CLEANER ENERGY COOLER CLIMATE

DEVELOPING SUSTAINABLE ENERGY SOLUTIONS FOR SOUTH AFRICA

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Abbreviations, acronyms and units

A	Ampere
AIM	Action Impact Matrix
Annex I	Annex to the Convention listing industrialised and transitioning countries
AsgiSA	Accelerated and Shared Growth Initiative for South Africa
ASSA	Actuarial Society of South Africa
CDM	Clean Development Mechanism
CFL	Compact fluorescent light
CGE	Computable general equilibrium
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DBSA	Development Bank of Southern Africa
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DSM	Demand-side management
EBSST	Electricity basic support services tariff (poverty tariff)
EDI	Electricity distribution industry
EJ	Exajoules, 10^{18} joules, or a billion billion joules
FBC	Fluidised bed combustion
FGD	Flue gas desulphurisation
GB	Geyser blanket
GDP	Gross domestic product
Gear	Growth, Employment and Redistribution (macroeconomic strategy)
Gg	Gigagram, 10^9 grams, a billion grams
GHG	Greenhouse gas
GJ	Gigajoules, 10^9 joules, a billion joules
Gt C	Gigatons of carbon
GW	Gigawatts (10^9W)
GW_e	$\text{Gigawatt}_{\text{electric}}$
GWh	Gigawatt-hour
HIV/AIDS	Human immunodeficiency virus/acquired immunodeficiency syndrome
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent power producer
IRP	Integrated resource planning
kg	Kilogram
kl	Kilolitre
kt	Kilotons, a thousand tons
kW	Kilowatts (power measurement)
kWh	Kilowatt-hour

LMRC	Long-run marginal cost
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
Markal	Market allocation (modelling framework)
MDG	Millennium Development Goal
MJ	Megajoule, 10^6 joules, a million joules
Ml	Megalitre, 10^6 litres, a million litres
Mt	Megatons, 10^6 tons, a million tons
Mt CO_2	Megatons of carbon dioxide, a million tons CO_2
MW	Megawatt (10^6 W)
MW_e	$\text{Megawatt}_{\text{electric}}$
MWh	Megawatt-hour, 10^6 Watt-hours, a million Wh
N_2O	Nitrous oxide
NAI	Non-Annex I (countries that are not Parties listed in Annex I)
Nepad	New Partnership for Africa's Development
NER	National Electricity Regulator
NGO	Non-governmental organisation
NIRP	National Integrated Resource Plan
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrogen oxides (plural, since they refer to nitrogen dioxide [NO_2] and nitric oxide [NO])
O&M	Operation and maintenance
OECD	Organisation for Economic Cooperation and Development
PBMR	Pebble Bed Modular Reactor
PJ	Petajoules, 10^{15} joules
ppmv	Parts per million by volume
PPP	Purchasing power parity
PWR	Pressurised water reactor
RDP	Reconstruction and Development Programme
RED	Regional electricity distributor
RET	Renewable electricity/energy technology
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SD-PAMs	Sustainable development policies and measures
SHS	Solar homes system
SO_2	Sulphur dioxide
SRES	Special Report on Emission Scenarios (of the IPCC)
SWH	Solar water heater
T&D	Transmission and distribution (power lines)
t C	Tons of carbon
t CO_2	Tons of CO_2
TJ	Terajoule, 10^{12} joules
Toe	Tons of oil equivalent
TPES	Total primary energy supply

TSP	Total suspended particulates
TWh	Terawatt-hours, 10^{15} watt-hours
UNFCCC	United Nations Framework Convention on Climate Change (the Convention)
VAT	Value added tax
W	Watt (a unit of power, or capacity, one joule per second)
WEPS	Wholesale electricity pricing system
Wh	Watt-hour

Household types as defined in this book:

RHE	Rural higher-income electrified
RLE	Rural lower-income electrified
RLN	Rural lower-income non-electrified
UHE	Urban higher-income electrified
ULE	Urban lower-income electrified
ULN	Urban lower-income non-electrified

For Janet, Kristy and Alexandra

1 Introduction

Energy, sustainable development and climate change in South Africa

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

Mitigation of climate change refers to reducing emissions of greenhouse gases (GHGs). In South Africa, this is primarily an energy problem, due to the dependence of our economy on fossil fuels. Coal accounts for three-quarters of primary energy supply (DME 2003a), and for over 90 per cent of electricity generation (NER 2002a). Industrial processes and agriculture also contribute to GHG emissions, but energy-related emissions constituted 78 per cent of South Africa's inventory of GHGs in 1994 (Van der Merwe & Scholes 1998).

