was based on current estimates of the cost of grid-connected wind power (Morris 2002). Such a subsidy would have a similar effect to negotiating a higher tariff, as the Darling wind farm has negotiated a preferential tariff of 50c/ kWh with the City of Cape Town (CCT 2004; CCT & SEA 2003).

Production subsidies would be given to renewable electricity generators. However, in implementing this policy in a modelling framework, rather than setting a renewable energy subsidy level (since no c/kWh price was known at the time of writing), we analysed the subsidy required to deliver 10 000 GWh from each renewable energy technology.

To put such values in context, one can do a rough calculation of the carbon revenues which renewable energy projects could earn through the Clean Development Mechanism. In June 2005 the carbon price was rising rapidly, with €20 being quoted for a ton of CO_2 in the EU Emissions Trading Scheme (www.pointcarbon.com). The price for certified emission reductions (CERs) (with higher risks related to future delivery) were closer to €10 / t CO_2, but were expected to converge as the issuance of the first CERs increased certainty. At an exchange rate of R8.50 to the euro and a grid system-average emission factor of 0.89 kg CO_2/kWh (Eskom 2003), a 'subsidy' of between 7.6 and 15.3c/kWh could potentially be recovered from CDM revenues for zero-emissions technologies like renewables.

In 2003, government adopted a target of 10 000 GWh renewable energy consumption (DME 2003b). Although this was not limited to electricity – it also includes solar water heating and biofuels – the policy document explicitly states that this would be 4% of expected electricity demand in 2013. A number of technologies could contribute to this goal, including solar thermal electricity (both the parabolic trough and 'power tower' options), wind turbines (at three availability factors, 25%, 30% and 35%), small hydroelectric facilities (Eskom and other), biomass co-generation (existing and new) and landfill gas (four sizes). The share of renewable electricity was set at 3.5% (10 TWh out of 283 TWh projected for 2013).

To implement the policy case with various renewable energy technologies in the Markal model, we set the sum of activities of all RETs equal to 36 PJ in 2013, interpolated linearly from existing 8.5 PJ in the base year (hydroelectricity and bagasse) and extrapolated beyond the target year.

Estimates of capacity developed for South Africa are shown in Table 8.25. Upper bounds are placed on landfill gas and wind. Solar thermal electric technologies are not limited as much by the available resource as by cost. Note that Table 8.25 includes the solar resource (the largest theoretical potential, see also Table 8.24) only for water heating, not for

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[17] See Winkler (2005) for analysis of the merits of different policy approaches for renewable energy in South Africa.

electricity generation. In the present study, we included solar thermal technologies for electricity generation to draw on the largest energy flow.

Table 8.25: Technically feasible potential for renewable energy, by technology

Source: DME (2004b)

Renewable energy technology	*Potential GWh contribution*	*Percentage*
Biomass pulp and paper	110	0.1
Sugar bagasse	5 848	6.9
Landfill gas	598	0.7
Hydro	9 245	10.3
SWH: commercial	2 026	2.0
SWH: residential	4 914	6.0
Wind	64 102	74.0
Total	**86 843**	**100**

The characteristics of the renewable options are summarised in Table 8.23. The data served as input to the modelling and is broadly consistent with the second NIRP. For many renewables, operations and maintenance (O&M) costs are only fixed ones, with no fuel costs. Efficiencies are typically assumed to be 100%, but availability factors are important in reflecting the intermittency of some resources. Note that the molten salt storage for the solar power tower increases its availability relative to the parabolic trough (without any storage).

The initial capital costs of renewable energy technologies are relatively high, but the costs of the new electricity technologies can be expected to decline as cumulative production increases (IEA & OECD 2000). Progress ratios are the changes in costs after the doubling of cumulative capacity, as a percentage of the initial cost. In addition to the International Energy Association's (IEA) overall work, specific progress ratios for wind have been published, around 87% (Junginger et al. 2004; Laitner 2002), and for solar thermal electric – 89% for power towers and 83% for parabolic troughs (Laitner 2002; NREL 1999; World Bank 1999). Information on global operation capacity and growth rates is available in the World Energy Assessment (UNDP et al. 2000).

The approach taken in this study has been to use the estimates from the National Integrated Resource Plan (NIRP) for the decline of wind and solar thermal costs. These costs are used to reduce investment costs, and are extrapolated to 2025, the end of the period.

Table 8.26: Declining investment costs for wind and solar thermal electricity technologies

Source: (NER 2004a)

R / kW	*Wind*	*Parabolic trough*	*Power tower*
2003	7 811	22 750	24 500
2010	6 639	19 250	18 375
2020	5 702	12 250	9 625

8.6.3 The nuclear route – the pebble-bed modular reactor (PBMR)

The South African government has repeatedly stated its intention to develop all energy sources, including nuclear (Mlambo-Ngcuka 2002a, 2003, 2004).The country currently has one nuclear light-water reactor at Koeberg (1840 MW), but Eskom is also developing the pebble-bed modular reactor, which entails further development on an earlier German design (Loxton 2004). The designers claim that it is 'inherently safe' since it uses helium as the coolant and graphite as the moderator (PBMR Ltd 2002). Helium flows can be controlled and the power station can be run to follow load. It can be produced in small modular units of 165MW, thus overcoming the redundancy constraints associated with large conventional nuclear stations. Due to its modular design, construction lead times are expected to be shorter. The fuel consists of pellets of uranium surrounded by multiple barriers and embedded in graphite balls ('pebbles').

The South African Cabinet has endorsed a 5- to 10-year plan to develop the skills base for a revived nuclear industry (Mlambo-Ngcuka 2004). The intention is to develop the PBMR for the export market and at the same time to prove the technology domestically. Exports will have to compete with China which is developing a similar but more complex reactor (AEJ 2005).

The PBMR does not appear in the National Integrated Resource Plan and therefore is not included in the reference case. In modelling the PBMR nuclear technology, we have assumed that waste management policy is completed and enforced. The policy case modelled assumes that twenty-five 165 MW stations are built in South Africa, and examines the implications for economic, social and environmental parameters. The investment costs for the PBMR are based on total assumed production for domestic use and export – over 32 modules produced in the period 2001-2025. It is assumed that cost reduction through learning will have been realised at this point. Specifically, costs are modelled to decline from R187 07 per installed kW in 2010 to R11 709 by 2021 (NER 2004a). These cost assumptions are illustrated in Figure 8.16.

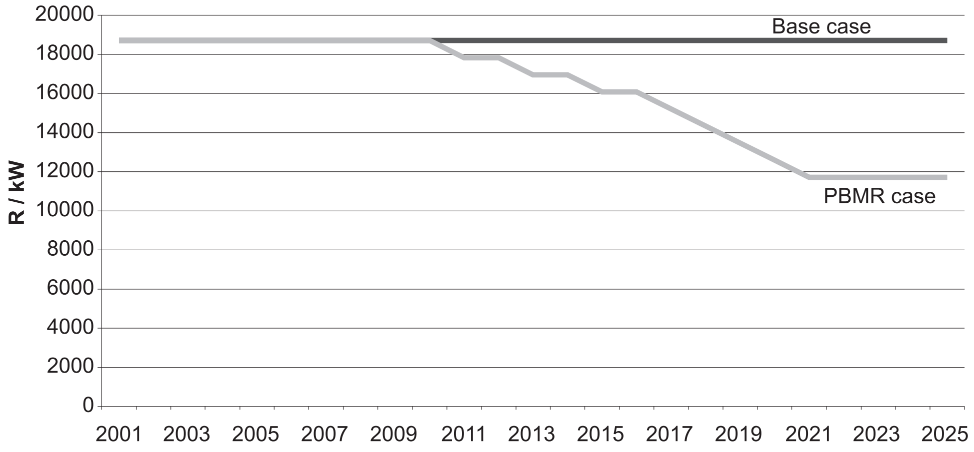

Figure 8.16: Schematic description of assumed PBMR costs in reference and policy scenarios

In the renewables case, learning is a function of global cumulative capacity, whereas for the PBMR, cost reductions are essentially a function of local production. Production is illustrated in Figure 8.17. The dotted line indicates the level of 32 units assumed to be built in the PBMR scenario.

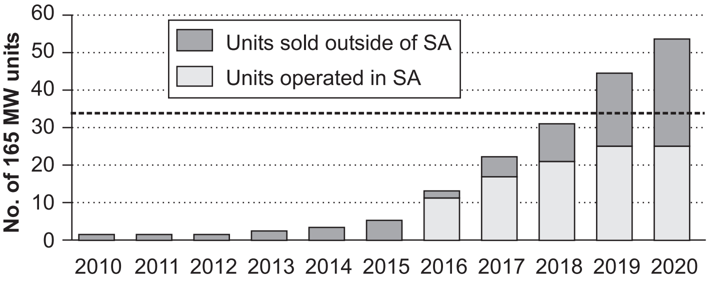

Figure 8.17: PBMR production for local use and exportImporting hydroelectricity from the region

8.6.4 Importing hydroelectricity from the region

One of the major options for diversifying the fuel mix for electricity is to meet growing demand by importing hydroelectricity from other countries in southern Africa. South Africa already imports electricity from the Cahora Bassa dam in Mozambique. The scale of this source is dwarfed by the potential at Inga Falls in the Democratic Republic of Congo (DRC), which is estimated to range between 40 000 MW for run-of-river to 100 000 MW for the entire Congo basin (Games 2002; Mokgatle & Pabot 2002). If the huge potential in the DRC is to be tapped, the interconnections between the national grids within the 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 the New Partnership for African Development (NEPAD) are electricity interconnectors (NEPAD 2002).

The Mepanda Uncua site in Mozambique has a potential for 1 300 MW and an annual mean generation of 11 TWh. It is located on the Zambezi River, downstream of Cahora Bassa and could be connected to the SAPP grid through four 400kV AC lines to Cahora Bassa and Maputo. An installed capacity of 1 300 MWe at a plant factor of 64% provides 7 288 GWh / year of firm energy (NER 2004a). We assumed the plant would come on line in 2011, with a lead-time of 6.5 years. Upper bounds were placed on the increase of imported hydroelectricity up to the generation from Mepanda Uncua and to limit existing hydroelectricity imports.

Table 8.27: Estimated costs during construction, at 2001 prices

Source: NIRP (NER 2004a: Appendix 3)

	Euro (€)	***US$***
Construction of dam and power plant	871 million	1 018 million
Construction of transmission lines	953 million	1 114 million
Environmental management	17 million	19.8 million
Note: costs do not include interest		

The estimated total financing requirement of the project, including price contingencies and interest during construction, is about €2.6 billion, half of which is for the power station and half for the transmission lines (NER 2004a). Assuming an exchange rate of R8/euro, and deflating to 2000 rands, this converts to R11.4 million for the 1300 MW station.

In terms of the institutional capacity required, the Southern African Power Pool has been established to facilitate the trading of electricity, including a short-term energy market. The prospect of increased interconnection and trade of electricity across borders requires regulation. A Regional Electricity Regulators' Association was formally approved by SADC Energy Ministers in July 2002 (NER 2002b), which will have as one of its tasks the establishing of fair tariffs and contracts.

We include in the analysis a scenario in which imported hydroelectricity is increased above its level in the reference case. Importing hydroelectricity from elsewhere in southern Africa is one of the major options for diversifying the fuel mix for generating electricity to meet the growing demand. South Africa itself has only small hydro resources (0.8% of generation) (NER 2002a), and already imports electricity from the Cahora Bassa dam in Mozambique (5294 GWh in 2000) (NER 2000). We have assumed that imports from Cahora Bassa continue and grow due to Mepanda Uncua.

In 2001 the average cost of electricity imports was 2.15c/kWh, well below the cost of South African generation (NER 2001). It is not certain that such low prices will continue into the future. The existing import costs are part of a long-term agreement with Mozambique for electricity supply from Cahora Bassa. The future fixed operation costs are assumed to be R234 million per year, with no variable cost (NER 2004a). Future prices could thus vary between R6/GJ (the existing import cost) up to R99/GJ for Mepanda Uncua. At the cost of avoided generation from a coal-fired plant, at 22.11c/ kWh (NER 2004a) or R61.5/GJ, no hydroelectricity would be used by the model. The approach we have taken is to assume that the weighted average of electricity imports from existing sources and Mepanda Uncua add up to 59 PJ at R47/GJ.

8.6.5 Reducing emissions from coal-fired power plants

A first step to reduce emissions from coal-fired plants would be modifications to existing pulverised fuel plants. Future plants are likely to be dry cooled (reducing specific water use) and install flue gas desulphurisation (FGD) to remove SO_2, even though local coal has a low sulphur content of about 1% (SANEA 2003). Both have cost implications. Dry cooling reduces efficiency by about one percentage point, and desulphurisation adds some 8.5% of the capital cost of stations (NER 2004a). This study has assumed that baseline plants include FGD and removal of particulates to World Bank standards. Existing stations do not have FGD, but use either electrostatic precipitators or bag filters to remove particulates.

The major option investigated in this study is the future use of fluidised bed combustion (FBC), a process in which coal is mixed with limestone and air is blown through it in a moving bed of particles. The Integrated Resource Plan (IRP) base case envisages 466 MW of FBC by 2013 (NER 2001/2, 2004b). Fluidised bed combustion has the advantage of making use of discard coal, and reducing the increase of dumps.

In the medium- to long-term, advanced coal technologies such as super-critical coal and integrated gasification combined cycle (IGCC) are possible. The baseline scenario of the integrated resource plan does not include such stations (NER 2001/2, 2004b), although some analysts indicate that IGCC plants are possible by 2025 (Howells 2000).

Emission standards can be set using target values or limit values. Target values are long-term goals intended to avoid harmful long-term effects on human health, and are pursued through cost-effective progressive methods. For SO_2 and NO_x, only limit values have been published so far, which are based on avoiding harmful effects (Standards SA 2004). The SO_2 emission standards for power stations will meet World Bank standards.

8.7 Transport and liquid fuels

8.7.1 Liquid fuel supply

Apart from modest production at the Oribi and Onyx fields of the south coast, South Africa imports all its crude oil, mainly from the Arabian Gulf. The total domestic supply in 2001 was 18 185 thousand metric tons. The imported crude oil is primarily landed at Durban, Cape Town and Saldanha Bay. In Durban the crude oil is stored at the Natcos tank farm owned by Sasol, and then piped to the refinery at Sasolburg. Another pipeline runs from Saldanha Bay to Cape Town. Both Saldanha Bay and Cape Town have bulk storage facilities.

Refined petroleum products come from two different sources: crude oil refineries and synthetic fuel plants. A unique aspect of the liquid fuels industry in South Africa is the significant contribution from synthetic fuels. Sasol and PetroSA, the synthetic fuel producers, use the Fischer-Tropsch process to convert a mixture of carbon monoxide and hydrogen into hydrocarbons and water. Sasol produces this syngas from coal at its Secunda plants. These plants are situated on a major coalfield and consume 30 million tons per annum.

PetroSA uses natural gas as feedstock in its gas-to-liquids plant at Mossel Bay. The gas and condensate is piped from the offshore FA and EM fields, which are also owned and operated by PetroSA. PetroSA produces 30 000 barrels of product a day from natural gas and a further 15 000 from condensate.

There are four conventional refineries in South Africa, namely, Calref – the Caltex plant at Milnerton in Cape Town, Enref owned by Engen, Shell- and BP-owned Sapref in Durban, and Natref at Sasolburg owned by Sasol and Total. Table 8.28 shows the expansion of capacity of all the South African refineries over the past decade.

Table 8.28: Capacities of South African refineries (barrels per day or crude equivalent)

Refinery	*1992*	*1997*	*2001*
Sapref	120 000	165 000	180 000
Enref	70 000	105 000	115 000
Calref	50 000	100 000	100 000
Natref	78 000	86 000	86 000
Sasol	150 000	150 000	150 000
PetroSA	45 000	45 000	45 000
Total	513 000	651 000	676 000

The products are transported from the refineries for bulk distribution by road, rail and pipeline, primarily by the refinery companies themselves. An important part of the primary distribution network is the Transnet subsidiary, Petronet, which owns and operates a high-pressure steel pipeline distribution network in the eastern parts of the country. Petronet transports a wide range of fuels including crude oil, petrol, diesel, jet fuel and methane rich gas. However the pipeline network does not have sufficient capacity to handle the increasing demand, and lack of capacity is becoming a major problem. Various expansion options are being considered.

The marketers of liquid fuels in South Africa are BP, Caltex, Engen, Sasol, Shell and Total. In general, they do not source solely from their own refineries. Thus, a litre of petrol bought at a service station in Cape Town will most likely come from the Calref refinery at Milnerton, regardless of the retailer. In this way, distribution costs are kept at a minimum.

8.7.2 Transport sector activity

The transport sector covers all tranport activity in mobile engines regardless of the sector to which it is contributing (SIC divisions 71, 72 and 73), and is divided into sub-sectors as given in Table 8.29.

Table 8.29: Transport sub-sectors by SIC code

SIC	*Description*
71	Land transport; transport via pipelines
711	• Railway transport
712	• Other land transport
713	• Transport via pipelines
72	Water transport
721	• Sea and coastal water transport
722	• Inland water transport
730	Air transport

8.7.3 Transport energy use

Transport energy use in 2001 is shown in Table 8.30. Total energy consumption in this sector was 613 PJ. Fifty-six percent of this was petrol, 30% was diesel, 10% was jet fuel, and 3% was electricity. The remainder was aviation gasoline, LPG, fuel oil and coal.

Table 8.30: Energy use in the transport sector (PJ)

Source	*Year*	*Electricity*	*Petrol*	*Diesel*	*Jet fuel*	*Aviation gasoline*	*Total*
This study	2001	13	349	184	66	0.88	613
DME	2001	20	349	184	66	0.88	620
IEA	2000	19	328	154	64	0.82	566
IEA non-OECD stats	1999	16	-	-	-	-	-
Eskom	2001	13	-	-	-	-	-
NER	2001	22	-	-	-	-	-

Eight-six percent of the energy was used for road transport, while 11% was used for aviation, which includes fuelling of international flights. Three percent was used by the railroad sector, while small amounts were used for pipeline transport and internal navigation.

The following end-use services were identified for the transport sector:

- passenger transport;
- car travel (vehicle-kms);
- bus travel (vehicle-kms);
- taxi travel (vehicle-kms);
- motorcycle travel (vehicle-kms);
- rail travel (passenger-kms);

- freight transport;
- light commercial truck transport (vehicle-kms);
- medium commercial truck transport (vehicle-kms);
- heavy commercial truck transport (vehicle-kms);
- rail transport (ton-kms);
- aviation;
- jet aircraft travel (PJ);
- propeller aircraft travel (PJ);
- pipeline transport;
- pipeline transport of liquids (tons);
- pipeline transport of gas (tons).

8.7.4 Characteristics of energy demand technologies

A bottom-up analysis based on vehicle population, average annual mileage and fuel efficiency was used to estimate the fuel use of different vehicle categories. The assumptions are summarised in Table 8.31. Vehicle survival rates were based on scrapping curves suggested by Verburgh (1999) and Stone and Bennett (2001), as shown in Figure 8.18.

Table 8.31: Vehicle population and characteristics

Vehicle type	***Vehicle population***	***Average annual mileage (km/vehicle)***	***Total mileage (Billion vehicle-kms)***	***Fuel efficiency (l/100km)***	***Total fuel use (PJ)***
Petrol cars	3 874 335	14 575	56.47	8.2	186.34
Diesel cars	39 135	15 000	0.59	7.8	1.76
Motorcycles	158 606	10 000	1.59	5.2	3.17
Petrol taxis	248 837	30 000	7.46511	13.3	37.33
Diesel taxis	0	30 000	0	11.9	0.00
Buses	25 943	39 495	1.0246	18.3	7.16
Light commercial diesel vehicles	377 964	30 000	11.34	11.3	48.99
Light commercial petrol vehicles	959 504	25 000	23.99	13.3	122.16
Medium commercial diesel vehicles	170 899	39 495	6.75	18.3	47.20
Heavy commercial diesel vehicles	71 313	79 163	5.65	33.1	71.64
Total					525.75

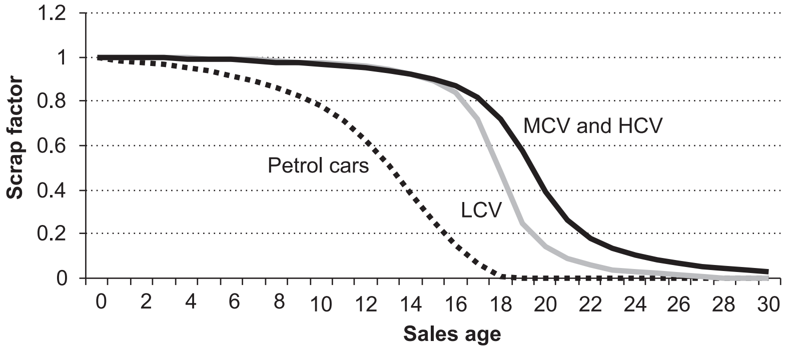

Figure 8.18: Vehicle scrapping curves

8.7.5 Demand projections

We assumed that population growth is the major driver of passenger transport demand. Demand was also adjusted to reflect an increase in private vehicle ownership as GDP per capita grows. Table 8.32 illustrates the assumed values for transport activity intensities.