The supply and use of energy also impacts on the local environment. At the point of use, electricity is a clean energy carrier, but upstream there are significant local environmental impacts due to coal mining and combustion. Outdoor air pollution is associated with the burning of coal (often of a poor quality) for electricity production. Other energy carriers are major contributors to indoor air pollution in South Africa. This impacts on health, with indoor use of coal and wood contributing to respiratory disease (Qase et al. 2000; Spalding-Fecher, Afrane-Okese et al. 2000; Van Horen 1996a). Transport fuels contribute to the 'brown haze' of local air pollution; paraffin use results in burns, deaths and poisonings (Biggs & Greyling 2001; Lloyd 2002; Mehlwana 1999a) (see Chapter 3, Environmental impacts). Making energy development more sustainable, therefore, is good energy policy at the national level and can also contribute to global sustainability by mitigating climate change.

The connection between sustainable development and climate change works in two directions. On the one hand, unmitigated growth in emissions has the potential to undermine sustainable development. The projected impacts of climate change affect water, food security, coastal systems, health and ecosystems, to name some major sectors identified in the most recent assessment by the Intergovernmental Panel on Climate Change (IPCC 2007a). On the other hand, making development paths more sustainable can contribute to climate change mitigation (Munasinghe & Swart 2005).

Under the United Nations Framework Convention on Climate Change (hereafter UNFCCC or 'the Convention') (UNFCCC 1992) and its Kyoto Protocol (UNFCCC 1997), industrialised countries adopted targets for climate change mitigation framed in terms of reducing GHG emissions. At that time, developing countries had only qualitative commitments to implement mitigation programmes, on the basis that their development should not be limited (Agarwal & Narain 1991; Mwandosya 2000). This is strengthened by the notion of historical responsibility, in that GHGs historically have been emitted mostly by industrialised countries. At the most recent negotiations in Bali in 2007, however, developing countries realised that they have a responsibility for the future (notably their projected growth in emissions) as well, and agreed to negotiate 'measurable, reportable and verifiable' (in other words, quantifiable) mitigation actions (UNFCCC 2007).

The starting point for developing countries is development, and ways can be sought to make energy development in particular more sustainable. The Bali Action Plan emphasises that quantifiable mitigation in developing countries must be 'nationally appropriate' and occur in the 'context of sustainable development', as well as being contingent on transfers of technology and finance from developed countries (UNFCCC 2007). Sustainable development policies are likely to be more attractive as an approach to mitigation for developing countries, being closer to their most important policy objectives than climate change (Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002). As the IPCC's Fourth Assessment Report put it, '[m]aking development more sustainable by changing development paths can make a major contribution to climate change mitigation' (Sathaye et al. 2007: 693). The approach taken in this book, therefore, seeks paths that meet development objectives in a more sustainable manner, rather than emission reduction objectives.

An approach is needed that puts development first. This book investigates whether such an approach – starting from making energy development more sustainable in local terms – is viable for South Africa and could form the basis for both future energy and climate change policies. This approach does *not* suggest that developing countries can sit back, or that they can continue to avoid responsibility by demanding action by industrialised countries without any mitigation on their part. That approach was valid while Kyoto was being negotiated and perhaps until it entered into force in 2005. But in the first decade of the twenty-first century, urgent action is required from rapidly developing countries as well. A fair distribution of responsibilities is still 'common but differentiated' (UNFCCC 1992: Article 3.1), but this no longer means developed countries taking quantified mitigation commitments and developing countries not. Given the urgency and scale of the climate problem, differentiation now must mean that developed and developing countries must act for the common good. Developed countries need to take on stricter targets, while developing countries (especially the larger emitters among them) need to take urgent action too. What this book tries to illustrate is that – at least initially – urgent action may be better defined in terms of sustainable development than in traditional climate targets.

Given its emission profile, South Africa is clearly among those rapidly industrialising developing countries (Ott et al. 2004; Winkler, Brouns et al.) that need to take action urgently. Our GHG emissions are high for the size of our population and our economy (RSA 2004). Key drivers of our relatively high GHG emissions are a fuel mix dominated by cheap coal, our inefficient use of energy and the energy-intensive structure of the economy (Winkler 2006; Winkler & Marquard 2007). Chapter 3 will discuss the emission profile and its context in energy development more fully.