Table 8.32: Per capita passenger transport intensities by mode

	2001	*2025*
Buses [vehicle-km/capita]	22.9	22.9
Private cars [vehicle-km/capita]	1 273.0	1 476.7
Taxis [vehicle-km/capita]	166.6	166.6
Motorcycles [vehicle-km/capita]	35.4	35.4
Rail [passenger-km/capita]	581.4	581.4

It was assumed that freight transport demand would grow in relation to value added in the transport sector. Simple linear regression for the years 1993 to 2004 showed a very good correlation ($R^2 = 0.99$) with the overall GDP. The relationship obtained from the regression was therefore used to forecast value added in transport, based on the predicted GDP growth rate. The resulting time series data is shown in Table 8.33.

Table 8.33: Forecast of value added in the transport sector

	2001	*2005*	*2010*	*2015*	*2020*	*2025*
Transport GVA	85 646	110 123	140 419	175 201	215 133	260 977

Past trends (measured in vehicle-kilometres travelled per unit of value added) were extrapolated to forecast the demand intensity for actual physical transport. These forecasts are shown in Table 8.34 and generally show declining intensities, i.e. fewer vehicle-kilometres per rand.

Table 8.34: Freight transport intensities

	2001	*2025*
Light commercial trucks (vehicle-kms/kR)	412.5	346.5
Medium commercial trucks (vehicle-kms/kR)	78.8	66.2
Heavy commercial trucks (vehicle-kms/kR)	65.9	55.4
Rail (ton-kms/kR)	1.2	1.2

Pipeline transport was assumed to be related to current and expected future pipeline capacity and utilization factors, rather than to any population or economic driver. Aviation demand was assumed to grow in relation to value added in the transport sector. The assumed intensity changes were based on current trends and are given in Table 8.35.

Table 8.35: Aviation transport intensities

	2001	*2025*
Jet aircrafts (GJ/mR)	770	524
AvGas aircrafts (GJ/mR)	10.3	4.3

8.7.6 Liquid fuel policies

Plans for the expansion of an existing refinery are part of the reference case and no further expansion is envisaged. The policy alternative would be the importation of petroleum products. Initiatives to refine bio-fuels are also examined, although these are expected to make up a relatively small share of the market within the study period. Bio-diesel and eco-diesel pay only 70% of the General Fuel Levy on mineral fuels. In 2001, the General Fuel Levy amounted to 98 cents per litre on petrol, 94.8 cents per litre on unleaded petrol, 81 cents per litre on diesel and 56.7 cents per litre on biofuels. Hence the exemption amounts to a tax break of 29.4c / litre of leaded petrol.

8.8 Energy-related environmental taxation

The use of economic instruments for environmental fiscal reform is being considered by the National Treasury (National Treasury, 2006). We analysed the option of a fuel input tax on coal used for electricity generation.

The indications are that if the full (mid-range) carbon costs were to be internalised, a tax of approximately R60-R80 per ton of coal combusted might be necessary (Blignaut, 2004). For a fuel input tax, the 'taxable event' would be the combustion of fossil fuels used for power generation. The tax would follow the established system of VAT payments and would be collected by South African Revenue Services. The revenue raised could be used for a variety of different purposes, including an allocation to municipalities to compensate for the lost revenue base resulting from restructuring; for projects to improve household energy efficiency; and/or for new projects promoting the development of renewable energy technologies. Such a tax could be implemented in a revenue-neutral manner, with the proceeds being recycled, either into subsidies for renewable energy, or for the general relief of poor communities, e.g. zero-rating of VAT on additional basic foodstuff items.

While R70 is close to the 2005 price of coal (approx R75/ton), the fuel costs overall are a relatively small part of the total cost of energy. We modelled the implications of a fossil fuel input tax at R40 and at R70 per ton of coal, examining the implications of such a major intervention by the national Treasury, were it to be adopted within the forthcoming framework (National Treasury 2006). Any tax – whether input or output-based – would have to be assessed against this framework. Such taxation policies could be extended to coal for synthetic fuel production and industrial use. Alternatively, environmental outputs could be taxed directly, e.g. in a pollution tax.

9

Modelling framework and drivers

Mark Howells, Thomas Alfstad and Harald Winkler

9.1 Model description

For this study we have used the Markal (acronym for market allocation) energy model (See www.etsap.org for documentation, and Loulou et al. (2004)). Markal is a mathematical model of the energy system that provides a technology-rich basis for estimating energy dynamics over a multi-period horizon. The objective function of Markal is to minimise the cost of the system being modelled (Loulou et al. 2004).

The data entered into the modelling framework includes detailed sector-by-sector demand projections and supply-side options. Reference case estimates of end-use energy service demands (e.g. car, commercial truck, and heavy truck road travel; residential lighting; and steam heat requirements in the paper industry) are developed by the user on the basis of economic and demographic projections. The user also provides estimates of the existing stock of energy related equipment and the characteristics of available future technologies, as well as new sources of primary energy supply and their potentials (Loulou et al. 2004).

Markal then computes energy balances at all levels of an energy system: primary resources, secondary fuels, final energy, and energy services, aiming to supply energy services at minimum global cost. The model simultaneously makes equipment investment and operating decisions and primary energy supply decisions in order to achieve minimum cost. For example, if there is an increase in demand for residential lighting energy services (perhaps due to a decline in the cost of residential lighting), then the model will tell the user that either existing generation equipment must be used more intensively or new equipment must be installed. The choice of generation equipment (type and fuel) will incorporate an analysis of both the characteristics of alternative generation technologies and the economics of primary energy supply. Supply-side technologies, e.g. power plants, require lead times. Markal is thus a vertically integrated model of the entire energy system.

Markal computes an inter-temporal partial equilibrium on energy markets, which means that the quantities and prices of the various fuels and other commodities will be in equilibrium. Their prices and quantities within each time period are such that at those prices the suppliers will produce at least the quantities demanded by the consumers. Further, this equilibrium will be such that the total consumer and producer surplus is maximized over the whole horizon. Investments made in any given period are optimal over the horizon as a whole.

In Standard Markal, several options are available to model specific characteristics of an energy system, such as the internalization of certain external costs, endogenous technological learning, the fact that certain investments are by nature 'lumpy',[18] and the

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[18] 'Lumpy' in the sense that the units of investment are large. For large power station investment, for example, this means that the time-series of investments is not a smooth line produced by lots of little investments, but shows discrete 'lumps' for each power station.

representation of uncertainty in some parameters. Markal is capable of including multiple regions, but in this study, South Africa is represented as a single region.

9.2 General assumptions and drivers of future trends

9.2.1 Economic growth

In the absence of interventions that 'de-couple' energy demand from economic growth, projections of GDP are an important driver. Economic growth over the next 25 years is in fact difficult to predict, although most government projections assume a smooth growth rate into the future. Annual GDP growth was assumed to be 2.8% per year in the first Integrated Energy Plan (DME 2003a), while the Integrated Resource Plan considers forecasts of 1.5% and 4% (NER 2001/2). A sensitivity analysis around a central GDP growth figure of 2.8% seemed to us a reasonable approach.

9.2.2 Population projections and impact of Aids

We have assumed that the pattern of household and population growth in the past will continue. However we have to assume lower growth rates due to the impact of Aids. While this is strongly debated, some highly respected studies show a substantial levelling off in population during our study period 2000-2030. Studies by Professor Dorrington of the University of Cape Town Commerce Faculty for the Actuarial Society of South Africa are well respected academically (ASSA 2002).

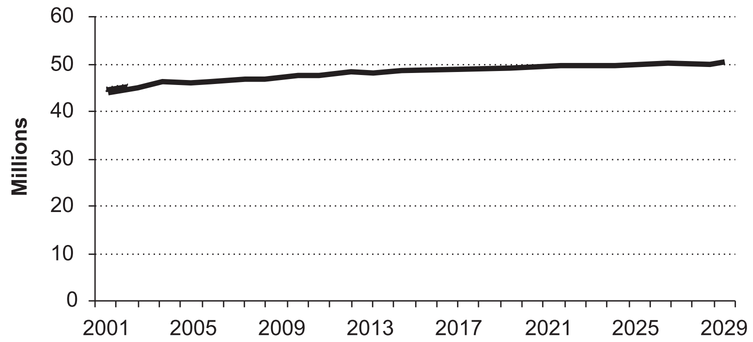


Figure 9.1: Population projections by ASSA model
Data source: ASSA (2002)

The DBSA also projects trends in population, differentiating between low and high impacts of HIV/Aids (Calitz 2000a, 2000b).The first Integrated Energy Plan included projections of population growth (ERI 2001), which are shown together with other estimates in Table 9.1. Not all projections covered the whole 2000-2030 study period.

Table 9.1: Population projections from various sources (in millions)

	DBSA low Aids impact	*DBSA high Aids impact*	*ASSA 2002 (base run)*	*IEP assumptions*	*UN world population projection*	*This study*
2001			45	44	43	44.8*
2006			46			46.4
2011	56	49	48	50		47.6
2016	61	50	48		45	48.5
2025	70	49	50	57	44	49.7
2030			50			50.0

* The 2001 Census reported 44 819 778 people in South Africa (SSA 2003a) and we use this number instead of ASSA's projection.

The Actuarial Society of South Africa (ASSA) projections seemed to us the most reasonable, indicating a growth of 12% over the period, with annual growth rates between 0.1% and 1.0%.

An important difference between this study and others relates to population projections in the reference case. The population projections used in the Integrated Energy Plan (IEP) were for 50 million in 2011 (here: 47.6 million) and 57 million in 2025 (49.7 million). While the IEP projections are lower than previous estimates, they are still higher than those of demographic experts. Another source of difference relates to confidential data which was used for previous studies and was not available for this study.

9.2.3 Technological change

Technology costs change over time. This is particularly true for new technologies, which benefit from learning-by-doing and economies of scale. The first prototype of a new technology is typically much more expensive than later models, which are likely to be produced in smarter, more cost-effective ways and in larger production runs. Learning by experience reduces costs (Arrow 1962) and this general finding has been found to be true for energy technologies as well (IEA & OECD 2000).These can be assessed by learning ratios, measuring the reduction of cost per installed capacity for each doubling of cumulative capacity.

The International Energy Agency (IEA) has published estimates of learning or 'experience curves', which show the decline in costs (measured in c/kWh) as cumulative electricity production doubles. It is clear that newer technologies, be they renewable or otherwise, have higher progress ratios than mature technologies, which integrated most of their cost savings decades or centuries earlier. According to the IEA, photovoltaics declined by 35% in price for doublings of cumulative capacity between 1985 and 1996, wind by 18%, electricity from biomass by 15%; while supercritical coal declined by only 3% and natural gas combined cycles by 4% (IEA & OECD 2000).

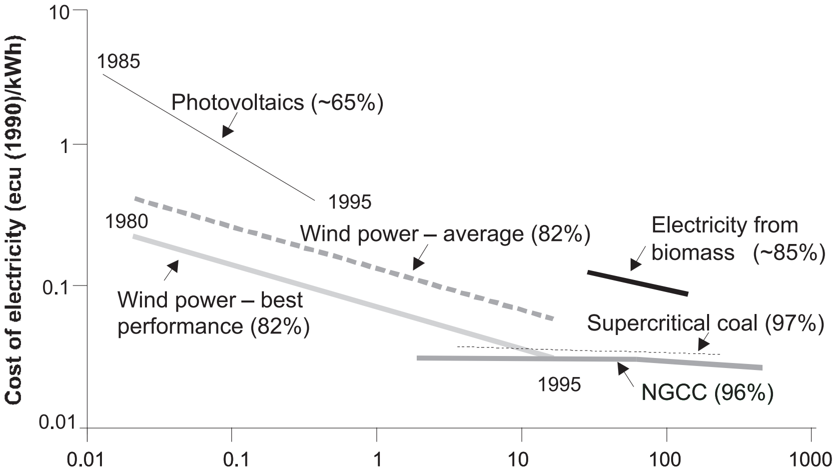


Figure 9.2: Learning curves for new and mature energy technologies
Source: IEA & OECD (2000)

In this study we assumed that technology costs for new energy technologies change over the period. We only examined technology learning for supply-side technologies in the modelling scenarios. Such analysis had to be conducted carefully, taking into account several factors:

- The cost reduction is a function of *global* cumulative production, especially where significant components are imported.
- A more detailed approach should consider the local content, and the component where the learning effect is likely less pronounced.
- The applicability of international learning rates to South Africa remains to be examined.

9.2.4 Future fuel prices

Fuel prices used for the study were taken from a variety of domestic and international sources, shown in Table 9.2. Generally preference was given to national statistical sources, except in the case of projections for internationally traded commodities such as oil.

Table 9.2: Fuel prices by fuel and for selected years

Price for fuel	*Units*	*2001*	*2013*	*2025*	*Source*
Crude oil price	Real crude oil price local production (R/GJ)	24.8	18.0	21.4	IEA (2004)
	Real crude oil price imports (R/GJ)	27.6	20.0	23.8	“
Petrol price	IBLC (R/GJ).	50.3	51.4	60.9	DME (2001)
Diesel price	IBLC (R/GJ).	44.9	45.9	54.4	“
Paraffin price	Bulk (R/GJ)	58.0	59.3	70.3	“
	Drum (R/GJ)	80.5	82.3	97.6	“
HFO price	Bulk (R/GJ)	35.7	36.4	43.2	“
LPG price	Bulk (R/GJ).	112.1	114.6	135.8	“
	Drum (R/GJ).	124.4	127.2	150.8	“
Coal price	Electricity generation (R/GJ).	3.02	3.02	3.02	Prevost in DME (2002b)

Price for fuel	***Units***	***2001***	***2013***	***2025***	***Source***
	Sasol (R/GJ)	2.54	2.54	2.54	“
	Domestic/commercial (R/GJ)	3.45	3.45	3.45	“
	Industry (R/GJ)	3.18	3.18	3.18	“
Biomass price	Wood (c/l)	30.0	30.0	30.0	See note below in 9.2.4.1
	Bagasse (R/GJ)	0.0	0.0	0.0	
Natural gas price	LNG (R/GJ)	21.5	21.5	21.5	NER (2004a)
	PetroSA (R/GJ)	20.0	20.0	20.0	DME (2003a)
	Sasol pipeline (R/GJ)	22.1	22.1	22.1	Sasol (2004a)
Electricity price	Import (R/GJ)	5.5	Endog-enous	Endog-enous	NER (2001)
	Export (R/GJ)	16.3	“	“	“
Electricity price inc. distribution costs	Agriculture (R/GJ)	41.4	“	“	NER (2001)
	Commercial (R/GJ)	41.0	“	“	“
	General (R/GJ)	57.4	“	“	“
	Manufacturing (R/GJ)	10.5	“	“	“
	Mining (R/GJ)	9.8	“	“	“
	Residential (R/GJ)	44.6	“	“	“
	Transport (R/GJ)	21.8	“	“	“
Uranium price	Import (R/GJ).	3.2	3.2	3.2	NER (2004a)

The cost of fuels used in the residential sector stands out as particularly high. If considered per unit of useful energy service, i.e. taking into account household appliance efficiency, the cost would be even higher.

9.2.4.1 Note on biomass costs

Biomass/fuelwood prices are in most cases low or even negative. For paper and sugar mills, biomass is a waste product. In the residential sector, most households report zero purchase costs, i.e. not counting time budgets and opportunity costs. In the Eastern Cape province, low household energy expenditure was attributed to the fact that ‘fuel needs are met almost exclusively by collected – not bought – fuelwood’ (ERC 2004b). Similar findings were made in Limpopo, another province with a predominantly rural poor population, where 95% of households do not pay for fuelwood (Mapako et al. 2004).This is true for urban areas such as Khayelitsha in the Western Cape as well: ‘In the survey, the reported expenditures on fuelwood/biomass were zero’ (Cowan & Mohlakoana 2005). However, in some dense rural settlements, biomass has become a scarce resource which has to be bought. The only national average estimate available of the cost of biomass is R28.24/GJ (De Villiers & Matibe 2000).

To derive a value more transparently, we used an estimate of 50c per kg of wood (Cowan 2005), while acknowledging that the cost of biomass varies widely and should be treated in a locally specific way. R0.50/kg wood, with 1 ton of wood yielding 15 GJ, gives R33.33 / GJ. This figure is of the same order of magnitude as the national average used by De Villers & Matibe (2000), which we have taken as an approximation for commercially used biomass. We apply this value for urban households. A much lower value (one-tenth) was used for rural households, i.e. R3/GJ.

9.2.5 Discounting costs

The general discount rate used in this study was 10%. However, we assumed that poor households had a higher discount rate than high-income households, with a time-preference for money of 30%. In other words, poor households strongly prefer money now to money later. The implication is that they will be less likely than others to invest in technologies that will lead to energy savings in the future, even though these would reduce monthly energy bills.

Costs are reported in rands for the year 2000; where there was a need to adjust cost data from other years, a deflator based on gross value added was used.

Table 9.3: Cost deflators based on gross value added

Source: (SARB 2005; SSA 2004)

1994	62.5
1995	69.0
1996	74.8
1997	80.8
1998	86.4
1999	92.1
2000	100.0
2001	107.7
2002	118.6
2003	123.5
2004	128.8

9.2.6 Emission factors

Emission factors are needed to convert energy consumption (in energy units, PJ or GJ) to emissions. The Intergovernmental Panel on Climate Change (IPCC) default emission factors (in tC / TJ, or t CO_2 / TJ) were used for emissions of CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO_2 (IPCC 1996: Tables 1-2, 1-7, 1-8, 1-9, 1-10, 1-11 and 1-12 respectively). Following IPCC methodology, local emission factors or adjustments to defaults based on local conditions were made.

For carbon dioxide from other bituminous coal, 26.25 tC/TJ was used instead of the IPCC default of 25.8 tC/TJ. This adjustment is based on direct measurements at a South African coal-fired power station (Lloyd & Trikam 2004). The higher emissions are consistent with the lower calorific value of South African sub-bituminous coal at 19.59MJ/kg, whereas the IPCC default value is for 25.09 MJ/kg coal. Further measurements at more stations in future may lead to a submission of a South Africa-specific emission factor to the IPCC. The above list already includes important local air pollutants (SO_2, NO_x, and NMVOC), but not particulate matter.

10

Results of scenario modelling

Thomas Alfstad, Harald Winkler and Mark Howells

10.1 Reference case

The reference case presents a path of South Africa's energy development that can also be called 'current development trends' or a base case. The reference case for this analysis was similar to that of government plans – for energy, the first Integrated Energy Plan (IEP) (DME 2003a) and for electricity, the second National Integrated Resource Plan (NIRP) (NER 2004a). The timeframe for the base and policy cases is from the base year of 2001 until 2025. However, the modelling approach extended the model run to 2030 to avoid sudden changes in the end year. Costs are reported in rands at the year 2000 value. The energy balance for the reference case is shown for 2001 in Table 10.1, with a projected future energy balance in the Appendix (see the second part of Table 10.1).

Table 10.1: Energy balance for the base case, start and end year

2001 (PJ)															
	Coal	***Dis-card***	***Crude oil***	***Av-Gas***	***Die-sel***	***LPG***	***Petrol***	***Jet-fuel***	***Paraf-fin***	***HFO***	***Gas***	***Bio-mass***	***Renew-ables***	***Nuc-lear***	***Elect-ricity***	***Total***
Production	4900	692	56	0	0	0	0	0	0	0	98	76	7	0	0	5830
Import	0	0	763	0	0	1	0	0	0	0	0	0	0	138	33	935
Export	-1716	0	0	-7	-117	0	-60	0	-3	-90	0	0	0	0	-24	-2018
Stock changes	0	692	0	0	0	0	0	0	0	0	0	0	0	0	0	692
TPES	3184	0	819	-7	-117	1	-60	0	-3	-90	98	76	7	138	9	4055
Transformation																
Electricity generation	-1734	0	0	0	0	0	0	0	0	0	0	-3	-7	-138	694	-1189
Oil refining	0	0	-1119	8	376	16	413	76	28	108	0	0	0	0	0	-94
Coal liquefaction	-859	0	300	0	0	0	0	0	0	0	0	0	0	0	0	-558
Transmission losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-60	-60
Total transformation	-2592	0	-819	8	376	16	413	76	28	108	0	-3	-7	-138	633	-1902
Final energy demand	592	0	0	1	259	17	353	76	24	18	42	101	0	0	633	2116
Statistical difference	0	0	0	0	0	0	0	0	0	0	56	-27	0	0	9	37
Agriculture	2	0	0	0	43	0	3	0	2	2	0	0	0	0	22	73
Commerce	20	0	0	0	0	13	0	0	0	0	1	0	0	0	64	98
Industry	562	0	0	0	32	0	1	0	1	17	41	72	0	0	414	1139
Residential	8	0	0	0	0	4	0	0	21	0	0	29	0	0	121	183

Transport	0	0	0	1	185	0	349	76	0	0	0	0	0	0	13	624
								2025 (PJ)								
	Coal	***Dis-card***	***Crude oil***	***Av-Gas***	***Die-sel***	***LPG***	***Petrol***	***Jet-fuel***	***Paraf-fin***	***HFO***	***Gas***	***Bio-mass***	***Renew-ables***	***Nuc-lear***	***Elect-ricity***	***Total***
Production	8563	1393	56	0	0	0	0	0	0	0	0	96	7	0	0	10115
Import	0	0	1283	0	0	19	0	22	0	0	0	0	0	138	33	1495
Export	-3408	0	0	-11	-59	0	-38	0	-1	-175	0	0	0	0	-24	-3716
Stock changes	0	1232	0	0	0	0	0	0	0	0	0	0	0	0	0	1232
TPES	5155	161	1339	-11	-59	19	-38	22	-1	-175	0	96	7	138	9	6663
Transfor-mation																
Electricity generation	-3063	-161	0	0	0	0	0	0	0	0	-57	-3	-7	-138	1266	-2163
Oil refining	0	0	-1639	12	539	15	536	114	34	193	0	0	0	0	0	-196
Coal lique-faction	-859	0	300	0	0	0	0	0	0	0	0	0	0	0	0	-558
Transmis-sion losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-139	-139
Total tran-sformation	-3921	-161	-1339	12	539	15	536	114	34	193	-57	-3	-7	-138	1127	-3056
Final ener-gy demand	1234	0	0	1	480	33	498	137	33	19	92	141	0	0	1127	3795
Statistical difference	0	0	0	0	0	0	0	0	0	0	-149	-48	0	0	9	-187
Agriculture	2	0	0	0	47	0	4	0	3	2	0	0	0	0	39	96
Commerce	45	0	0	0	0	29	0	0	0	0	3	0	0	0	127	204
Industry	1187	0	0	0	43	0	1	0	1	17	89	131	0	0	798	2267
Residential	1	0	0	0	0	4	0	0	29	0	0	10	0	0	151	194
Transport	0	0	0	1	389	0	494	137	0	0	0	0	0	0	13	1034

Final energy demand, which includes the fuel consumption for industry, transport, commercial, residential, non-energy and agricultural sectors, is shown in Figure 10.1. Fuel consumption in industry and transport clearly dominates, other sectors contributing smaller shares. As can be seen from the shape of the transport fuel consumption, demand in this sector grows over the period. The data underlying this figure is reported in the Appendix.

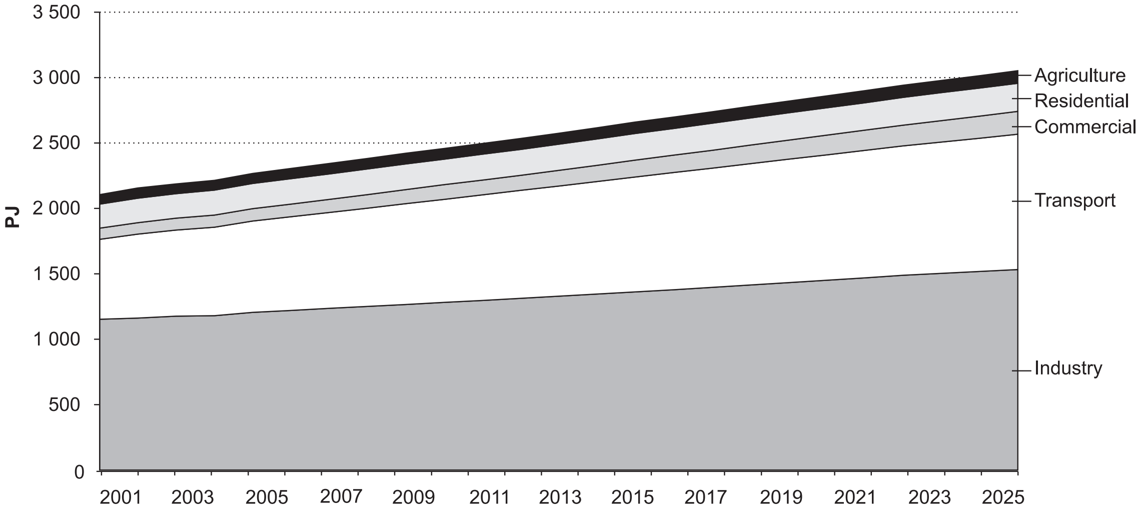


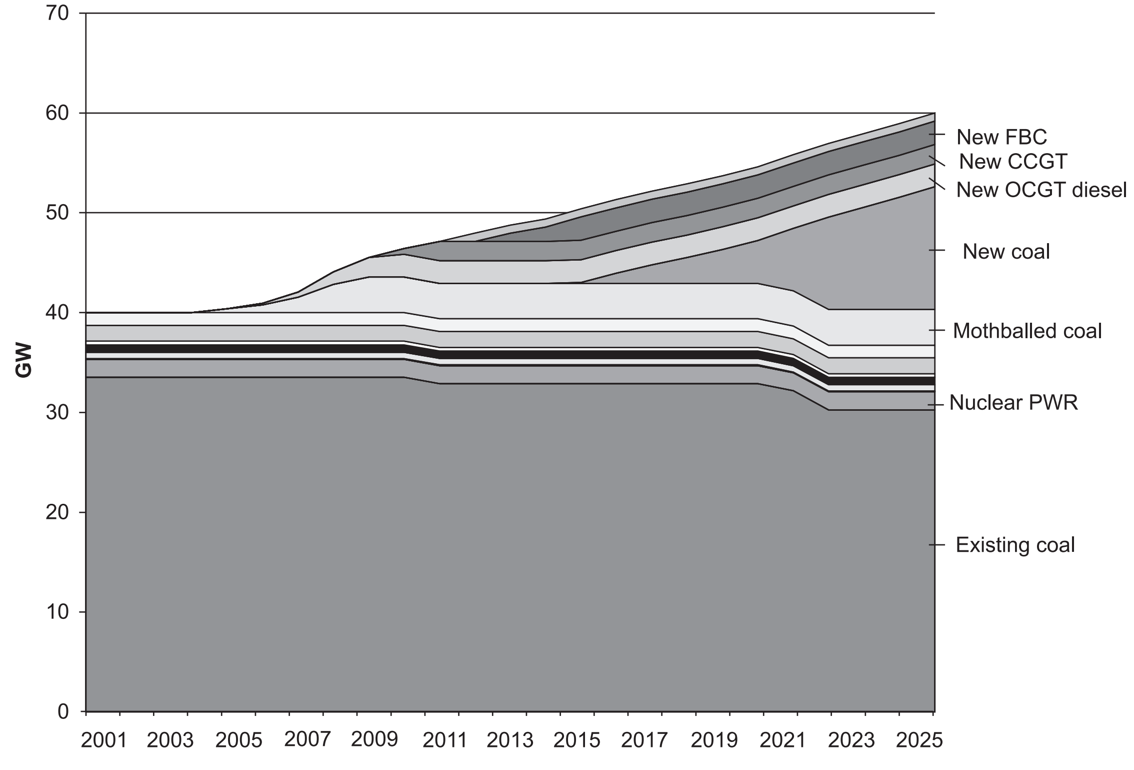
Figure 10.1: Fuel consumption by major energy demand sector

The expansion of electricity generation capacity is shown in Figure 10.2: , grouped by plant type. The underlying projections are reflected in Table A5 in the Appendix.

The reference case is broadly consistent with the National Integrated Resource Plan (NIRP), since it was drawn up in collaboration with Eskom, the NER and the ERC's modelling group (NER 2004b). Small differences between the reference case presented here and that of the NIRP relate to the treatment of the reserve margin and the exact timing of new investment.

Table 8.23 summarises the key characteristics of the technologies for electricity generation. Demand in our reference case is after demand-side management, and we include interruptible supply.

Existing coal continues to supply most of the capacity in the reference case. Mothballed coal stations are brought back into service, and new pulverised fuel stations are built. The major sources of new capacity in the reference case are gas (open cycle and combined cycle) and new fluidised bed combustion, using discard coal. Smaller contributions come from existing hydroelectric and bagasse, electricity imports, existing and new pumped storage and interruptible supply.



Note: Unlabelled plant types in the figure are: new pumped storage, new CGGt, Imported electricity, pumped storage, interruptible supply, hydro, diesel gas turbines, and bagasse.

Figure 10.2: Electricity generation capacity by plant type

The reference case shows that existing power stations will continue to provide a substantial part of capacity up to 2025. Investment in new capacity is directed towards the re-commissioning ('de-mothballing') of three coal-fired power stations, building new pulverised coal stations, open cycle gas turbines (diesel-fuelled) as well as combined cycle gas, and some new pumped storage. The total capital investment in each year is shown in Table 10.2.

Table 10.2: Capital investment in electricity generation capacity (R millions)

	Mothballed coal	*New coal*	*New OCGT diesel*	*New CCGT*	*New FBC*	*New pumped storage*
2001	-	-	-	-	-	-
2002	-	-	-	-	-	-
2003	-	-	-	-	-	-
2004	-	-	-	-	-	-
2005	308	-	-	-	-	-
2006	308	-	548	-	-	-
2007	784	-	1 162	-	-	-
2008	2 088	-	2 308	-	-	-
2009	2 000	-	2 308	-	-	-
2010	-	-	946	2 669	-	-
2011	-	-	-	6 267	-	-
2012	-	-	-	-	-	4 178
2013	-	-	-	-	7 479	-
2014	-	-	-	-	5 763	-
2015	-	868	-	-	8 910	-
2016	-	9 254	-	-	-	-
2017	-	8 315	-	-	-	-
2018	-	7 293	-	-	-	-
2019	-	8 201	-	-	-	-
2020	-	9 026	-	-	-	-
2021	-	19 502	-	-	-	-
2022	-	30 705	-	-	-	-
2023	-	10 001	-	-	-	-
2024	-	10 110	-	-	-	-
2025	-	10 931	-	-	-	-

Figure 10.3 shows the capacity of refineries in South Africa, as well as the imports of finished petroleum products. Most of the capacity is provided by existing refineries, including Secunda and PetroSA. There is some expansion of refineries ('new crude oil refineries'). Imports of finished products account for a small part of overall capacity.

Figure 10.4 shows the total CO_2 emissions for the reference case, while Figure 10.5 shows local air pollutants, specifically SO_2, NO_x and NMVOCs.

Emissions of both local and g4lobal air pollutants increase steadily over the period in the reference case. Carbon dioxide emissions increase from 337 Mt CO_2 in 2001[19] to 591 Mt CO_2 in 2025 – an increase of 75% over the entire period.

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[19] The base year number is fairly close to the CO_2 emissions reported in the Climate Analysis Indicator Tool (WRI 2005) for 2000, namely 344.6 Mt CO_2. It is somewhat higher than the 309 Mt CO_2 from fuel combustion reported in the Key World Energy Statistics for 2001 (IEA 2003a).

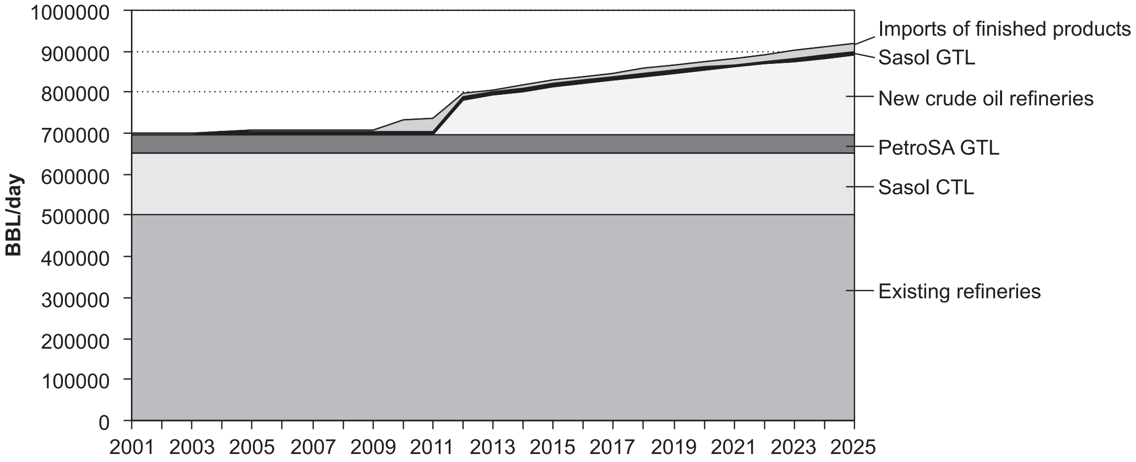

Figure 10.3: Refinery capacity in the base case

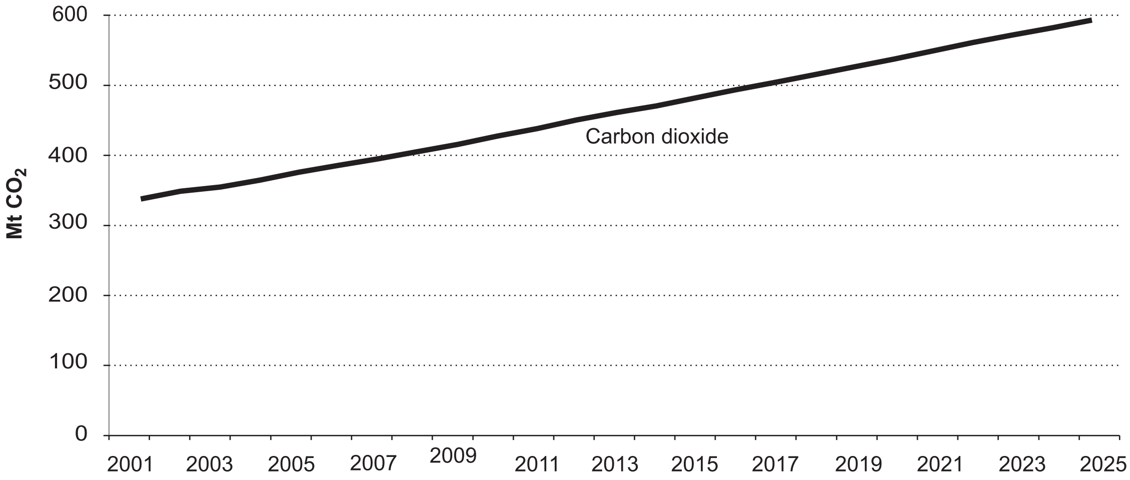

Figure 10.4: CO_2 emissions in the reference case (Mt CO_2)

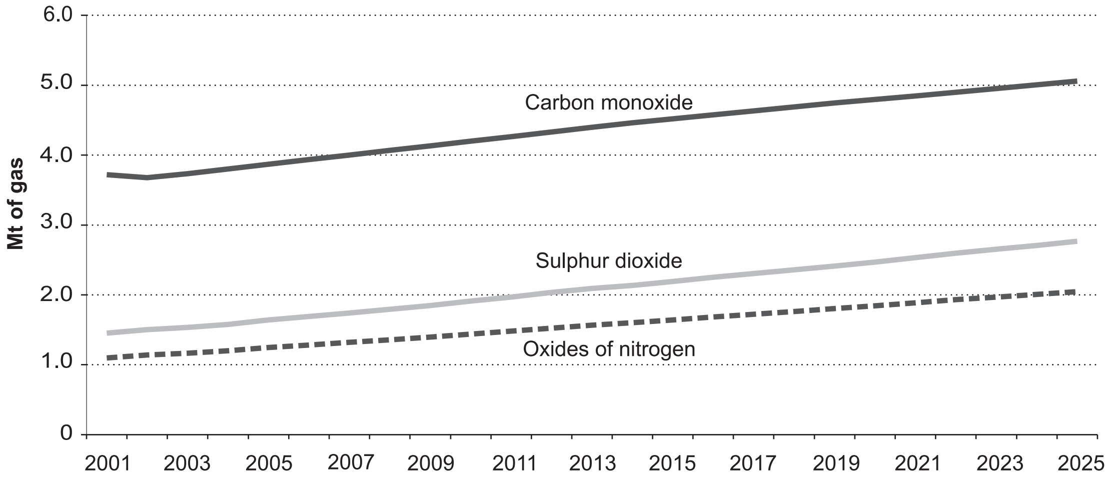

Figure 10.5: Local air pollutants in the reference case

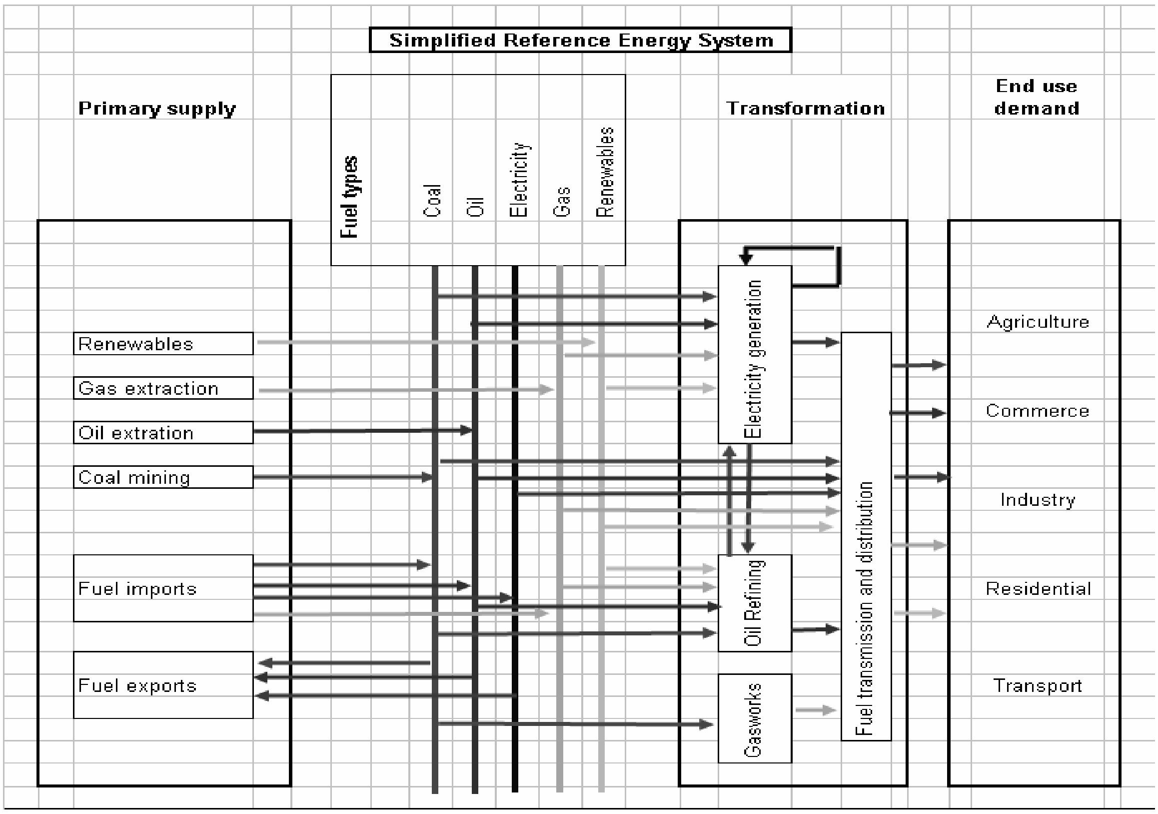

Figure 10.6: Reference energy system

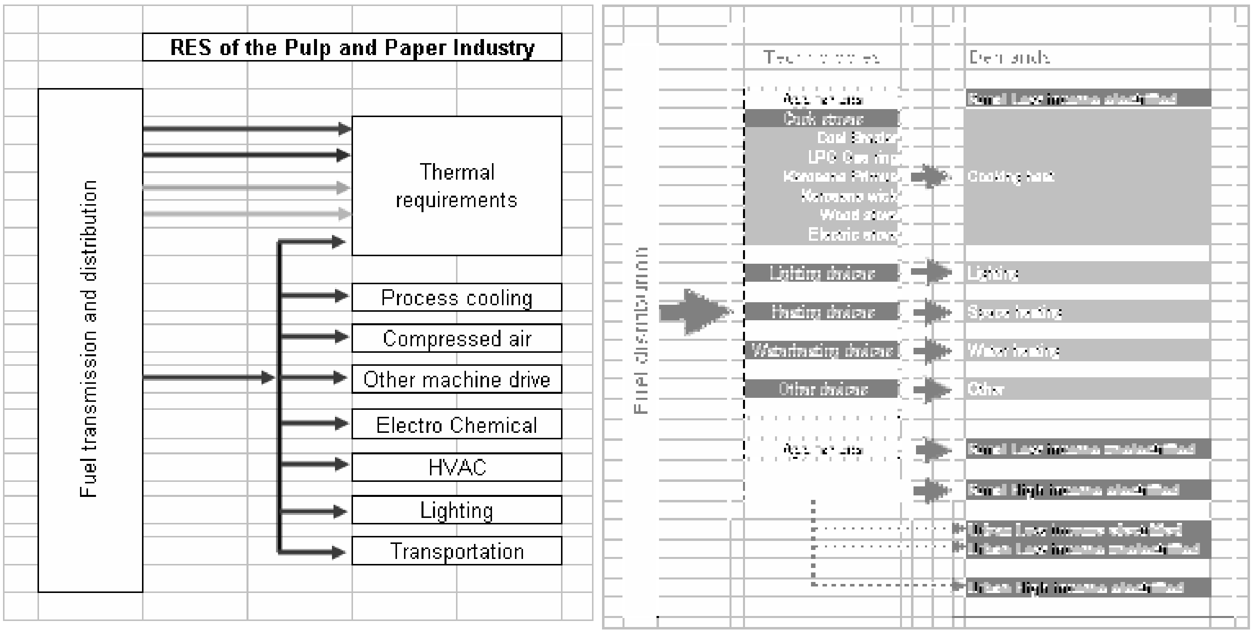

Figure 10.7: Detailed view of reference energy system for pulp and paper and residential demand sectors

Figure 10.6 shows a high-level overview of the reference energy system and the flows from the primary energy supply through transformation to energy demand in different sectors. The actual database is significantly more disaggregated. To give some impression of the detail, Figure 10.7 shows a simplified reference energy system for a pulp and paper mill and part of the residential sector.