This book therefore takes as its starting point development objectives, as in quantified mitigation commitments, rather than climate change targets. The form of climate action which it investigates is sustainable development policies and measures (Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002). While sustainable development measures might be similar in practice to climate change policy, the motivation is different – the one pursues emission reductions, the other local development. Making development more sustainable at the local level is a higher policy priority for most developing countries than addressing a global problem such as climate change, particularly since the latter has been caused mainly by industrialised countries. South Africa has a rather atypical emissions profile for a developing country – high emissions per capita and per gross domestic product (GDP). A development-focused approach seems more likely to be implemented than the imposition of GHG targets by the international community, especially as the country has adopted development targets such as the Millennium Development Goals (MDGs) (UN GA 2000) and the Johannesburg Plan of Implementation (WSSD 2002).

The current multilateral framework under the UNFCCC and its Kyoto Protocol sets emission targets only for industrialised countries. There is growing realisation that the climate change problem is global and requires participation by all countries, including action by developing countries that does not limit their development prospects. The urgency for some developing countries to take on some kind of commitment is growing. In this context, demonstrating *at a national level* that energy policies can both promote local sustainable development and reduce GHGs can make a major contribution to climate change mitigation.

This book seeks to demonstrate energy policies for sustainable development in South Africa. Are there obvious solutions that solve both energy and climate change problems, or do priorities have to be traded off – and if so, where? Is there such a thing as an optimal solution, or do considerations of durability (or sustainability) mean that multiple objectives must be balanced?

The research in this book explores the central question whether there is a locally sustainable path of energy development in the South African residential and electricity sectors that also reduces GHG emissions. Making the development paths more sustainable would require increases in a set of 'development indicators' over time, without negative social, economic and environmental feedback (see Chapter 2 for a working definition of sustainable development).

Outline of the book

The remainder of the book is organised into nine chapters. Following this brief introduction, Chapter 2 reviews the body of literature assessing the intersection of energy, climate change and sustainable development. Chapter 3 implements the approach of starting from development by outlining development objectives – first for South Africa as a whole, then in the energy sector and homing in on electricity in particular. Chapter 4 identifies policy options in the residential demand and electricity supply sectors, using the five major goals of energy policy as a framework (DME 1998a). The implications of future energy policies are examined in a modelling framework, introduced in Chapter 5. The chapter then turns to the key drivers of energy development and the base case. It explains how the implications of policies are analysed using the Markal (Market allocation) energy modelling framework. The results for each policy in energy modelling terms are discussed and interpreted in Chapter 6. The final part of the book synthesises the analysis of sustainable development, energy and climate change policy. Chapter 7 evaluates the policies, drawing on modelling results, against a set of indicators of sustainable development. Policy analysis in Chapter 8 starts with considerations of what is required to shift energy policy that looks good in analysis to implementation. Chapter 9 returns to the international scale and what the findings of this book might mean for multilateral climate negotiations. Chapter 10 provides a brief conclusion.

2 Sustainable development, energy and climate change

This chapter explores *how* sustainable development can be applied to South Africa's energy, through a review of the literature relating the concept to both energy and climate change. Sustainable development for the residential and electricity sectors is conceived in all three of its dimensions – economic, social and environmental. The chapter develops a working definition of sustainable development, firstly in the context of energy and secondly in relation to climate change. It lays the conceptual basis for developing indicators of energy for sustainable development, which are used to evaluate different energy policies in the remainder of this book.

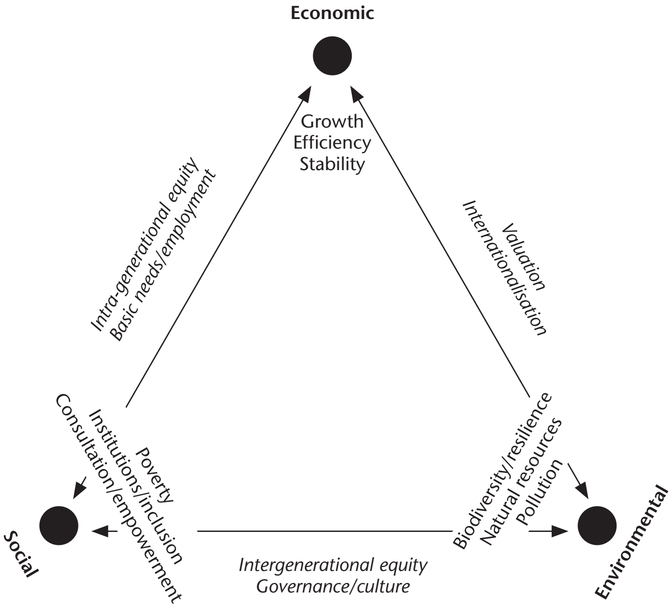
Working definition of sustainable development