Having outlined the structure of the model and the reference case, we can now turn to examining alternative possible futures. None of these policy cases are predictions of the future, nor is any one more likely than another. The rationale for each policy case is described. Note that policy cases do not require the same level of effort, e.g. electricity supply options are designed according to available resources and technologies, not to all add the same capacity or generate the same amount of electricity. The cases seek to understand the implications if particular options are promoted – economically, socially and environmentally.

10.2 Industrial energy efficiency scenario

The industrial energy efficiency scenario is effective both in lowering the cost of the energy system and reducing emissions from both coal-fired power stations and industrial facilities. Emissions from power stations are reduced as a result of decreased electricity consumption. The cost of the energy system, relative to the base case, is reduced by R18 billion. Over the entire period, CO_2 emissions are reduced by 770 Mt CO_2.

The scenario was modelled by expanding the potential penetration of a range of energy efficiency technologies to achieve a target of 12% savings by 2014 over the base case. Interestingly, different energy efficiency technology options are taken up by the industrial sector as the marginal cost of generating electricity increases. Thus energy efficiency technologies that are economic in the middle of the scenario period (when new base-load power stations are required) are not economic at the beginning of the period (characterized by low electricity costs). The trend is summarised in Figure 10.8.

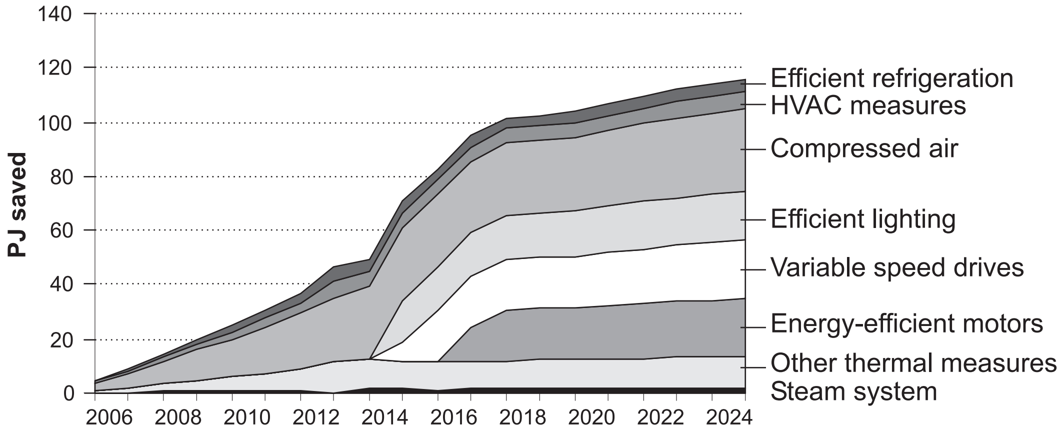

Figure 10.8: Electrical energy saved by energy efficiency technology

Most of the energy saved is coal and electricity, these two being the most important fuels for industry, as shown in Figure 10.9. The savings were limited to 12%. Potentially more saving would be possible in an economic and cost-effective manner.

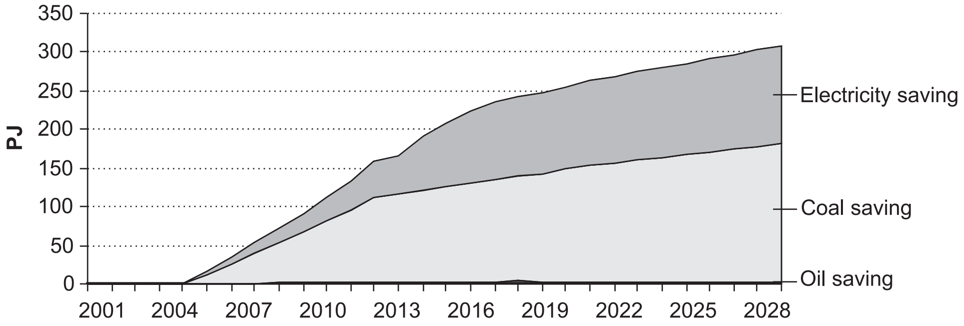

Figure 10.9: Energy saved by carrier in the industrial sector

If the targets for this scenario were achieved through a focussed and aggressive policy, it would have great implications for power generation in South Africa. It would postpone the need for new base load power stations by four years, and the need for peaking power plant by three years. In other words, energy efficiency could play an important role in managing electricity supply needs, especially if one considers the likely lead-time constraints with building new power plant (including environmental impact assessments and other preparation work) and possible short-term peak supply shortages. The overall changes in generation requirement are significant, as shown in Figure 10.10.

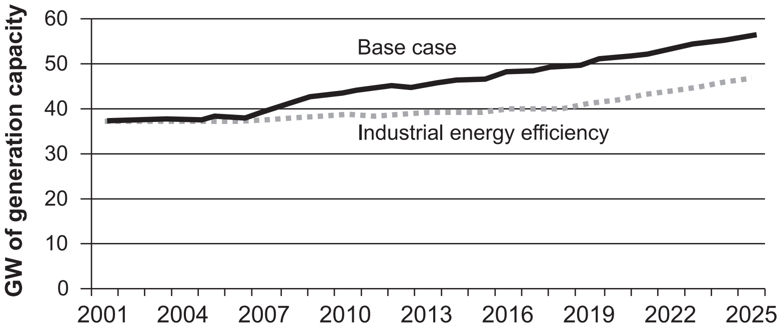

Figure 10.10: Changes in capacity requirements

It is important to note that the uptake of energy efficiency to these levels cannot be achieved without significant policy intervention. Electricity in South Africa is not priced at its marginal cost of production, but rather at its average cost of production – and in a situation where new power plants need to be constructed, the average cost of production is significantly less than the marginal cost of production. This means that someone (a consumer) saving a unit of energy is not rewarded to the same level as someone producing a unit of electricity.[20]

If the electricity price were to equal the marginal cost of production, the uptake of energy efficient practice would be encouraged. However pricing electricity at its marginal cost of production would result in undesirable effects. South Africa's industry has historically relied on low-cost electricity. Poor households cannot afford existing tariffs, making it unwise to

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[20] If *producers* were to build a new power station, they would be guaranteed a return on their investment. They would be paid their (long run) marginal cost of production and the average tariff would be increased to accommodate this. However if *consumers* were to save a unit of energy, they would only be rewarded through a reduced bill based on this average tariff.

increase electricity prices. More targeted 'economic signals' will have to be used to encourage the uptake of energy efficiency options by consumers.

A further conclusion that can be drawn from the model results is that ideally there should be a significant uptake of energy efficiency options during the medium term to allow time for appropriate policy implementation. However, depending on the effectiveness of the measures chosen, energy efficient practices might penetrate the market at a less than optimal level. Further modelling should attempt to accurately match the penetration rates to be appropriate to the policy action taken.

Future modelling might also investigate a different industrial policy, which emphasises higher energy-efficiency (and lower energy- and emissions-intensity) as a competitive advantage, as opposed to the present focus on low electricity prices.

Finally, even though saving energy is 'under-encouraged' by the use of average rather than marginal pricing, there are energy efficiency measures which have a low payback period and which should be encouraged. These were reported earlier (see section 8.1.12) and include improved compressed air management and thermal measures such as boiler optimisation and steam saving.

10.3 Commercial efficiency and fuel switching scenario

The measures described in section 8.2 are combined in this scenario. A target of a 12% reduction in final energy demand by 2014 for the sector was imposed in the modelling, in accordance with the Department of Minerals and Energy's energy efficiency targets (DME 2005a). The results indicate that the target is achievable and would lead to a substantial saving of R13 billion over the time period.

It is important to note that the costs here are based only on engineering estimates of the various measures. Several cost categories are not included in the analysis – information campaigns, costs of formulation, implementation and enforcement of building codes, costs of lost business hours due to heating, ventilation and cooling (HVAC) or similar retrofits and other downtimes and inconveniences. The actual costs would therefore be most certainly higher than what is reported here, but not high enough to obviate the additional gains. International experience suggests that such costs might be in the order of 5% of the investment costs (Spalding-Fecher et al. 2003).

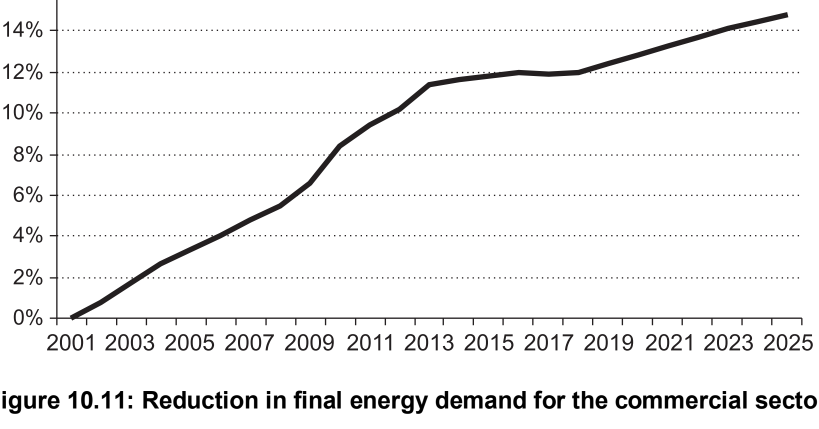

Figure 10.11: Reduction in final energy demand for the commercial sector

The reduction in energy use compared to the base case is given in Figure 10.11. Improvement rates are highest in the period leading up to the target year of 2014. After that, in the absence of more stringent targets, progress predictably slows down. The rate of improvement picks up again towards the end of the time horizon. This can be explained by the fact that the costs of optimal energy efficiency improvements are 2%-3% lower than the 12% target. To reach the target, one thus has to invest in more energy efficiency equipment and measures than those required purely for economic efficiency.

The main savings accrue due to improvements in HVAC systems and the thermal design of buildings. Implementation of building codes and retrofits occur at the maximum allowed by the specified rates. Cooling demand is effectively halved by 2025 compared to the base case. Efficient lighting practices and more efficient lamps also account for some of the savings, with savings of approximately 30% for this end use. As in the case of HVAC systems, efficient design of lighting systems is implemented at a rapid rate. We also see a switch to more efficient fluorescent and high intensity discharge lamps. The change in final energy use by end-use is given in Figure 10.12. There is also significant fuel switching to natural gas for heating purposes.

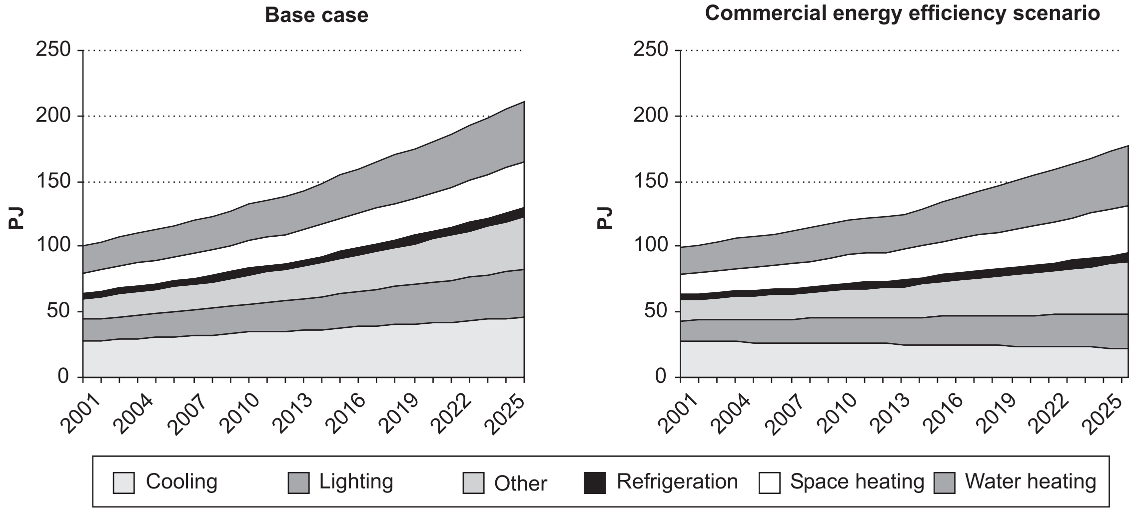

Figure 10.12: Commercial energy demand by end-use

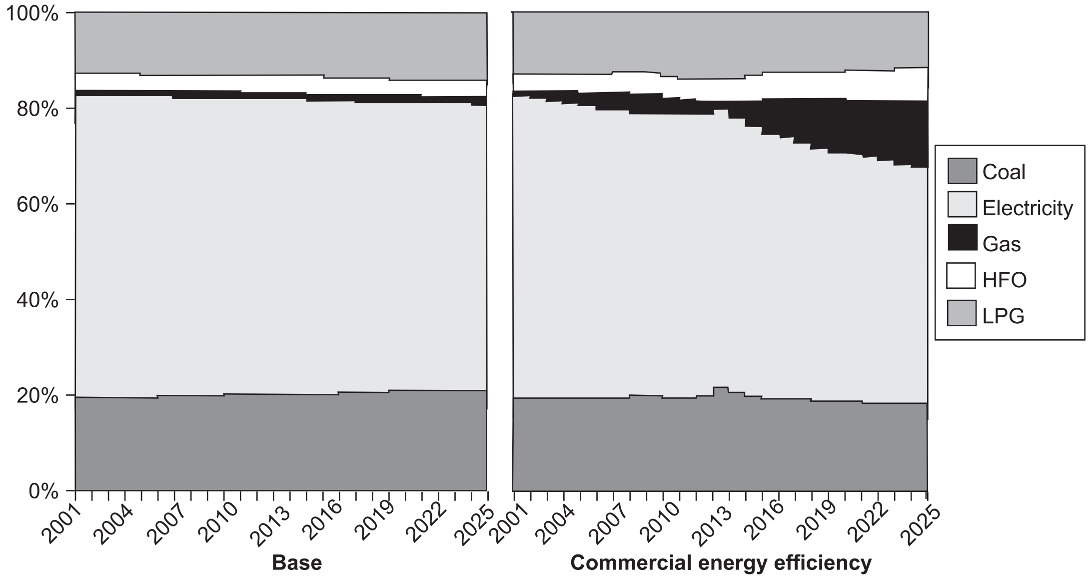

Figure 10.13: Fuel shares for the commercial sector

Fuel shares for final energy demand in the commercial sector are given in Figure 10.13. The relative reduction in electricity demand is largely due to efficiency improvements in the use of electric demand devices rather than fuel switching away from electricity. We also see a significant switch to natural gas, mainly at the expense of liquid fuels used for heating.

10.4 Cleaner and more efficient residential energy scenario

The residential policy case implements the policies described in section 8.3 – solar water heaters (SWHs) and geyser blankets, LPG for cooking, efficient housing shells, and compact fluorescent lights (CFLs) for lighting. The bounds on these technologies are freed up to the levels shown in Table 10.3, allowing the model to choose the most cost-effective options in a wider range.

Table 10.3: Upper and lower bounds for CFLs, SWH / geyser blankets and LPG in the policy case

		UHE	ULE	ULN	RHE	RLE	RLN
CFLs	Up	50%	40%		50%	40%	
	Lo	10%	10%		10%	10%	
SWH	Up	50%	30%		30%	20%	
	Lo	20%	20%		20%	20%	
Geyser	Up	20%	30%	20%	30%		
Blanket	Lo	10%	10%	10%	10%		
LPG	Up	50%	60%	40%	50%	40.0%	30%
	Lo	20%	20%	21%	33%	20.0%	6%

Note: Estimates of bounds are based on the following sources: for water heating by SWH (De Villiers & Matibe 2000; DME 2003b, 2004b); for cooking and space heating (Cowan & Mohlakoana 2005; Davis & Ward 1995; Howells et al. 2005); and for lighting by CFLs on data from the Efficient Lighting Initiative (Bredenkamp 2005; ELI 2005).

For efficient housing, a bound is placed on the number of houses that would be efficient, no more than half of all houses by the end of the period, but allowed to increase from the current 0.5%. The costs of SWHs are assumed to decrease from R6 500 in the base year to R5 000 by 2010, based on the data reviewed in section 8.3.5. These cost assumptions are converted to R/GJ in Markal and interpolated linearly.

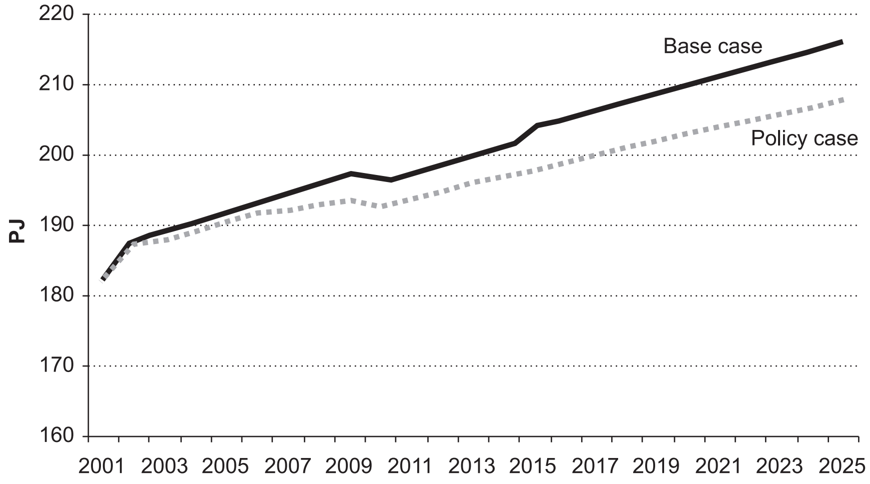

Figure 10.14: Total residential fuel consumption, comparing policy and base cases

The results of the policy case show a reduction in total fuel consumption. Figure 10.14 shows the lower fuel consumption compared to the base case, due to efficiency improvements requiring less energy to deliver the same service. Note that the y-axis of the graph is not at zero. The difference by 2025 amounts to 8.13 PJ.

The reduction in Figure 10.14 is due to greater energy efficiency, but also to some increase in the use of solar energy for water heating. The increase can be seen in the lowest two lines of Figure 10.15, indicating that more solar energy is used in the policy case. Electricity as well as solid and liquid fuels, by contrast, are all lower in the policy case than the base case.

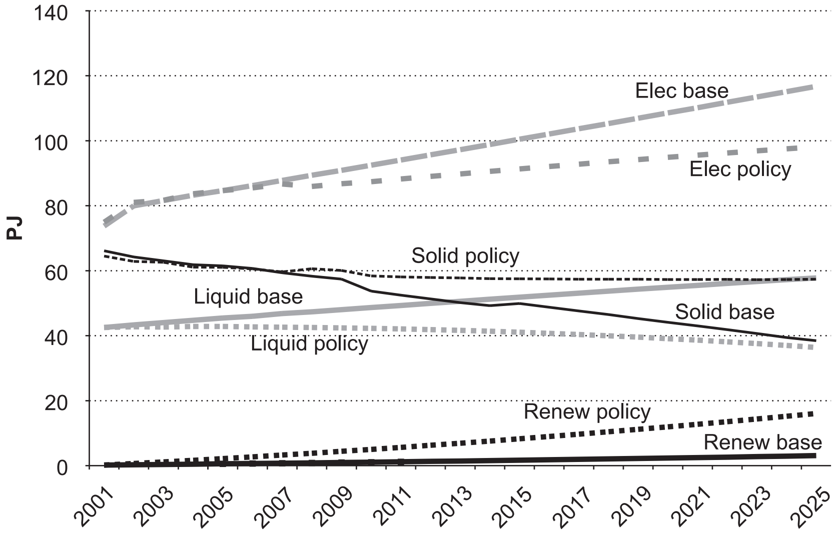

Figure 10.15: Changes in use of electricity, solid fuel, liquid fuel and renewable energy

Some of the shifts caused by the policies for cleaner and more efficient residential energy use are shown in the following figures. Figure 10.16 shows that compact fluorescent lights increase their share for richer rural electrified households significantly beyond the base case. CFLs displace mainly incandescent lights (with paraffin lighting having a very small share). CFLs are also taken up by other electrified household types (not shown here).