'Sustainable development' is a term widely used with many different associations and multiple definitions.[1] The concept emerged from concerns about a sustainable society and the management of renewable resources (Brown 1981). Early debates on 'green issues' focused on preservation or conservation of natural resources and developed concepts such as maximum sustained yield (Nash 1982; Wilson 1988). Another strand of the debate focused on 'brown issues' such as pollution, population growth and the limits of resources (Ehrlich 1968; Meadows et al. 1972). Questions were raised about the limits to growth, and sustainability was conceived by some as keeping society within ecological limits. In the 1980s, the concept of sustainable development emerged in attempts to link concerns about ecological limits with those about poverty and development (IUCN et al. 1980; WCED 1987). The concept was popularised by the Brundtland Report as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987: 8). The implication was that ecological sustainability could not be achieved if poverty was not addressed, requiring action on both environment and development (Robinson 2004). Perhaps it is in implementing – the process of making development more sustainable – that the concept becomes more clearly defined for a particular context, rather than in abstract definition.

While the Brundtland definition is commonly cited, there is no consensus in academic or policy circles on the concept or how to apply it in practice (IPCC 2001a). Despite the absence of any single authoritative definition, in practice many people would recognise development that is *not* sustainable. For the purposes of this book, a working definition of sustainable development is required for the energy sector, not least because the South African government is committed to this principle. Having hosted the World Summit on Sustainable Development in 2002, and having ensured that the outcome took the form of an action plan, government has a vested interest in realising at least some of the Summit goals – after all, it is the *Johannesburg* Plan of Implementation.

There does, however, appear to be consensus that sustainable development has three broad dimensions – economic, social and environmental. Sustainable development at its simplest is 'development which lasts' (Munasinghe 2000: 71). In Figure 2.1, the economic dimension is related to growth, efficiency and stability; key social issues include poverty, participation and empowerment; while the environmental corner of the triangle is concerned with issues such as pollution, biodiversity and natural resources. The concepts are further defined below.

Figure 2.1 *Elements of sustainable development*



Source: Munasinghe (2000: 72)

The concept of sustainability has been further defined in relation to non-declining stock of capital, or wealth. 'Any growth path characterised by non-decreasing stocks of assets (or capital) is sustainable' (Munasinghe 2000: 76). This broad definition has been refined by Daly, who distinguishes between 'weak' and 'strong' forms of sustainability (Daly & Cobb 1989). Capital, or assets capable of generating flows of goods and services, comes in different forms: natural and human-made capital (the latter often being further subdivided into manufactured, human and socio-cultural subcategories). Natural capital refers to natural resource assets; durable structures or equipment are manufactured by human beings; human capital is the productive potential of human beings; while social capital captures the norms and institutions that influence human interactions (Banuri & Weyant 2001). Development may be considered sustainable if capital is non-decreasing. Accumulating the various kinds of capital increases the resilience of an economy, a society and its environment to external shocks.

Weak sustainability assumes that different forms of capital are substitutes and can be traded off against one another; strong sustainability assumes they are complements (Daly & Cobb 1989). Weak sustainability requires only that capital stocks are maintained across all types, but a deficit in one kind of capital can be made up in another. Strong sustainability, on the other hand, requires that all kinds of capital increase. One implication is that increases in human-made capital stocks cannot make up for losses of natural capital under strong sustainability.

Development is clearly a process that unfolds over time. Time matters in considering the sustainability of development, notably with the concerns about future generations reflected, for example, in the Brundtland definition. The time frames typically adopted for energy planning, for example, are within a generation, usually 25 or 30 years. The shorter, intra-generational time frame is adopted in the analytical parts of this book. Beyond 2025, many projections become highly uncertain – one need only try to predict the oil price in 10 years' time. But it is still true that decisions made in the next two decades or so will have implications for much longer, given the longevity of energy systems. The concern for future generations is integral to the analysis of short-term considerations, in the sense that some of the dimensions reflected in the indicators of sustainable development have implications beyond the medium-term time frame of energy planning.

A working definition of sustainable development needs to incorporate the concept of maintaining or enhancing stocks over time, with assets relating to economic, social and environmental dimensions. Munasinghe provides one approach that incorporates the concerns of sustainability and development:

> [A]n approach that will (inter alia) permit continuing improvements in the present quality of life at a lower intensity of resource use, while leaving behind for future generations enhanced stocks of assets (i.e. manufactured, natural and social capital) that will provide undiminished opportunities for improving their quality of life. (Munasinghe 2000: 71)

This conception is used as a working definition of sustainable development in this book. While any definition of energy for sustainable development may be contested in the abstract, it is possible to identify which energy development paths are more sustainable than others. This book does not treat sustainable energy development as an end state. Rather, different policy options are compared to see which are more sustainable. Making development more sustainable does not require a precise definition of some ideal state of sustainable development; what is important is to address those parts of current development trends that are clearly unsustainable. In this sense, a working definition of energy for sustainable development is needed for the book.

Energy for sustainable development

Sustainable development has as its primary aim the search for a path of economic progress which does not impair the welfare of future generations (Pearce et al. 1989). A sustainable energy development path for the electricity sector would need to be socio-economically viable, as well as meet local and global environmental criteria. A key global environmental impact of electricity production and use is its likely impact on climate stability, while air pollution is a significant local environmental impact of electricity supply and use (see Chapter 3). The social welfare of future generations will be determined in no small measure by employment and income distribution. Sustainable development for the sector must therefore reduce energy poverty[2] by promoting affordable access to modern energy services.

Sustainable energy development is more than sustainable energy growth. An energy growth path may deliver an increase in energy consumption per capita, but energy development should also improve – or at least maintain – social and environmental quality. This has implications for the *pattern* of energy development. Several studies document issues of energy and poverty in South Africa (for some examples, see Bank et al. 1996; Eberhard & Van Horen 1995; Jones et al. 1996; Mehlwana & Qase 1998). In the context of a society where large sections of the population still suffer from energy poverty, growth in energy services is an essential first step to energy development. Put in different terms, sustainable growth is a necessary but not sufficient condition for sustainable energy development. The Reconstruction and Development Programme (RDP) balanced social goals (electricity for all) with environmental concerns (promoting diverse energy sources and energy efficiency) (ANC 1994). The working definition of sustainable development above suggests that sustainable energy development requires more than simply growth in energy consumption.

Some further working definitions are elaborated below (adapted from Pearce et al. 1989: 33):

- *Energy growth* means that energy consumption per capita is increasing over time. However, observation of such a trend does *not* mean that growth is sustainable.
- *Sustainable energy growth* means energy consumption per capita is increasing over time *and* the increase is not threatened by 'feedback' from either biophysical impacts (local air pollution, GHG emissions) or social impacts (social disruption, for example if services are unaffordable).
- *Sustainable energy development* means that a set of 'development indicators' is increasing over time. Indicators would be drawn from social, economic and environmental dimensions, but different stakeholders might emphasise various criteria. The same feedback requirements apply.

The definition could similarly be extended to the electricity sector, suggesting that growth in electricity consumption per capita alone is necessary but not sufficient to demonstrate sustainable development. Growth in electricity consumption must not undermine its own achievement by contributing to social disruption, and therefore has to remain affordable. Social sustainability is particularly relevant in the residential sector, where affordable access to modern energy services is a key goal. A core development indicator that needs to increase is access to energy services. To meet criteria of strong sustainability, increasing electricity supply and more affordable services should be achieved while minimising local air pollution and global environmental pollution. In this context, efficient use of energy is a necessary condition for sustainable development. The debate on energy for sustainable development is integral to the linkages between sustainable development and climate change.

Sustainable development and climate change

The concept of sustainable development is widely applied in the climate change debate (Banuri & Weyant 2001; Byrne et al. 1998; Davidson & Nakicenovic 2001; Markandya & Halsnaes 2002; Metz et al. 2002; Munasinghe 2001; Sachs 2000). Most simply, mitigating climate change is part of the broader sustainable development agenda. Unchecked growth of GHG emissions due to development is not sustainable, as it exceeds the capacity of the atmosphere to absorb pollutants. The linkage between climate change and sustainable development is seen as working in both directions – sustainable development is a key component of mitigating climate change, while the impacts of unmitigated climate change threaten to undermine any possibility of sustainable development (IPCC 2001a; Munasinghe & Swart 2005).

In the literature on energy and climate change, environmental, economic and social dimensions were initially analysed separately and sustainability treated as their sum. More recently, and particularly in relation to climate change, the focus has shifted to analysing the potential areas for synergies – as well as trade-offs – in realising sustainable development (Banuri & Weyant 2001; Byrne et al. 1998; Davidson 1994; Metz et al. 2002; Munasinghe 2001; Sachs 2000). The IPCC's Third Assessment Report identified three broad approaches to climate change: efficiency and cost-effectiveness; equity and sustainable development; and global sustainability and societal learning. It noted that consensus appeared limited to acceptance that three broad dimensions must be integrated to achieve sustainable development – economic prosperity (development), ecological integrity (sustainability) and social justice (equity) (Banuri & Weyant 2001). This broader discussion (compared to a focus on poverty reduction, as in the MDGs) is used in this book to analyse the three dimensions of sustainable development: development (primarily economic), sustainability (environmental) and equity (social). This is an analytical distinction, recognising that all three dimensions are interrelated.