Energy savings through the more efficient design of houses are taken up only by urban higher-income electrified (UHE) households. However, the energy savings for this group are substantially higher than in the base case, as illustrated in Figure 10.17.

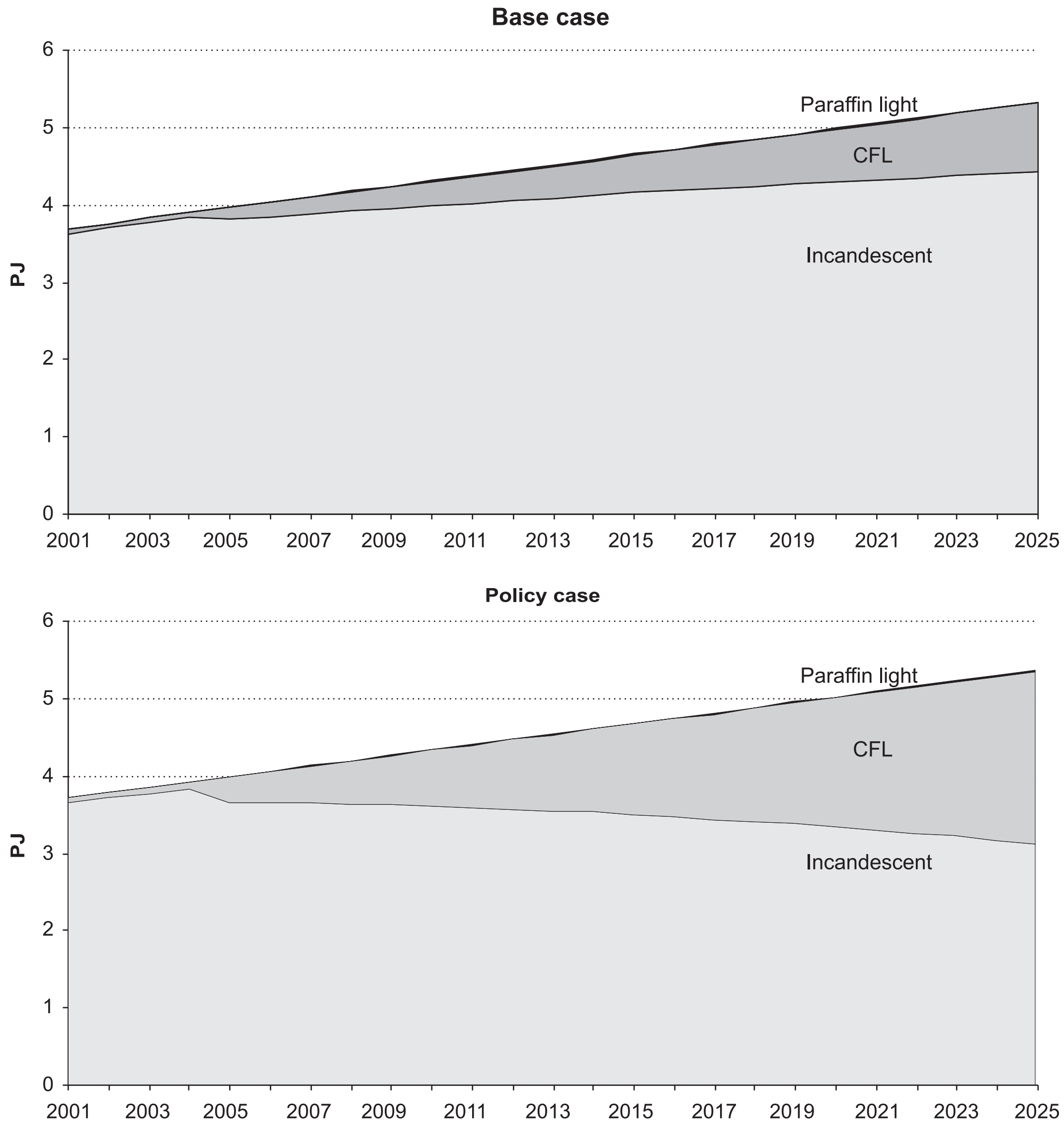

Figure 10.16: Shifts in lighting for RHE households from base to policy case

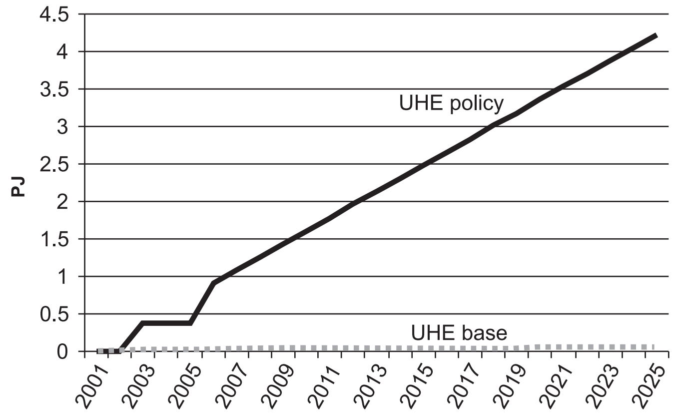

Figure 10.17: Energy savings through efficient houses for UHE households

Two policy interventions in water heating – solar water heaters and geyser blankets – offer an interesting comparison. Table 10.4 shows a much lower total investment for geyser blankets, and less energy saved in aggregate across all household types. However, the energy savings are large in relative terms, and the cost per unit of energy saved is significantly lower for geyser blankets. The lower cost – both upfront and per unit of energy saved – suggests that geyser blankets are appropriate policy interventions in poor electrified households.

Table 10.4: Cost of saved energy for water heating

	Saved energy	***Total investment***	***Cost of saved energy***	
	PJ	***R million***	***R / GJ***	***c / kWh***
Geyser blanket	2.9	5.57	1.9	0.7
Solar water heater	13.0	317	24.5	8.8

While energy efficiency makes sense from a societal perspective for low-cost housing, poor households cannot themselves afford the upfront costs of better thermal design or more efficient lighting and water heating (Winkler et al. 2002). To simulate the impact of a subsidy that would make efficient houses more affordable, the higher discount rate of poorer households was reduced from 30% (no subsidy) to 10% ('subsidised'), and used as the general discount rate for the model. This change was made only for efficient building shells for poorer households.

Household energy consumption patterns in the residential policy case are shown in Table 10.5. A mid-year between 2001 and 2025 was chosen, and the consumption by household type and end use represented. The table shows that poorer households, in both rural and urban areas, use very little electricity for 'other' end uses. Probably this represents a small share of households using some other appliances like refrigeration or washing machines, and a large share using no appliances at all for 'other' uses. Among non-electrified households, average lighting consumption is low, suggesting that there is little or no access to other commercial fuels such as kerosene or LPG for this end use. A limitation in the analysis is that households do not appear in the model directly, only through their energy demand, or as units.

Table 10.5: Household fuel consumption by end use in 2013

MJ / (HH/month)	***Cooking***	***Lighting***	***Other electrical***	***Space heating***	***Water heating***
RHE	126	261	246	118	201
RLE	45	100	6	40	51
RLN	162	2	-	178	102
UHE	324	156	273	334	475
ULE	95	136	8	160	289
ULN	117	1	-	113	53

Which fuels deliver these energy services? As expected, the share of electricity used declines in the residential policy case compared to the base case, as electricity is used more efficiently. A less obvious result, shown in Table 10.6, is that the shares of LPG and paraffin – two other commercial fuels – increase. Coal use remains constant.

Table 10.6: Shares of commercial fuels of total residential energy fuel use

		2001	*2013*	*2025*
Coal	Base case	4%	1%	0%
	Residential policy case	4%	1%	0%
Electricity	Base case	66%	73%	75%
	Residential policy case	66%	70%	68%
LPG	Base case	2%	2%	2%
	Residential policy case	2%	5%	8%
Paraffin	Base case	11%	14%	17%
	Residential policy case	10%	14%	18%

Further research would be useful to translate this analysis into an energy burden per household (energy expenditure as a share of total household income). However, this requires further assumptions about average incomes for poorer and richer households, and goes beyond the scope of this report. What can be reported, however, are the shadow prices of electricity used in the residential sector, shown in Table 10.7. Shadow prices do not represent tariffs, but rather the difference between the technologies used in this policy case and the least-cost alternative. This information could be used in further work on the energy burden.

Table 10.7: Shadow price of residential electricity in the base and policy case

c/ kWh	*2001*	*2013*	*2025*
Base	21.4	23.0	38.4
Residential policy	21.4	57.0	31.1

The level of subsidy required to make energy efficiency economic to poorer households can be approximated in a separate Markal scenario. The level of the subsidy can be approximated by comparing the marginal investment with the higher and lower discount rates – with and without the ‘subsidy’.

Table 10.8: Subsidy required for making efficient housing as affordable for poorer as for richer households

Unit: Rand/household	*2001*	*2014*	*2025*
RLE	-138	-195	-166
RLN	-726	-761	-871
ULE	-524	-738	-682
ULN	-112	-100	-117

Note: The values show the reduction in marginal investment as a result of lowering the discount rate for poor households from 30% to 10%. Negative values indicate payments required.

The reduction in the investment needed is larger for the RLN (rural lower income non-electrified) households and ULE (urban lower income electrified) households. The size of the subsidy required to make efficient housing as affordable for poorer households as for richer ones is in the hundreds of rands, but less than a thousand rand. Thus a relatively small additional investment in housing for poor communities creates more comfort and reduces household energy costs, as well as cutting emissions from the residential sector. Energy efficiency in social housing is an area where a policy of direct state financial support to promote energy efficiency seems warranted. In practice, municipal government would need to play an important role in administering a subsidy scheme and providing bridging finance.

Throughout the policy scenarios we have assumed that electrification rates would increase substantially, as outlined in section 8.3.4. An increase from the current 70% to near-universal access to electricity is also part of the residential energy policy scenario.

10.5 Electricity supply scenario options

10.5.1 Imported gas

The imported gas policy case increases the overall system cost by R0.98 billion over the 25-year time horizon, compared to the base case. The additional costs imply a much longer and more sustained investment in combined cycle gas turbines (CGGTs), as shown in Figure 10.18.

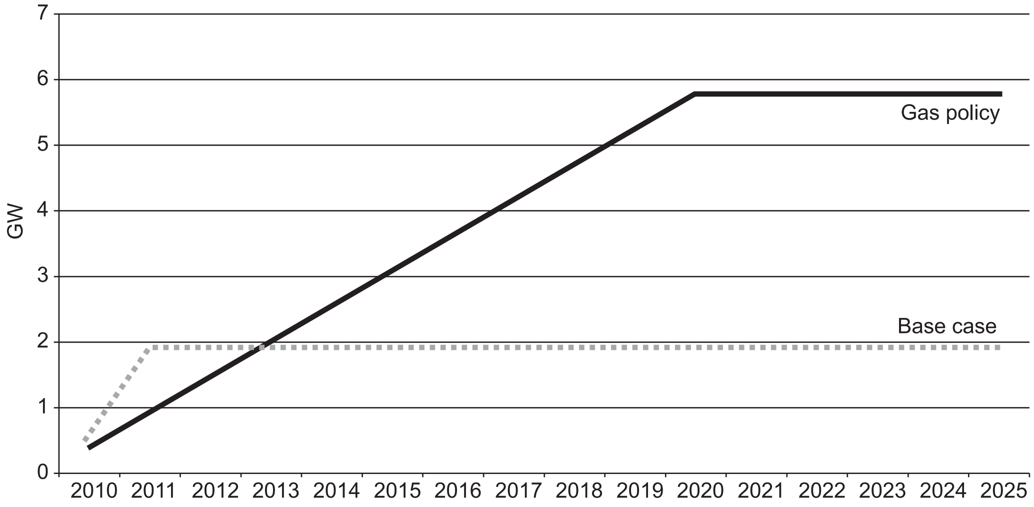

Figure 10.18: Capacity of CCGT in gas policy and base cases

The base case reflects the level of investment in one CCGT in Alternative 1 to the reference plan in the National Integrated Resource Plan (NIRP); the preferred plan itself only had open-cycle gas turbines (NER 2004a). In both cases, investment starts from 2010, but levels off much earlier in the base case and increases up to 2020 in the policy case.

Despite the small changes, gas is a cleaner-burning fuel than coal, and some reductions in local and global air pollutants are observed. Over the 25-year period, 199 Mt of CO_2 emissions can be avoided. Relative to the base case, the reduction for sulphur dioxide, oxides of nitrogen and greenhouse gases are 2.1% lower for the policy case.

10.5.2 Imported hydroelectricity

The policy case of importing hydroelectricity increases the amount of hydroelectricity from the base year's 9.2 TWh to 17 TWh. The sharp rise in Figure 10.19 occurs as the combined price (the fixed contract cost of existing imports and likely higher future costs) becomes competitive.

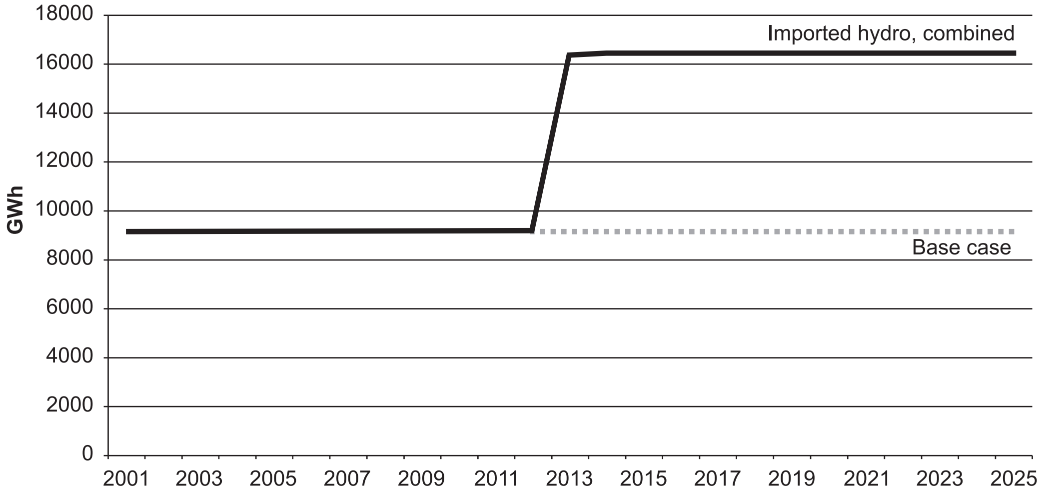

Figure 10.19: Imports of hydroelectricity

More money is spent on hydroelectricity imports in the policy case – an undiscounted R38 billion – compared to R4.6 billion in the base case over the period. Analysis of the direct costs, however, only tells part of the story – the other side is the reduction in investment in other supply-side options. The discounted total system costs are *reduced* by R3.6 billion over the period of 25 years. Some 167 Mt CO_2 can be avoided compared to business-as-usual, and there is a 1.9% decrease in sulphur dioxide emissions.

It should be noted that included in this is a reduction in methane emissions. The emission of methane from large dams is now a subject of ongoing research (IPCC 2001), and the assumption that hydroelectricity is zero-emissions may change as more information becomes available.

10.5.3 PBMR nuclear

Figure 10.20 shows the increase in local capacity, starting from 2012 (prior to this there is no investment). A steady increase in the installed capacity up to the total of 4480 MW can be seen, as well as the investment requirements in billions of rands.

Substantial investments are required here, amounting to R63 billion of undiscounted investments over the period. With these investments, 246 Mt CO_2 can be avoided compared to the coal-dominated reference case. However, the impact should also be considered in the overall energy system, with discounted total energy system costs increasing by R4.6 billion for the PBMR case compared to the base case. Sulphur dioxide emissions are 3% lower than in the base case.

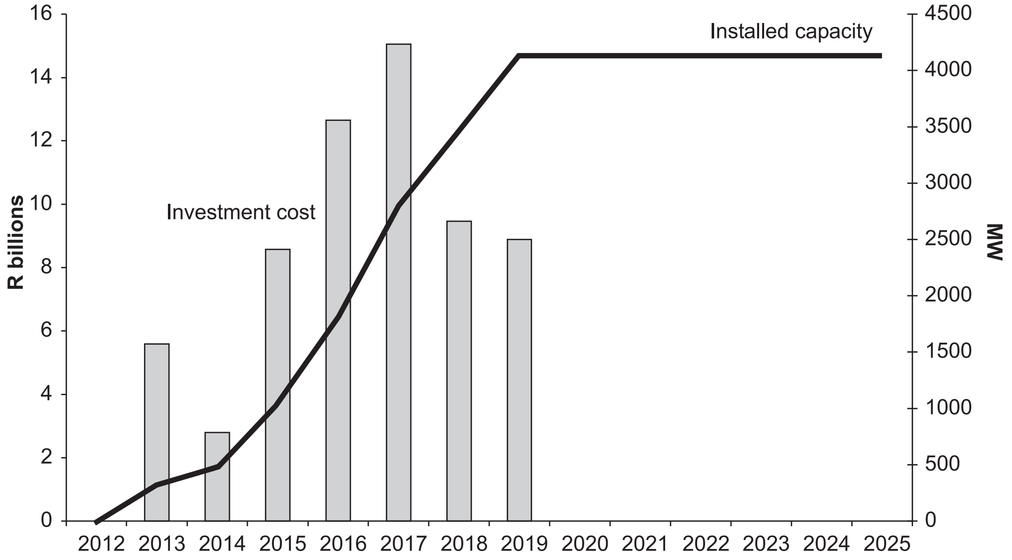

Figure 10.20: Installed capacity and undiscounted investment costs in the PBMR policy case

10.5.4 Electricity supply: renewable energy

The renewable energy policy case was designed to meet the target of 10 000 GWh by 2013, with a portfolio of renewable energy technologies. The costs of renewable energy technologies were assumed to decrease as global markets grow.

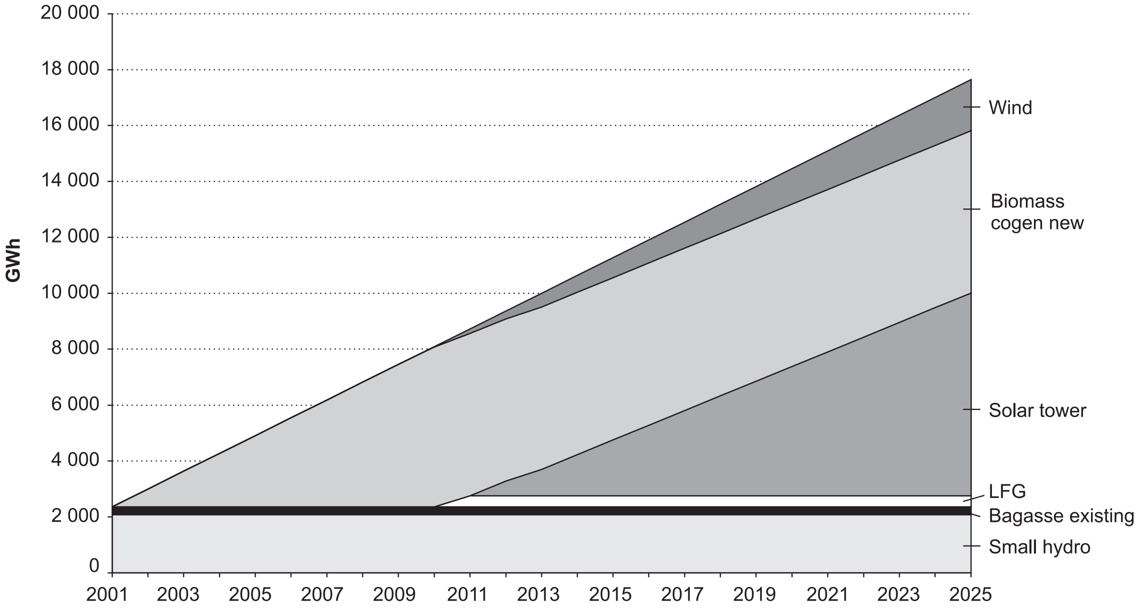

Figure 10.21: Renewable energy technologies for electricity generation in the policy case

Existing renewable energy sources, mostly small hydroelectricity and some bagasse, are supplemented initially, primarily by new biomass co-generation plants. From 2011, some landfill gas is introduced, as well as the solar 'power tower' or central receiver. Solar technology takes over a much larger share of the renewables supply towards the end of the period (2025) as its costs become competitive.

Additional undiscounted investments in the various renewable energy technologies amount to R29.3 billion, of which just over half (51%) is made in the solar 'power tower', a third in new bagasse co-generation, and one-tenth in wind. The discounted total system cost for the renewables case over the period is R4.5 billion higher than in the base case. Sulphur dioxide emissions are 1.6% lower than in the base case. Together, renewable energy technologies avoid 180 Mt CO_2 over 25 years.