Development

Development is often associated with economic prosperity. In the first instance, economic prosperity may be measured in total output. However, the concept of economic development implies not only increase in total output over time (economic growth), but also progress towards some set of social goals. In South Africa's macroeconomic policy Gear (Growth, Employment and Redistribution strategy), growth is allied to goals of job creation and redistribution of income (DTI 1996). More detailed development objectives, however, are spelled out in the RDP (ANC 1994).

If economic development is to be sustainable, its impact on the environment – human and natural, social and ecological – must be limited. In the social context, the distribution of income is as important as economic output (see the discussion on equity below); otherwise social crises that might arise from inequality may undermine economic development. Societies with high levels of inequality – approximated by the Gini coefficient, for example – may struggle to maintain the social stability needed for economic development. Environmental concerns require that economic development should not undermine its own basis – ecosystems and their natural resources and services. Sustainable development broadens the concept of development from its narrow focus on economic growth to include human development, poverty eradication and social equity (Banuri & Weyant 2001). The social dimension of development should include measures that reduce vulnerability, improve equity and meet basic human needs (Munasinghe 2000). While basic human needs are specific to different contexts, the MDGs have given some broader definitions – quantifying goals to eradicate extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria and other diseases; and ensure environmental sustainability (UN GA 2000). Within these international goals, South Africa has defined its own priorities in terms of interpreting the MDGs (RSA 2007), but also in the evolution of its own thinking around development (see Chapter 3).

Sustainability

Sustainability in simple terms means that something lasts over time. Sustainability is linked to *durability*. But durability does not mean that no change takes place over time. In economic and ecological systems, sustainability relates to the system's *resilience*, the ability to adapt to change, as well as its vigour and level of organisation (Munasinghe 2000). It is often assumed that greater *diversity* in ecological and economic systems makes them more resilient to shocks and stresses (Pearce et al. 1989). For development to be sustainable, it must improve the health of ecological and socio-economic systems and their ability to adapt to change. 'Policies must address simultaneously the goals of social equity and ecological resilience' (Tellus Institute 2001: 40). Similarly in the economic dimension, greater resilience to external shocks and surprises is important for sustainability.

Equity

Does development with sustainability add up to sustainable development? Many argue that a higher degree of social equity is also required by the standards of sustainable development (Byrne et al. 1998; Kartha et al. 1998; Nakicenovic 2000;

Sachs et al. 1998). This is consistent with a concept of development that does not undermine itself by causing disruption through social inequality.

Developing countries have frequently expressed the concern that their development should not be constrained by considerations of climate change (Agarwal 2000; Mwandosya 2000; Sari 1998; Zhou 2001). This is considered unfair, given that industrialised countries bear most of the responsibility for cumulative historical GHG emissions. For developing countries, mitigation efforts might focus on de-linking economic growth from rising GHG emissions (Banuri & Weyant 2001; Baumert et al. 1999).

Equity in the context of climate change requires 'that neither the impact of climate change nor that of mitigation policies exacerbates existing inequities both within and across nations' (Banuri & Weyant 2001: 87). Given the time frames of climate change, equity between generations is part of this discussion. Clearly, both mitigation and adaptation have implications for equity.

Four central issues in the climate change negotiations have strong implications for equity:

- fair allocation of costs to prevent further climate change;
- sharing the costs of adapting to climate change impacts;
- fair process to determine the previous two issues; and
- fair allocation of GHGs in the long term and the transition (Toth & Mwandosya 2001).

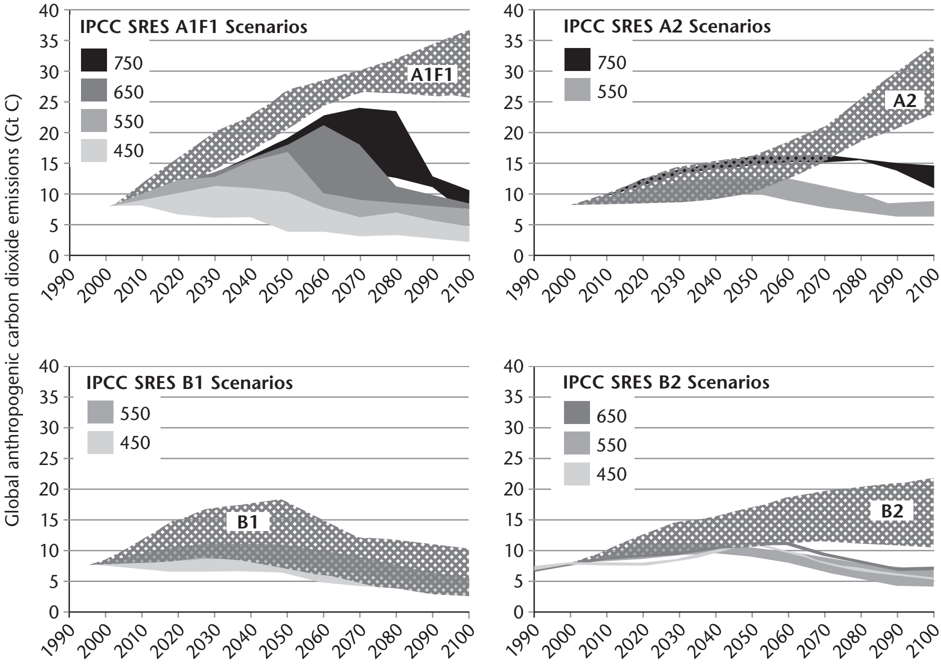
While mitigation can be enhanced by sustainable development, strict mitigation targets may place a limit on sustainable development, especially in developing countries. The link is explicit in Article 2 of the UNFCCC (1992), which places three conditions on the ultimate objective of stabilising GHG concentrations in the atmosphere – allowing ecosystems to adapt naturally, avoiding threats to food production and enabling 'economic development to proceed in a sustainable manner'. This is reinforced in Article 3.4, which recognises as one of its guiding principles that '[p]arties have a right to, and should promote sustainable development'.[3]

Equity is framed in the Convention process both in terms of the greater historical responsibility of industrialised countries and in terms of the limited capability of developing countries to divert resources to climate change mitigation. These differences have become known as the 'common but differentiated responsibilities' of developed and developing countries in the climate change regime. To allow them to continue developing, Non-Annex I countries (developing countries) do not currently have binding commitments to reduce GHG emissions. Their voluntary mitigation programmes under the Convention are to be enabled by funding and technology transfer from Annex I[4] countries (UNFCCC 1992). Under the Kyoto Protocol, they may participate in the Clean Development Mechanism (CDM), which has sustainable development as one of its two major goals (UNFCCC 1997).

The emphasis in this book is on equity in mitigating climate change. Approaches that meet local development needs (for example, energy services) are presumed to be more equitable for developing countries, since developed countries industrialised in the absence of climate constraints (Mwandosya 2000). Hence an approach that starts from energy development objectives is more appropriate and equitable for developing countries. The argument is that more equitable approaches will help generate support for mitigation (see, for example, Agarwal 2000). Promotion of more sustainable development in developing countries both contributes to international equity and enhances mitigation efforts by reducing emissions of the reference case (IPCC 2001b; Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002). This has important implications for the economic analysis, given the finding – in analysing the economics of the Kyoto Protocol – that '[i]n general, other things being equal, the higher the reference case emissions, the higher the costs of implementing the Protocol' (Weyant & Hill 1999: xxxv).

Figure 2.2 shows four of the families of scenarios from the IPCC's Special Report on Emission Scenarios (SRES). Each of the dotted scenario families (A1F1, A2, B1 and B2, more fully described in IPCC 2000) represents a different storyline of how global emissions might evolve in future. The SRES scenarios deliberately do not consider policies explicitly aimed at combating climate change. Thus, the dotted reference scenarios shown in Figure 2.2 do not include climate policy and are shown together with mitigation scenarios resulting in atmospheric concentrations of carbon dioxide (CO_2) ranging from 450 to 750 ppmv (various shades).

Figure 2.2 *Comparison of SRES non-policy emissions scenarios and 'post-SRES' mitigation scenarios*



Source: Morita & Robinson (2001: 151, Figure 2.14)

Choosing a sustainable development path means that the baseline – or reference – GHG emissions are lower than in other possible futures. Put differently, a more sustainable development path has lower emissions, *even without* any explicit climate policy. The IPCC's Third Assessment Report found that this choice of future 'world' was more important than the drivers determining GHG emissions (Morita & Robinson 2001). The Fourth Assessment Report put it another way: 'Climate policy alone will not solve the climate problem' (Sathaye et al. 2007: 12.2.1, 700).