10.6 Liquid fuel – bio-fuel refinery scenario

The Department of Science and Technology (DST 2003) estimates that there is potential to produce 1.4 billion litres of biodiesel annually, equivalent to approximately 45 PJ, from sunflower oil, without prejudicing food production (Wilson et al. 2005). Biodiesel refineries do not exhibit significant economies of scale (Wilson et al. 2005) and production from smaller units is feasible. Amigun and Von Blottnitz (2004) evaluate biodiesel refinery sizes through an optimisation framework and conclude that the optimal plant size is 48 000 litres per day. Assuming that the plant operates 300 days of the year, this is equivalent to 1.44 million litres per annum. A plant of this size would require 96 tons of sunflower seed feedstock per day.

Based on Amigun and Von Blottnitz (2004), we assume that a 48 000 litres per day plant would require an investment of R12 million, have fuel costs of R35 per GJ, and operational costs of R50 per GJ. We have assumed that biodiesel production starts in 2010 and reaches 35 PJ by 2025, and that maximum year-on-year production growth is 30%. Diesel exports are fixed to the base case level to ensure that the biodiesel is used to replace diesel rather than to boost exports.

The production cost of biodiesel translates into roughly R3 per litre in 2010, compared to the IBLC of approximately R1.70 per litre for diesel. The price of biodiesel decreases somewhat over the period to R2.60 per litre in 2025, while the IBLC of diesel increases to R2.10 per litre. The tax on biodiesel is R0.61 per litre compared to R0.87 per litre for standard diesel. Figure 10.22 gives the resulting biodiesel share of total transport diesel demand. Relative growth in biodiesel production is highest in the early stages of introduction, slowing down as cultivation moves to increasingly marginal areas. Towards the end of the period, biodiesel market share is 9% of transport diesel, with an annual yield of 35 PJ.

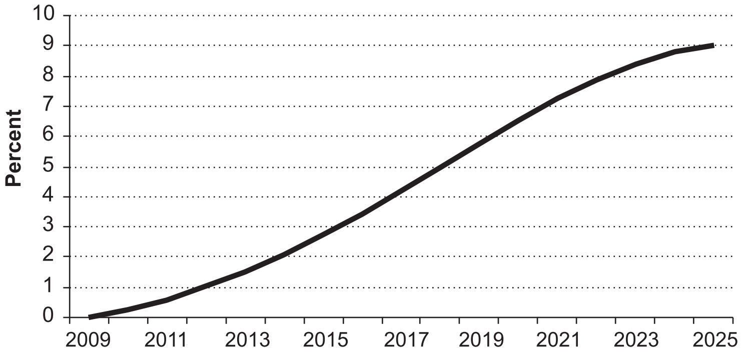

Figure 10.22: Share of biodiesel in marketed transport diesel

The harvesting of feedstock for biodiesel production is assumed to be on, or below, the sustainable yield (photosynthesis and respiration is in balance). Biodiesel is effectively a zero-carbon energy source and its introduction reduces total CO_2 emissions. Total reduction in CO_2 emissions reaches 5 Mt CO_2 per annum in 2025. Cumulative savings are 31 Mt CO_2 for the entire period. There are also some smaller reductions in local pollutants.

Biodiesel production also increases the local production of transport fuels, thereby reducing the need for imported petroleum products. The introduction of biodiesel also reduces the capacity required for crude oil refining by an average of 4 500 barrels/day every year. Figure 10.23 shows the relative reduction in total imports of liquid fuels and in CO_2 emissions. The present value of total system cost for this scenario is R2.4 billion higher than for the reference scenario.

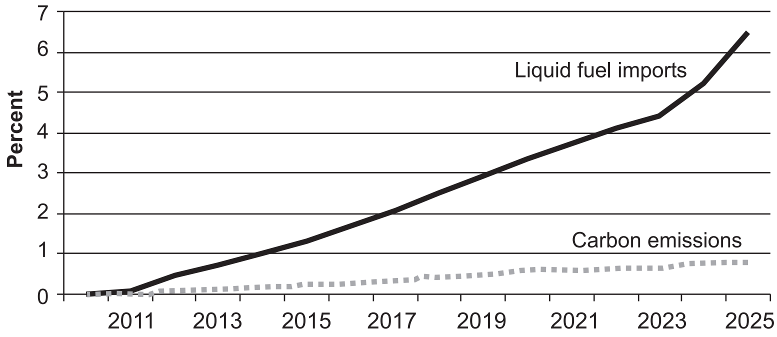

Figure 10.23: Reduction in carbon emissions and liquid fuel imports

10.7 Fuel input tax scenario

A fuel input tax is one of several environmentally related tax instruments that might be considered for South Africa. Any such measures will have to be assessed against a framework for environmental fiscal reform (National Treasury, 2006). The analysis here considers one possible option, although others might be examined in future work (see section 8.8).

A tax on coal for electricity generation could be implemented at various levels. One point of comparison is the coal price, around R60/t coal in 2001 (see Table 9.2). A more positive perspective is that the costs of a tax could be offset through electricity suppliers selling emission reductions through the Clean Development Mechanism (CDM). R100/GJ would represent a carbon price of €6.46/t CO_2 (at 20.1 GJ/t coal, 96.25 t CO_2/TJ and an exchange rate of R8/€1). Such a carbon price is substantially lower than the €20-€30 reported for the European emissions trading scheme in 2005. For certified emission reductions under the CDM, however, a lower price should be assumed. We assume a conservative estimate of R25/t CO_2 (roughly €3/t CO_2) starting in 2001. Expressed in terms of the fuel input, this is equivalent to R50/t coal, an increase of approximately 80% on the coal price. The tax can be thought of as a conservative estimate of the carbon revenues that could be earned by reducing emissions.

The tax was implemented in Markal by attaching an emissions tax of R25/t CO_2 applied to all coal mined for electricity generation from 2005 onwards. This resource technology supplies all coal-fired power plants, but is separate from coal mining for Sasol and other uses (which have no tax attached).

The results show that the reductions of CO_2 emissions from coal for electricity generation are small relative to the reference case. The emission projections in Figure 10.24 are hardly distinguishable, even though the abscissa has been set at 150 Mt CO_2 rather than zero.

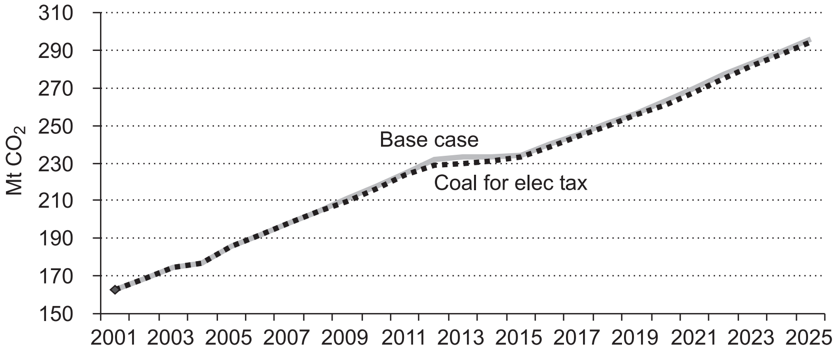

Figure 10.24: Emissions from coal-fired electricity in coal tax policy and reference cases

The fuel cost is a small component of the life-cycle cost of a new plant (see NER 2004a for a comprehensive breakdown of costs). Taking into account all the investments in the energy system, the fuel costs are a small share of the total energy system costs. Even a four-fifths increase in a cost component that only accounts for a small percentage of total costs makes little difference to the technology chosen by a least-cost optimising model.

Nonetheless, the emission reductions (policy case minus reference) reach 3.25 Mt CO_2 in 2013-2014 (see Figure 10.25, reductions shown here as positive numbers). Cumulatively, they add up to 28 Mt CO_2 over the period.

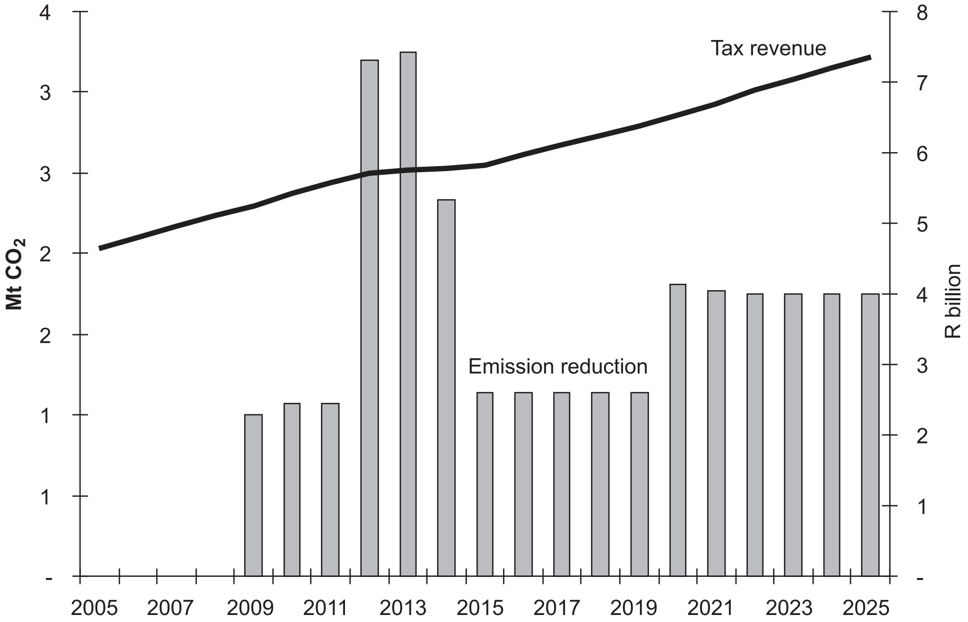

Figure 10.25: Emission reductions for coal tax compared to reference and undiscounted tax revenues

The line in Figure 10.25 shows that the revenues generated by the tax start even in the early years, when there is little difference from the base case. Each ton of coal is taxed, regardless of whether it would have been used in the base case or not.

The difference, in discounted total system costs, over the period is R67 million, while the discounted tax revenues generated add up to R49 billion. The effects of these revenues are mixed – on the one hand, they add to the discounted total energy system costs (which is usually reported as net of taxes and subsidies), but they generate revenue, which could be recycled in the economy and generate benefits. The increase in energy system costs will certainly impact on the affordability of energy for end-users, whether industry or households, and therefore it will have implications for other government policies. However if revenues were used to shift the tax burden for those least able to cope with increased energy costs, the net social effect could be positive.

11

Energy indicators of sustainable development

Harald Winkler, Mark Howells and Thomas Alfstad

The modelling results had to be assessed against a set of sustainable energy indicators. The selected indicators were drawn from those used in previous Sustainable Energy Watch reports (Spalding-Fecher 2001, 2002) and from work done on IAEA indicators for sustainable energy development (Howells et al. 2004). Indicators were selected that could be quantified with energy-economy-environment models and covered the major dimensions of sustainable development.

Taken together, the energy indicators of sustainable development can be used as a tool to assess policy options and alternative energy futures. This method, we argue, provides the means for policymakers to identify synergies and trade-offs between options, and to evaluate the economic, social and environmental dimensions of various options. While the modelling framework ensures that the dynamics of the whole energy system are taken into account in a consistent fashion, the use of indicators of sustainable development helps to make policy approaches more integrated across social, economic and environmental levels.

The indicators presented here provide a means of assessing the implications of some fairly ambitious policy options. They help to spell out the implications of 'what if' cases, and encourage a deeper policy analysis by going into the reasons why certain changes take place.

An overview of the key results is provided in the Appendix (see Table A1). In this section we discuss the results for each indicator.

11.1 Environment indicators

The fuel mix of the energy system is a key indicator affecting the environmental impacts of energy supply and use. Table 11.1 shows how the mix of fuels changes for three selected years (2005, 2015 and 2025) in the policy case.

The dominant impression is that across all cases and years, the share of solid fuel (mostly coal) remains high. The share of renewables increases to 3.1% in the renewables case, compared to 1.5% in the base case. The PBMR case similarly shows some growth in nuclear fuel us9e in the middle of the period. Clearly a sustained move to greater diversity will require more than a single policy.

Analysis of greenhouse gas emissions in South Africa's energy sector focuses mainly on carbon dioxide. Table 11.2 shows emissions reductions for the various policy cases. The first row gives the total annual CO_2 emissions for the base case, while the emissions reductions (difference between that case and the base case) are shown in the rest of the table.

Table 11.1: Fuel mix for policies and selected years (percentages)

	2005					*2015*				
	Solids	***Petroleum***	***Renewables***	***Nuclear***	***Electricity***	***Solids***	***Petroleum***	***Renewables***	***Nuclear***	***Electricity***
Base case	78	17	1.9	3.1	0.2	78	18	1.7	2.5	0.2
Biodiesel	78	17	1.9	3.1	0.2	78	17	2.3	2.4	0.2
Commercial	78	17	1.9	3.1	0.2	78	18	1.7	2.5	0.2
Industrial EE	78	17	1.9	3.1	0.2	77	19	1.8	2.6	0.2
Gas	78	17	1.9	3.1	0.2	77	19	1.7	2.5	0.2
Hydro	78	17	1.9	3.1	0.2	77	18	1.7	2.5	1.1
PBMR nuclear	78	17	1.9	3.1	0.2	77	18	1.7	3.7	0.2
Renewables	76	17	3.3	3.0	0.2	76	17	3.5	2.4	0.2
Residential	78	17	1.9	3.1	0.2	78	18	1.7	2.5	0.2
Fuel tax	78	17	1.9	3.1	0.2	78	18	1.7	2.5	0.2

	2025				
	Solids	***Petroleum***	***Renewables***	***Nuclear***	***Electricity***
Base case	78	18	1.5	2.0	0.1
Biodiesel	79	17	2.0	2.0	0.1
Commercial	78	18	1.6	2.1	0.1
Industrial EE	78	19	1.6	2.2	0.1
Gas	76	20	1.5	2.1	0.1
Hydro	78	18	1.5	2.1	1.3
PBMR nuclear	74	18	1.5	6.2	0.1
Renewables	77	18	3.1	2.0	0.1
Residential	78	18	1.5	2.0	0.1
Fuel tax	78	18	1.5	2.0	0.1

Table 11.2: CO_2 emission reductions for policy cases and base case emissions (Mt CO_2)

	2001	***2005***	***2015***	***2025***
Base	350	389	492	596
Biodiesel		0	-1	-5
Commercial		-1	-5	-12
Industry		0	-28	-44
Gas		0	-5	-12
Hydro-electricity		0	-13	-17
PBMR nuclear		0	-7	-32
Renewables		-3	-7	-15
Residential		0	-1	-4
Fuel tax		0	-2	-2

The largest emissions reductions are shown for the industrial energy efficiency case. The PBMR and renewables have the same reductions up to 2015, but by 2025 the PBMR has increased to a capacity where its reductions are higher.

To compare emissions reductions across electricity cases, the installed capacity, load factor and associated costs need to be borne in mind. By the end of the period, the PBMR has reached 4.48 GW, while renewable energy technologies amount to 4.11 GW and gas 5.81 GW. Notably, imported hydroelectricity reduces the total system cost, while the other three options increase it. The emission reductions are shown graphically in Figure 11.1.

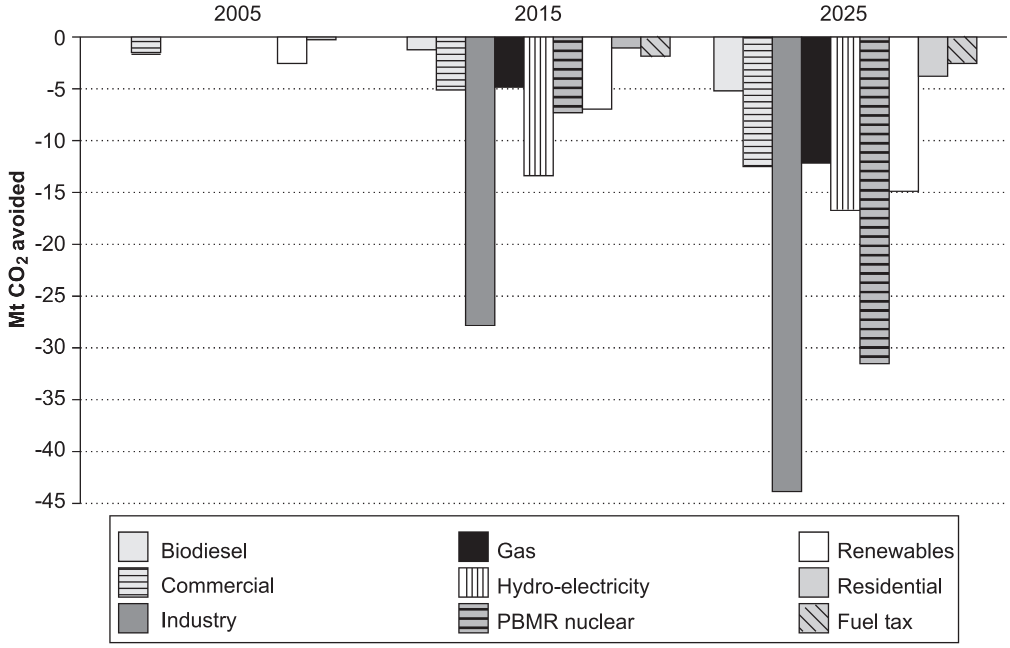

Figure 11.1: Emission reduction by policy case for selected years

Emission reductions increase over time. Several cases have no emission reductions by 2005, either because of the lead times of technologies, or because the reductions have not yet reached the scale of Mt CO_2. The changes over the 25 years are shown in Figure 11.2. The individual policy case that contributes the most to this reduction is industrial energy efficiency.

Taken together, the emission reductions achieved by the policies we analysed add up to 50 Mt of CO_2 (14% of base case) by 2015 and 142 Mt of CO_2 (24%) for 2025. Figure 11.2 shows that combining all the policies analysed would reduce emissions below their projected growth. All policy cases were included in a combined scenario, to avoid double counting within the energy system.

However, even with all these reductions (and the associated investments), CO_2 emissions would continue to rise from approximately 350 Mt in 2001 to 450 Mt CO_2 in 2025. Stabilising emissions levels would require some additional effort from 2020 onwards.

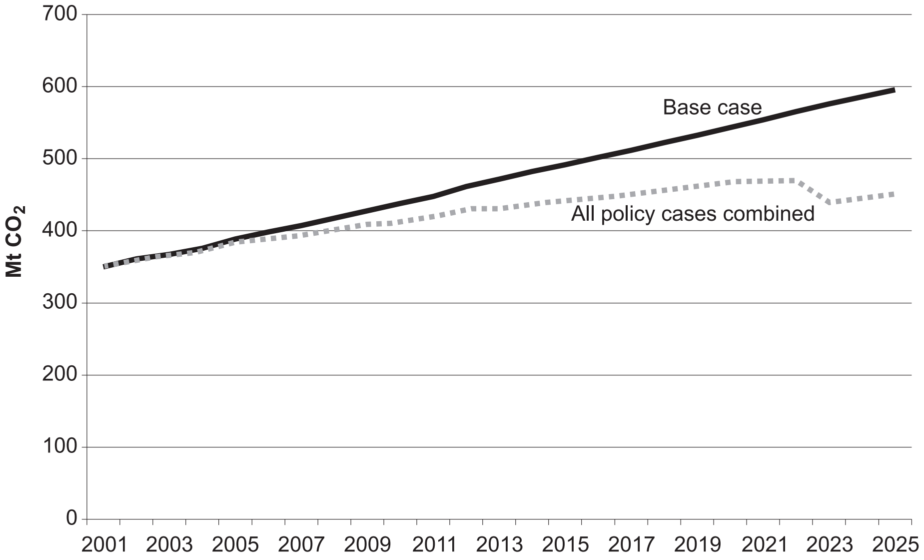

Figure 11.2: CO_2 emissions for base and with emissions reductions from all policy cases combined

Turning to local air pollutants, the largest percentage reductions are achieved by industrial efficiency. Emissions factors for several local air pollutants were included in the database, and some of the interesting and significant results are reported here. Reductions in sulphur dioxide emissions contribute to less acidification of water bodies and impacts on plantations. This is particularly significant for the north-east part of the country, where both coal-fired power stations and forestry plantations are concentrated.

Table 11.3: Sulphur dioxide emissions in the base case, reductions in the policy cases in absolute (kt SO_2) and percentage terms

	2001	***2005***	***2015***	***2025***	***Percentage reductions***			
Base	1491	1684	2226	2772	2001	2005	2015	2025
Biodiesel	0	0	0	0	0	0	0	0
Commercial	-1	-10	-31	-76	0	-1	-1	-3
Industry	0	0	-163	-239	0	0	-7	-9
Gas	4	5	-45	-122	0	0	-2	-4
Hydroelectricity	-3	-3	-90	-92	0	0	-4	-3
PBMR nuclear	0	0	-48	-205	0	0	-2	-7
Renewables	13	-3	-32	-84	1	0	-1	-3
Residential	-1	-1	-9	-30	0	0	0	-1
Fuel tax	4	4	-7	-15	0	0	0	-1

Table 11.3 shows SO_2 emissions almost doubling in the base case over 25 years. The largest reductions in percentage terms come from industrial energy savings (Figure 11.3), amounting to 239 kt SO_2 avoided in 2025.

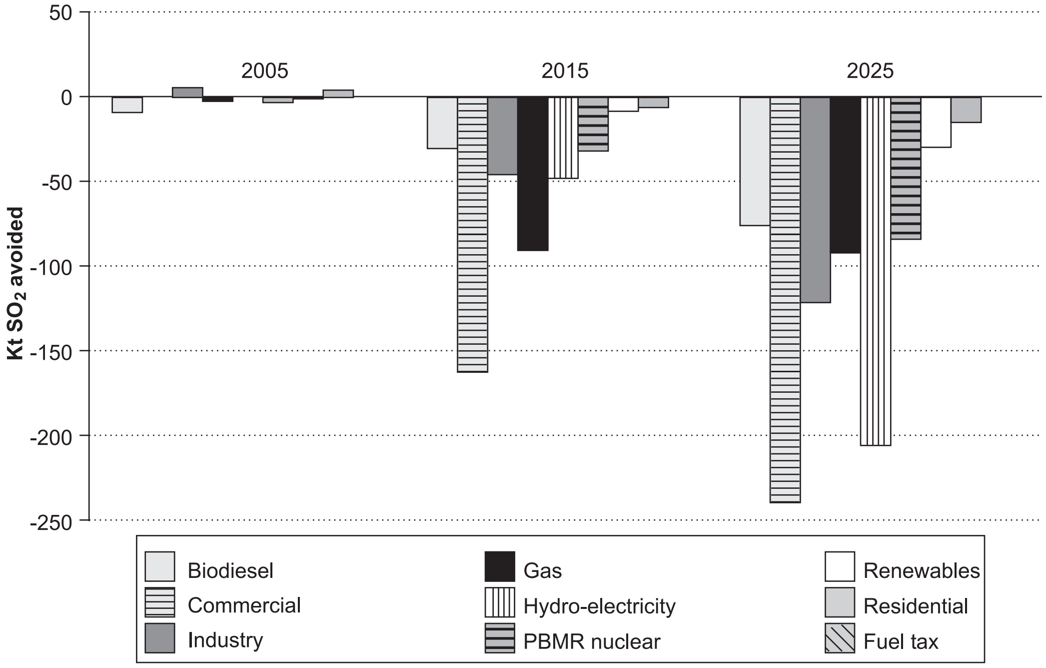

Figure 11.3: Avoided sulphur dioxide emission by policy case

If one adds up the emission reductions in the combined case, they amount to 614 kt SO_2 in the last year of the period. Simple adding up would have yielded 863 kt SO_2, so using the combined case does reduce double counting across policies. In other words, sulphur dioxide emissions would still grow, but only to 2 158 kt SO_2, i.e. a little less than a quarter of the growth (22%) would be avoided.

Following the pattern shaped by large energy savings in industry, Figure 11.4 shows a steady decline in non-methane volatile organic compounds, compared to the base case.

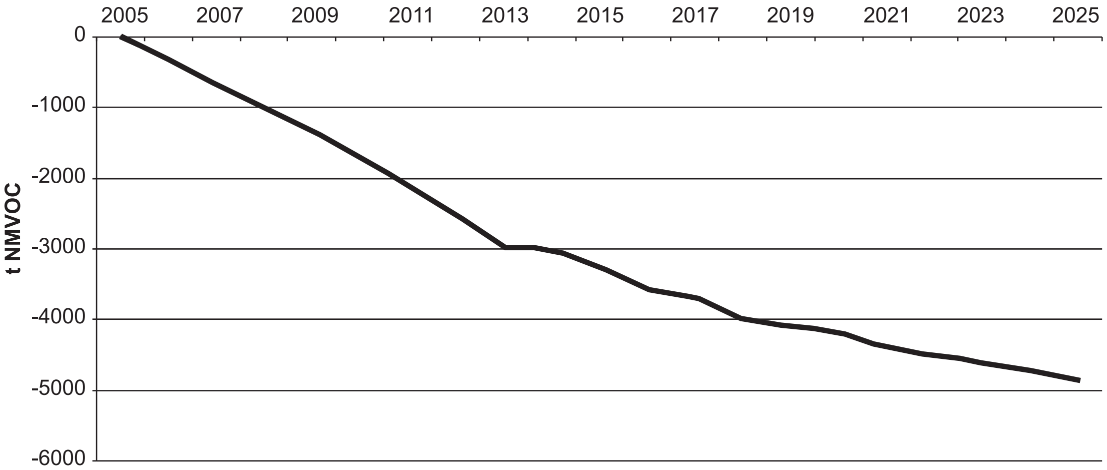

Figure 11.4: Reductions in non-methane volatile organic compounds for industrial efficiency

For oxides of nitrogen (NO_x), base case emissions rise from roughly one million tons to over two million over 25 years. Substantial emission reductions around can be seen in 2025 for industrial and commercial demand-side measures, and all of the electricity-supply options.

Table 11.4: Base case emissions and reductions of oxides of nitrogen for policy cases

kt Nox	*2001*	*2005*	*2015*	*2025*
Base	1 109	1 257	1 645	2 035
Biodiesel	0	0	-1	-3
Commercial	0	-5	-15	-36
Industry	0	0	-88	-136
Gas	2	2	-15	-39
Hydroelectricity	-1	-1	-43	-52
PBMR nuclear	0	0	-23	-98
Renewables	5	-3	-17	-42
Residential	0	-1	-4	-13
Fuel tax	2	2	-4	-6

Regarding damage to people's health, the most important factors are emissions reductions and other social effects in the residential sector, which we discuss next.

11.2 Social indicators

The implications of policies for social sustainability are most readily seen in the residential sector. In section 8.3, several important indicators were presented, capturing changes in residential fuel use patterns. Across all policy cases, we assumed that the share of households with access to electricity would rise to 99% in urban and 90% in rural areas. The share of other commercial fuels (LPG and paraffin) also increases (see Table 10.6).

To capture changes across all scenarios, overall changes in residential fuel use patterns are shown in the following tables. These vary across policy scenarios, but do not distinguish household types.

Table 11.5: Changes in household energy consumption across policy cases, selected years

GJ / household	*2005*	*2015*	*2025*	*2005*	*2015*	*2025*
Base case	16.4	15.6	14.8			
	Reduction from base case			*Percentage reduction*		
Biodiesel	-0.04	-0.04	-0.05	-0.3	-0.3	-0.3
Commercial	-0.04	-0.04	-0.05	-0.3	-0.3	-0.3
Industrial EE	-0.04	-0.05	-0.05	-0.3	-0.3	-0.3
Gas	-0.04	-0.04	-0.05	-0.3	-0.3	-0.3
Hydro	-0.04	-0.04	-0.05	-0.2	-0.3	-0.3
PBMR nuclear	-0.04	-0.04	-0.05	-0.3	-0.3	-0.3
Renewables	-0.04	-0.04	-0.05	-0.3	-0.3	-0.3
Residential	-0.01	-0.03	-0.11	0.0	-0.2	-0.7
Fuel tax	-0.04	-0.04	-0.05	-0.3	-0.3	-0.3

The reductions in household energy consumption are small in both absolute and percentage terms. Nevertheless, energy savings of small amounts can be significant for poorer households.

Developing a deeper understanding of the implications for the energy burden for households (energy expenditure as a share of total household expenditure) requires further work. Either energy models have to be adapted to explicitly include household characteristics such as income, geographical location and electrification status, or analysis needs to be conducted outside of the model.

We have argued that the household is an appropriate unit of analysis for the social dimensions of sustainable energy use. However, it is also useful to consider per capita consumption to enable cross-country comparison, and also because household size is declining (see 8.3.4.2).

If one looks at the energy savings in industry per capita, then reductions of almost 8 percentage points are seen for households and close to 2% for the commercial sector.

Table 11.6: Per capita energy consumption across policy cases

	2005	***2015***	***2025***	***2005***	***2015***	***2025***
Base case	97.6	116.8	136.6	***Percentage reduction from base case***		
Biodiesel	97.7	116.5	135.1	0.1	-0.3	-1.1
Commercial	97.4	115.6	134.2	-0.3	-1.0	-1.7
Industrial EE	96.5	109.3	125.8	-1.2	-6.4	-7.9
Gas	97.7	116.1	135.5	0.1	-0.6	-0.8
Hydro	97.7	115.0	134.5	0.1	-1.5	-1.5
PBMR nuclear	97.7	116.6	135.9	0.1	-0.1	-0.5
Renewables	97.5	117.4	135.9	-0.1	0.5	-0.5
Residential	97.7	116.6	136.3	0.1	-0.2	-0.2
Fuel tax	97.4	116.5	136.5	-0.2	-0.2	0.0

Social sustainability is not only about access to fuels, however, it is also concerned with the affordability of using those fuels. Table 11.7 shows how monthly household expenditure varies across the policy cases. Note that this averages across household types, with variations for the different types described. The dominant trend shows rising monthly average household expenditure.

Interestingly, some of the supply-side options can reduce the marginal cost of residential energy. However, it should be noted that these values represent the shadow price – the difference between the costs of the chosen technology and the optimal one. They do not represent market prices or tariffs, but rather a proxy estimate. Such estimates are useful in relative terms, giving an idea how actual monthly household expenditure might vary across time or policy cases. The absolute numbers may differ from the actual expenditure incurred by households.

Specific examples show that policy interventions in the residential demand sector provide cost savings to households. In particular, we calculated the subsidy required to make efficient houses affordable to poorer households (Table 10.8), which turned out to be smaller than the savings accrued to users.

Finally, at a broader societal level, energy security is an important consideration. Noting that energy security can have several definitions (Langlois et al. 2005), we focus on one particular aspect.

Table 11.7: Proxy estimates of monthly average household energy expenditure across policy cases

*R / (HH * mth)*	*2001*	*2005*	*2015*	*2025*	*2005*	*2015*	*2025*
	Monthly household energy expenditure				*Percentage reduction*		
Base case	69.5	67.9	109.1	109.5			
Biodiesel	69.5	67.9	109.1	109.5	0	0	0
Commercial	69.5	67.9	108.5	109.5	0	-1	0
Industrial EE	69.5	67.9	80.5	108.7	0	-26	-1
Gas	69.5	67.9	107.9	109.1	0	-1	0
Hydro	69.5	67.9	107.5	109.5	0	-1	0
PBMR nuclear	69.5	67.9	108.3	109.1	0	-1	0
Renewables	69.5	67.9	108.8	109.5	0	0	0
Residential	69.6	68.5	108.8	109.1	1	0	0
Fuel tax	69.5	67.9	109.4	116.9	0	0	7

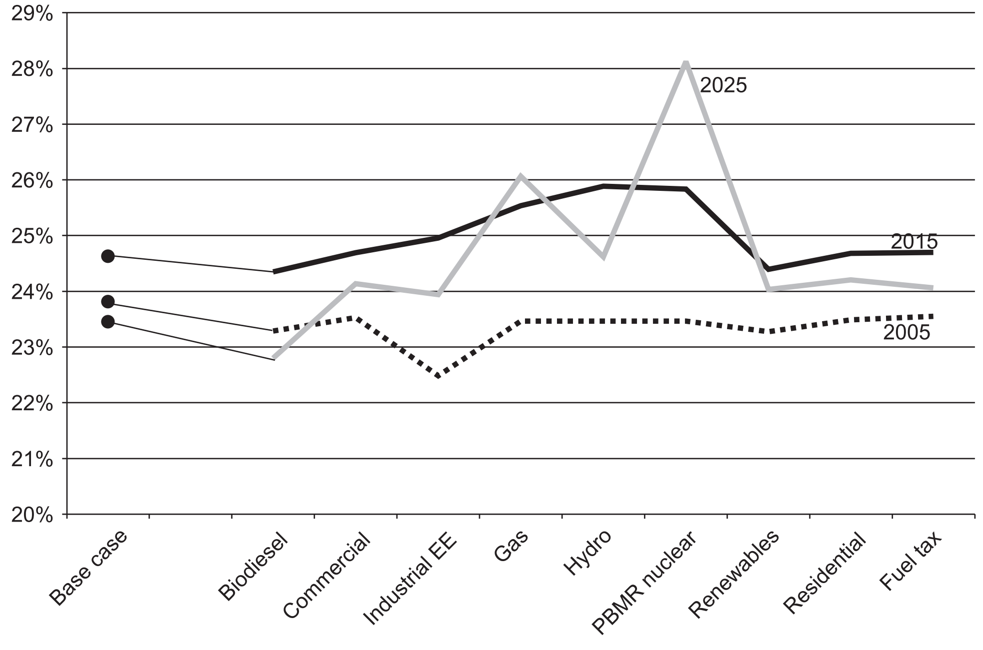

Figure 11.5: Import shares for policy cases over time

Figure 11.5 shows the share of imports. The base case is shown at left, and the change over time with each of the policy cases represented by a data point. Overall, the variation in import shares is relatively small. However, some differences in the implications of policy cases are worth closer attention. Given South Africa's reliance on imported oil, net energy import dependency is an important indicator, shown in Table 11.8.

Table 11.8: Imported energy as share of total primary energy supply

	2005	*2015*	*2025*
Base case	23.5%	24.6%	23.8%
		Percentage point change	
Biodiesel	-0.2	-0.3	-1.0
Commercial	0.0	0.1	0.3
Industrial EE	-1.0	0.3	0.1
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
Residential	0.0	0.1	0.4
Fuel tax	0.1	0.1	0.2

Unsurprisingly, the imports of gas or hydroelectricity 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 continues to be imported. Nuclear fuels, under certain circumstances, lend themselves to increased energy security because they are concentrated and readily stored. In fact domestic supply options, including renewable energy technologies, perform better in this regard.

11.3 Economic indicators

Costs are important economic parameters, and they can be reported at different levels, providing differing information. In this study we report costs at three different scales – the impact of policies on the entire energy system, the impacts of electricity supply options on the whole grid, and the investment requirement for specific electricity options (new gas, renewables, nuclear or imported hydroelectricity).

A key economic parameter is the total energy system costs. System costs help us understand the impact on the entire energy system, showing its interactions in a consistent framework. However they draw a wide costing boundary, because all costs are included – from power stations, through transmission and distribution systems, to end-use appliances and equipment. Some of these costs may not be what are typically thought of as 'energy investment'.

We have discounted total energy system costs to the present value, using the discount rate for the study of 10%. These costs are not the same as the total investment required, as total investment does not take into account savings or avoided investment in alternative policies or technologies.

Over 25 years, energy system costs add up to large numbers. Since the energy system is large, and the costing boundary is wide, individual policies – which affect only one part of the energy system – do not produce large changes in the bulk of the system or its structure. The cost changes, although small in relative terms, are in the order of millions to billions of rands.

Table 11.9 shows that energy efficiency in the industrial, commercial and residential sector reduces system costs substantially. The other large potential saving is from imported hydroelectricity. On the supply side, investing in domestic options – whether renewable energy or nuclear PBMR – increases the costs of the energy system. While these increases are only 0.06% of energy system costs, in both cases they amount to over R3 billion over the period.

Table 11.9: Total energy system costs for base and policy cases

	Discounted total system costs over 25 years	*Difference from base case*	
	R billion	***R million***	***Percentage***
Base case	5 902		
Biodiesel	5 904	2 397	0.04
Commercial	5 889	-13 078	-0.22
Industrial EE	5 885	-17 011	-0.29
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
Residential	5 900	-1 136	-0.02
Fuel tax	5 902	23	0.00

Table 11.10 shows the total investment costs over the whole period, together with the installed capacity that results in each policy case. Clearly, domestic investments in capacity in the hydroelectricity case are lower, and to a lesser extent this is also true for gas. The largest investment requirement is for the PBMR case, where installed capacity is the same as for the base case. The additional investment needed for the renewables case lies between the base and the PBMR cases. Here a larger electricity supply system is needed, given the lower availability factor.

Table 11.10: Investments in electricity supply options and total electricity generation capacity by 2025

	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

Narrowing the costing boundary even further allows us to consider the investment required for each technology in its own policy case, e.g. the PBMR in the PBMR policy case, or various renewable energy technologies (biomass co-generation, wind and solar power tower)[21] in the renewables case. Table 11.11 shows three items – the discounted investment costs in the technology over 25 years (derived by summing annualised investment costs), the newly installed capacity of that technology over the period, and the cost per unit (kW) of new capacity.

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[21] As Figure 10.21 above showed, these are the renewable energy technologies that dominate the new capacity in the renewables case.

The PBMR case shows the largest investment requirement. It also adds more capacity than renewables does, but not as much as from gas or imported hydroelectricity. Per unit cost, imported gas is cheapest, with hydroelectricity and renewables next, at roughly similar levels. Note that these numbers are not identical to the upfront investment costs (expressed in R/kW in Table 8.23 above). However, the general pattern of unit costs is consistent with the ranges shown there. Gas is significantly cheaper than other options by unit cost, followed by the renewables. The PBMR's costs per installed capacity (R/kW) are at the upper end of the range in Table 8.23. The unit costs of renewables are an average of biomass co-generation, wind and solar power tower, which were chosen by the model in the renewables case, and are within the range of the investment costs in Table 8.23.

Table 11.11: Investment requirements for specific electricity supply technologies in their policy case, capacity provided in 2025 and cost per unit

	Annualised cost of investment in the specific technology for its policy case, summed over 25 years (R billion)	*New installed capacity of the technology in its case by 2025 (GW)*	*R / kW of new capacity*
CCGT in gas case	30.7	5.79	5 297
Imported hydro in hydro case	36.9	3.73	9 871
PBMR in PBMR case	55.7	4.48	12 430
RETs in renewables case	33.3	3.73	8 937

Note: Investment costs for hydro scenario do not include investment in stations in neighbouring countries.

The direct investment costs for new capacity in Mepanda Uncua were reported in section 8.6.4; they suggest a slightly lower unit cost than shown in Table 11.11 at R8 793/kW.

An important indicator is South Africa's energy intensity, which is shown in Table 11.12.

Table 11.12: Energy intensity over time and across policies

	2005	*2015*	*2025*			
Base case	226	238	261	*2005*	*2015*	*2025*
	Reduction from base case			*Percentage reduction*		
Biodiesel	- 0.21	0.71	2.87	-0.1	0.30	1.10
Commercial	0.57	2.37	4.57	0.25	1.00	1.75
Industrial EE	2.69	16.28	22.34	1.19	6.84	8.57
Gas	- 0.21	1.41	2.02	-0.10	0.59	0.78
Hydro	- 0.22	3.74	3.94	-0.10	1.57	1.51
PBMR nuclear	- 0.21	0.36	1.30	-0.10	0.15	0.50
Renewables	0.32	- 1.18	1.23	0.14	-0.50	0.47
Residential	- 0.19	0.44	0.54	-0.09	0.19	0.21
Fuel tax	0.57	0.55	0.13	0.25	0.23	0.05

The chief reductions in energy intensity are by the largest energy savings analysed in this study – namely those achieved through greater energy efficiency in industry and commerce.

In summary, the global costs (discounted total energy system costs) for the combined scenario are lower than for the base case by some R16 billion over the full period. The impact of cost-saving policies on balance and over time is greater than that of positive-cost measures. This suggests that the savings of the combined efficiency measures outweigh the additional costs of investing in a diversified electricity supply.

The economic, social and environmental dimensions of sustainable development should be considered together in order to draw any conclusions about the sustainability of various technologies, policies and measures. An overview of some key energy indicators of sustainable development is provided in the Appendix in Table A1. Based on these, and the findings of this chapter, we can now offer some conclusions.

12

Conclusions

Harald Winkler

This report has modelled a range of energy policies for sustainable development in South Africa, both demand-side and supply-side policies, which can contribute to energy objectives and to broader sustainable development goals. This chapter summarises the authors' conclusions.

12.1 The reference case

The base (reference) case presented 'current development trends' over the period 2001-2025, using policies which are close to the Integrated Energy Plan (DME 2003a) for the energy sector as a whole, and close to the electricity regulator's second National Integrated Resource Plan (NIRP) (NER 2004a). The features of the base case are as follows:

- On the demand side, fuel consumption in industry and transport dominates, with transport growing most rapidly among the various sectors.
- On the supply-side, electricity generation continues to be dominated by existing and new coal power generation, supplemented by gas turbines and new fluidised bed combustion using discard coal. Smaller contributions come from existing hydroelectricity and bagasse, nuclear energy, electricity imports, existing and new pumped storage, and interruptible supply.
- The liquid fuel supply is met mostly from existing refineries allowing for some expansion, with a small proportion from imports of finished petroleum products.
- Emissions of both local and global air pollutants increase steadily in the reference case over the 2001-2025 period. Carbon dioxide emissions increase from 337 Mt CO_2 in 2001[22] to 591 Mt CO_2 in 2025 – an increase of 75% over the period.

A set of energy policy cases was then modelled and compared to the base case. Table 12.1 provides a short summary the assumptions behind each of the policy cases modelled.

Table 12.1: Summary of policy cases in residential and electricity supply sectors

Sector	*Summary of assumptions regarding technologies, policies and measures*
Industry	Industrial energy efficiency meets the national target of 12% less final energy consumption than business-as-usual. This is achieved through greater use of variable speed drives; efficient motors, compressed air management, efficient lighting, heating, ventilation and cooling (HVAC) system efficiency and other thermal saving. Achievement of this goal depends on forcefully implementing the policy.
Commercial	New commercial buildings are designed more efficiently; HVAC systems are retrofitted or new systems have higher efficiency; variable speed drives are employed; efficient lighting practices are introduced; water use is improved both with heat pumps and solar

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[22] The base year number is fairly close to the CO_2 emissions reported in the Climate Analysis Indicator Tool (WRI 2005) for 2000 – 344.6 Mt CO_2. It is somewhat higher than the 309 Mt CO_2 from fuel combustion reported in the Key World Energy Statistics for 2001 (IEA 2003a).

Sector	Summary of assumptions regarding technologies, policies and measures
	water heaters. In addition to specific measures, fuel switching for various end uses is allowed. Achievement of this goal depends on forcefully implementing the policy.
Residential	Cleaner and more efficient water heating is provided through increased use of solar water heaters and geyser blankets. The costs of SWHs decline over time, as new technology diffuses more widely in the South African market. More efficient lighting, using compact fluorescent lights spreads more widely, with a slight further reduction. The shells of houses are improved by insulation, prioritising ceilings. Households switch from electricity and other cooking appliances to LPG. A subsidy is required to make interventions more economic for poorer households.
Bio-fuels	Biodiesel production increases to 35 PJ by 2025, with a maximum growth rate of 30% per year from 2010, displacing some petroleum. Energy crops do not displace food production, and sustainable production means the fuel is effectively zero-carbon.
Electricity from renewables	The share of renewable electricity increases to meet the target of 10 000 GWh by 2013. Shares of solar thermal, wind, bagasse and small hydroelectricity increase beyond the base case. New technology costs decline as global production increases.
PBMR nuclear	Production of PBMR modules for domestic use increases capacity of nuclear power generation up to 4 480 MW (32 modules). Costs decline with national production, and initial investments are written off.
Imported hydro-electricity	The share of hydroelectricity imported from the SADC region increases from 9.2 TWh in 2001, as more hydroelectric capacity is built in southern Africa.
Imported gas	Sufficient LNG is imported to provide 5 850 MW of combined cycle gas turbines, compared to 1 950 MW in the base case.
Tax on coal for electricity generation	A fuel input tax is imposed on coal used for electricity generation. Such policies could be extended to coal for synfuel production and industrial use, or alternatively, the environmental outputs could be taxed directly, via a pollution tax.

12.2 Demand-side scenarios

On the demand side, energy efficiency policies were found to be particularly important.

12.2.1 Industrial sector

The overall strategy of reducing final energy demand by 12% compared to business-as-usual can be implemented most effectively in the industrial sector. Industrial energy efficiency is effective both in lowering the cost of the energy system by R18 billion, and reducing global and local air pollution. Carbon dioxide emissions are reduced by 770 Mt CO_2 over the 25-year period. Greater efficiency has benefits in delaying the need for investment in power stations, allowing the building of new base load power stations to be postponed by four years, and the building of peaking power plant by three years.

It is important to note that realising the potential for industrial energy efficiency requires forceful, even aggressive, implementation. Clear signals are needed to induce industry to take more responsibility. The agreement between industry and government to implement the energy efficiency strategy (DME 2005a), and the recent announcement that a dedicated Energy Efficiency Agency is to be established, both bode well in this regard.

12.2.2 Commercial sector

A strong legal and institutional framework is needed to implement energy efficiency for the commercial sector. The modelling suggests that a 12% energy efficiency target is achievable and that it can save R13 billion over the 25 years. However the results also suggest that the cost of optimal energy efficiency improvements are 2-3% lower than the 12% target; and that these savings come at a cost in the order of 5% of the investment costs (Spalding-Fecher et al. 2003). The government can play an important role here by taking the lead in making its own buildings and practices more efficient.

12.2.3 Residential sector

The residential sector is of key importance for social sustainability. A sustainable development approach would mean delivering services that meet basic human needs, but in a cleaner and more efficient manner. Policy interventions focus on all end uses, using solar water heaters and geyser blankets, LPG for cooking, efficient housing shells, and CFLs for lighting. Making social housing more energy-efficient through simple measures, such as including insulating ceilings, should be adopted as a general policy.

All policy cases assume near-universal electrification, and we find in the residential scenario that the share of other commercial fuels (LPG and paraffin) also increases. The overall fuel consumption, however, is lowered compared to the base case (8.13 PJ less in 2025), because of increasing efficiency and use of solar energy for water heating. Not all interventions are used by all household types – for example, efficient houses are only taken up by urban higher-income electrified households. The lower cost – both upfront and per unit of energy saved – suggests that geyser blankets are appropriate policy interventions in poor electrified households.

Access to energy in physical terms needs to be accompanied by affordability in economic terms. The findings suggest that interventions can be made economic for poorer households with a relatively small subsidy. The order of magnitude of the subsidy required to make efficient housing as affordable for poorer households as richer ones, is in the hundreds of rands, and less than a thousand rand.

12.3 Supply-side scenarios

12.3.1 Electricity supply

On the supply side, four policy cases focused on electricity supply – imported gas, imported hydroelectricity, domestically-generated electricity from PBMR nuclear, and domestically-generated electricity from renewables.

Imported hydroelectricity potentially reduces investment costs, but increases the share of imported energy as a percentage of total primary energy supply (TPES). Imported gas increases the share of imports, while making little difference to total energy system costs. The PBMR case with imported fuel also shows an increase in the imports share, up to 4.3% of TPES in 2025. Domestic supply options, including renewable energy technologies, perform better, but they include substantial imported components. We can conclude that a sustained move to greater diversity will require more than a single policy.

Investing in the PBMR and renewables options increases the costs of the energy system, while imported gas has a small effect on costs, and hydroelectricity imports actually reduce costs. While the increases are only 0.06% of energy system costs, they are nonetheless large – over R3 billion in both the PBMR and renewables cases over the period. In unit costs (R/kW of new capacity), gas is significantly cheaper than other options, followed by the renewable energy technologies (an average of biomass co-generation, wind and solar power tower). However, the PBMR and renewables options do show quite substantial emission reductions – 246 Mt CO_2 for the PBMR and 180 Mt CO_2 for renewable energy technologies respectively over the 25-year period. Both reduce local pollutants, notably sulphur dioxide, by 3% and 1.6% respectively relative to the base case.

12.3.2 Liquid fuels and biodiesel

A key policy option, which addresses liquid fuels for transport, is the supply of biodiesel. The potential to produce 1.4 billion litres of biodiesel was modelled to start in 2010 and reach a biodiesel market share of 9% of transport diesel by 2025. Through this, an average of 4 500 barrels per day of oil-refining capacity can be avoided. Total reduction in CO_2 emissions reaches 5 Mt CO_2 per annum in 2025 and cumulative savings are 31 Mt CO_2 for the entire period. There are also smaller reductions in local pollutants. The present value of the total system cost for this scenario is R2.4 billion higher than for the reference scenario.

12.3.3 Tax on coal

The results for a tax on coal for electricity generation show that the reductions of CO_2 emissions from coal for electricity generation are small relative to the reference case. The economic difference lies less in system costs (R67 million over 25 years) and more in the tax revenues. These revenues impose added costs on producers, but could also generate economic benefits if recycled. A more detailed analysis is required of this policy option, possibly extending the tax to coal for synfuels and industry as well, and quantifying the indirect economic effects of tax recycling and impacts on other policy objectives.

12.4 Overall conclusion

The tools used in this analysis – a modelling framework combined with indicators of sustainable development – provide a useful way of examining trade-offs, as well as some room for compromise.

Over the 25-year timeframe, energy efficiency makes much sense when measured against indicators of sustainable development. Industrial efficiency in particular shows significant savings in energy, costs and air pollution, with commercial energy showing a similar pattern on a slightly smaller scale. Residential energy efficiency is very important for social sustainability, and even small energy savings can make a big difference to poorer households. In the short-term, then, energy efficiency is critical to making South Africa's energy development more sustainable.

In the longer-term, transitions that include the supply-side become 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.

Combined, the emission reductions achieved by all the policies analysed here add up to 69 Mt CO_2 (10% of base case emissions) by 2015, and 142 Mt (24%) CO_2 by 2025. One important conclusion is that significant emission reductions ('avoided emissions') compared to business-as-usual are possible. This should be understood together with a second conclusion, namely that stabilising emissions levels (e.g. at 2010 levels) would require some additional effort from 2020 onwards.

In general, the modelling shows that the global costs (discounted total energy system costs) for the combined scenario are lower than for the base case by some R16 billion over the full 25-year period. This certainly suggests that the savings of the combined efficiency measures outweigh the additional costs of investing in a diversified electricity supply.

Appendix

Table A1: Overview of energy indicators of sustainable development

Environment

	2001	***2005***	***2015***	***2025***	***2001***	***2005***	***2015***	***2025***	***2001***	***2005***	***2015***	***2025***
CO_2 emissions and reductions			***Mt CO_2***		***Sulphur dioxide***		***kt SO_2***		***Oxides of nitrogen***		***kt Nox***	
Base	350	389	492	596	1 491	1 684	2 226	2 772	1 109	1 257	1 645	2 035
Biodiesel	0	0	-1	-5	-1	-10	-31	-76	0	0	-1	-3
Commercial	0	-1	-5	-12	0	0	-163	-239	0	-5	-15	-36
Industry	0	0	-28	-44	4	5	-45	-122	0	0	-88	-136
Gas	0	0	-5	-12	-3	-3	-90	-92	2	2	-15	-39
Hydro-electricity	0	0	-13	-17	0	0	-48	-205	-1	-1	-43	-52
PBMR nuclear	0	0	-7	-32	13	-3	-32	-84	0	0	-23	-98
Renewables	0	-3	-7	-15	-1	-1	-9	-30	5	-3	-17	-42
Residential	0	0	-1	-4	4	4	-7	-15	0	-1	-4	-13
Fuel tax	0	0	-2	-2	0	0	0	0	2	2	-4	-6

Social

	2005			***2015***			***2025***		
	GJ/ capita	***R/GJ***	***GJ / h'hold***	***GJ/ capita***	***R/GJ***	***GJ / h'hold***	***GJ/ capita***	***R/GJ***	***GJ / h'hold***
Base case	97.62	225.90	16.36	116.80	237.83	15.57	136.57	260.68	14.76
Biodiesel	97.71	225.69	16.32	116.45	238.54	15.53	135.08	263.55	14.71
Commercial	97.37	226.47	16.32	115.65	240.20	15.53	134.21	265.24	14.71
Industrial EE	96.47	228.59	16.32	109.32	254.11	15.53	125.79	283.02	14.71
Gas	97.71	225.69	16.32	116.11	239.24	15.53	135.51	262.70	14.71
Hydro	97.71	225.68	16.32	115.00	241.56	15.53	134.53	264.62	14.71
PBMR nuclear	97.71	225.69	16.32	116.63	238.18	15.53	135.89	261.98	14.71
Renewables	97.52	226.22	16.32	117.38	236.65	15.53	135.92	261.91	14.71
Residential	97.70	225.71	16.35	116.58	238.27	15.54	136.28	261.22	14.65

Economic

Total system costs			***Share of imports (%)***			
	R billion	***R million***				
Base case	5 902	change	change	2005	2015	2025
Biodiesel	5 904	2 397	0.04	23	25	24
Commercial	5 889	-13 078	-0.22	23	24	23
Industrial EE	5 885	-17 011	-0.29	24	25	24
Gas	5 902	95	0.00	22	25	24
Hydro	5 890	-11 525	-0.20	23	26	26
PBMR nuclear	5 905	3 706	0.06	23	26	25
Renewables	5 905	3 488	0.06	23	26	28
Residential	5 900	- 1 136	-0.02	23	24	24
Fuel tax	5 902	23	0.00	23	25	24

Table A2: Projections of household numbers over the period

	2001	***2005***	***2010***	***2015***	***2020***	***2025***	***2030***
UHE	4 074 438	4 319 029	4 624 768	4 930 508	5 236 247	5 541 987	5 847 726
ULE	1 255 728	1 416 680	1 617 870	1 819 060	2 020 250	2 221 440	2 422 629
ULN	1 349 240	1 174 661	956 436	738 212	519 988	301 763	83 539
RHE	1 181 279	1 268 071	1 376 561	1 485 050	1 593 540	1 702 030	1 810 520
RLE	1 095 449	1 256 511	1 457 839	1 659 167	1 860 494	2 061 822	2 263 150
RLN	2 249 571	2 001 717	1 691 899	1 382 082	1 072 265	762 447	452 630

Table A3 : Projections of energy demand by end use and household type (PJ)

	2001	***2005***	***2010***	***2015***	***2020***	***2025***	***2030***
Cooking							
UHE	15.8447	16.9044	18.2290	19.5537	20.8783	22.2029	23.5275
ULE	1.4270	1.6230	1.8680	2.1131	2.3581	2.6032	2.8482
ULN	1.8230	1.5877	1.2935	0.9993	0.7051	0.4110	0.1168
RHE	1.7882	1.9196	2.0839	2.2481	2.4123	2.5766	2.7408
RLE	0.5916	0.6786	0.7873	0.8960	1.0047	1.1135	1.2222
RLN	3.0503	2.7142	2.2941	1.8740	1.4539	1.0338	0.6137
Water heating							
UHE	23.1604	24.7094	26.6456	28.5818	30.5181	32.4543	34.3905
ULE	4.3362	4.9319	5.6765	6.4212	7.1658	7.9105	8.6551
ULN	1.2064	1.0506	0.8559	0.6613	0.4666	0.2719	0.0773
RHE	2.8427	3.0516	3.3126	3.5737	3.8348	4.0959	4.3569
RLE	0.6706	0.7692	0.8924	1.0157	1.1389	1.2621	1.3854
RLN	5.3223	4.7359	4.0029	3.2699	2.5369	1.8039	1.0709
Space heating							
UHE	16.3063	17.3968	18.7601	20.1233	21.4865	22.8497	24.2129
ULE	2.4165	2.7485	3.1635	3.5784	3.9934	4.4084	4.8234
ULN	1.9941	1.7367	1.4149	1.0931	0.7713	0.4495	0.1277
RHE	1.6832	1.8068	1.9614	2.1160	2.2706	2.4251	2.5797
RLE	0.5305	0.6085	0.7060	0.8035	0.9010	0.9985	1.0960
RLN	6.0526	5.3857	4.5521	3.7185	2.8850	2.0514	1.2178
Lighting in PJ							
UHE	7.3896	7.8838	8.5016	9.1194	9.7371	10.3549	10.9727
ULE	2.6887	3.0581	3.5198	3.9815	4.4432	4.9050	5.3667
ULN	2.3475	2.0445	1.6657	1.2868	0.9080	0.5292	0.1504
RHE	4.1415	4.4458	4.8261	5.2065	5.5868	5.9672	6.3476
RLE	2.0251	2.3228	2.6950	3.0672	3.4394	3.8116	4.1837
RLN	4.1684	3.7091	3.1350	2.5610	1.9869	1.4128	0.8387
Other electrical appliances							
UHE	12.5741	13.6854	15.1304	16.6397	18.2156	19.8604	21.5767
ULE	0.1085	0.1259	0.1486	0.1723	0.1972	0.2232	0.2504
ULN	-	-	-	-	-	-	-
RHE	3.2810	3.5930	3.9989	4.4230	4.8660	5.3285	5.8113
RLE	0.0771	0.0902	0.1073	0.1252	0.1439	0.1635	0.1840
RLN	-	-	-	-	-	-	-

Table A4: Total residential energy demand and end use total demands for selected years

	2001	***2005***	***2010***	***2015***	***2020***	***2025***
Cooking	24.5248	25.4275	26.5558	27.6842	28.8125	29.9409
Water heating	37.5386	39.2486	41.3861	43.5236	45.6611	47.7986
Space heating	28.9832	29.6831	30.5580	31.4329	32.3078	33.1827
Lighting in lighting units	22.7608	23.4641	24.3432	25.2224	26.1015	26.9806
Other electrical appliances	16.0407	17.4946	19.3853	21.3603	23.4227	25.5757
All residential energy demand	113.8073	117.8232	122.8431	127.8630	132.8829	137.9028

Table A5: Projections of electricity capacity by plant type (GW)

	2001	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***
Existing coal	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	32.9	32.9
Nuclear PWR	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Bagasse	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Diesel gas turbines	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Hydro	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Interruptible supply	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Pumped storage	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Imported electricity	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Mothballed coal	-	-	-	-	0.4	0.8	1.5	2.8	3.6	3.6	3.6	3.6
New coal	-	-	-	-	-	-	-	-	-	-	-	-
New OCGT diesel	-	-	-	-	-	0.2	0.6	1.4	2.1	2.3	2.3	2.3
New CCGT	-	-	-	-	-	-	-	-	-	0.6	2.0	2.0
New FBC	-	-	-	-	-	-	-	-	-	-	-	-
New pumped storage	-	-	-	-	-	-	-	-	-	-	-	0.7

	2013	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***
Existing coal	32.9	32.9	32.9	32.9	32.9	32.9	32.9	32.9	32.2	30.3	30.3	30.3	30.3
Nuclear PWR	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Bagasse	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Diesel gas turbines	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Hydro	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Interruptible supply	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Pumped storage	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Imported electricity	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Mothballed coal	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
New coal	-	-	0.1	0.9	1.7	2.5	3.3	4.2	6.1	9.2	10.2	11.2	12.2
New OCGT diesel	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
New CCGT	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
New FBC	0.8	1.6	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
New pumped storage	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Table A6: Total fuel consumption by demand sector (PJ)

	2001	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***
Agri-culture	73	78	74	75	77	78	79	80	81	82	83	84	85
Commercial	85	87	90	93	95	97	100	103	107	111	113	116	119
Industry	1 151	1 162	1 176	1 180	1 205	1 220	1 235	1 250	1 265	1 281	1 297	1 312	1 329
Non-energy	-	-	-	16	32	32	32	32	32	32	32	32	32
Residential	183	188	189	190	192	194	195	196	197	196	197	198	199
Transport	613	642	659	677	698	717	735	753	771	789	807	825	843

	2014	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***
Agriculture	86	86	87	88	89	90	91	92	93	94	95	96
Commercial	124	129	133	137	141	145	150	154	159	164	169	175
Industry	1 345	1 362	1 379	1 396	1 414	1 432	1 450	1 469	1 488	1 503	1 518	1 533
Non-energy	32	32	32	32	32	32	32	32	32	32	32	32
Residential	201	204	205	206	208	209	210	211	212	214	215	216
Transport	861	878	895	911	928	945	960	975	989	1 004	1 019	1 034

Table A7: Investments required in energy supply by case and years

	2 001	***2 002***	***2 003***	***2 004***	***2 005***	***2 006***	***2 007***	***2 008***	***2 009***	***2 010***	***2 011***	***2 012***	***2 013***
Base case	1 074	382	1 541	318	445	712	992	2 269	1 832	1 249	2 110	2 236	2 033
Biodiesel	1 074	382	1 541	318	445	712	992	2 269	1 832	1 355	2 119	2 118	2 014
Commercial	1 074	374	1 205	310	439	436	754	2 157	1 851	1 016	2 028	2 168	1 067
Industrial EE	1 074	382	1 538	318	259	562	562	878	666	640	678	1 903	726
Gas	1 074	382	1 531	318	445	712	992	2 269	1 832	1 274	2 335	2 370	1 379
Hydro	1 074	382	328	294	259	227	201	251	349	555	641	1 867	447
PBMR nuclear	1 074	382	1 541	318	445	712	992	2 269	1 832	1 249	2 110	2 236	2 565
Renewables	1 074	1 268	1 788	318	760	685	933	2 329	1 963	1 128	2 226	2 666	1 500
Residential	1 074	395	1 211	320	456	594	800	2 226	1 823	1 174	2 037	2 181	1 849
Fuel tax	1 074	382	1 541	318	445	712	841	2 245	2 325	1 140	2 110	2 368	2 033

	2 014	***2 015***	***2 016***	***2 017***	***2 018***	***2 019***	***2 020***	***2 021***	***2 022***	***2 023***	***2 024***	***2 025***
Base case	1 889	1 735	1 465	1 288	1 124	981	841	1 700	2 379	926	558	453
Biodiesel	1 869	1 714	1 444	1 267	1 104	963	825	1 687	2 368	918	549	445
Commercial	1 687	1 498	1 260	1 146	1 010	882	750	1 593	2 290	799	496	401
Industrial EE	628	1 029	1 231	738	1 193	1 186	1 499	1 686	2 428	1 133	879	653
Gas	1 285	1 176	980	858	754	661	697	1 677	2 355	927	553	449
Hydro	236	1 502	1 754	1 581	1 439	1 276	1 120	1 625	2 313	717	515	420
PBMR nuclear	2 584	2 258	1 891	1 608	1 359	1 147	953	1 750	2 409	962	553	449
Renewables	2 029	1 845	1 523	1 345	1 175	1 014	861	1 709	2 475	908	557	475
Residential	1 750	1 610	1 344	1 186	1 041	909	782	1 663	2 347	849	538	437
Fuel tax	1 889	1 735	1 466	1 282	1 129	981	841	1 455	2 377	926	558	453

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