The corollary is also true – development objectives can be met in more or less emission-intensive ways. Beginning with one or more future development ambitions, it would be possible to describe paths towards those goals (Berk et al. 2001; Metz et al. 2002; Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002). The scenarios in Figure 2.2 show clearly that to reach the same atmospheric concentrations, significantly less effort is required if reference emissions are low (in the B family) than if the future world has higher emissions (in the A scenarios).[5] A key challenge for South Africa's contribution to mitigating GHG emissions is to make energy development paths more sustainable.

Sustainable development paths as an approach to mitigation

As outlined in Chapter 1, policy in developing countries starts from development rather than from climate. Making energy development more sustainable is a different challenge from a direct focus on climate change targets.

Focusing on policy for sustainable development raises the question of how this differs from climate policy. The motivation or intent of the policy is more relevant in distinguishing between the two, rather than the kind of action taken. Climate change mitigation policy focuses primarily on reducing atmospheric GHG concentrations (Banuri & Weyant 2001). Similarly, one could say that sustainable development policies are primarily motivated by the aim of delivering development services (water, housing, food, energy, etc.) with due regard to social and environmental impacts. These are more pressing concerns than conventional approaches to climate change for most people (Berk et al. 2001). In practice, however, climate and sustainable development measures are often the same or similar, even if they are motivated by different reasons.

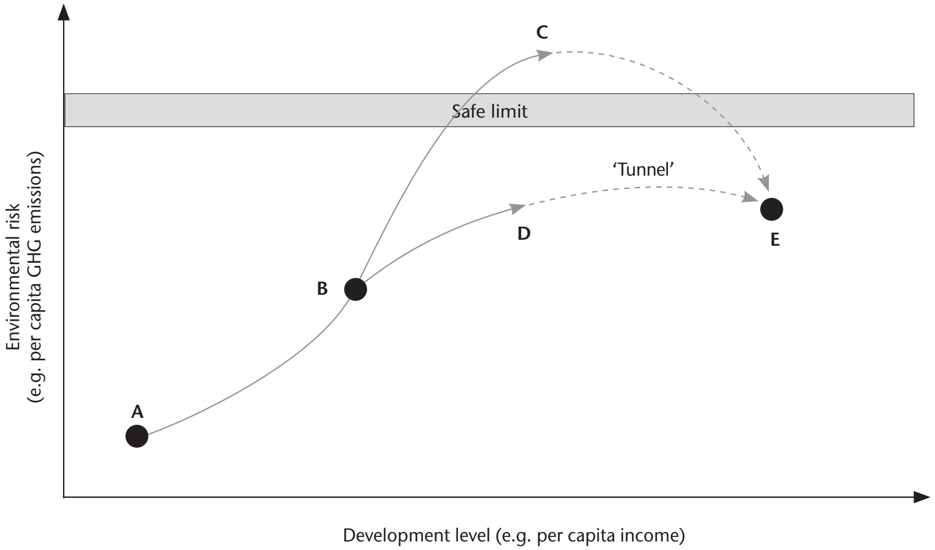
The IPCC's Third Assessment Report draws a distinction between climate and non-climate policies (Morita & Robinson 2001). Climate policies have GHG emission reductions as a primary goal, while non-climate policies do not aim at this. The confusion arises when non-climate policies nonetheless reduce emissions. Sustainable development policies are a classic example: energy efficiency in low-cost housing may be motivated by sustainable development, but have the effect of reducing the emissions compared to the baseline – the development path that would have happened otherwise. Clear separation is not always possible, since many policies have multiple goals.

The Fourth Assessment Report went a little further in making clear that sustainable development policies have a key role to play. A key message is that 'with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades' (IPCC 2007b: 3), that is, additional policies – focused either on climate or on sustainable development or both – will be needed. Climate and sustainable development policy are mentioned in the same breath. The argument put forward in this book is that sustainable development policies are an appropriate and effective starting point for a developing country like South Africa.

The focus of this book is therefore on non-climate policies, with GHG emission reductions as a co-benefit. Supply options are examined that can make electricity generation more sustainable. The South African electricity sector accounted for 40 per cent of South Africa's GHG emissions in 1994 (calculated from RSA 2004), implying that the potential for climate co-benefits of cleaner electricity development is large. On the demand side, residential energy policies are examined that make social development more sustainable. This will entail not only increased access, but also making energy services more affordable for households, in particular the poor.

South Africa's development path in the electricity sector needs to 'tunnel' under a conventional electricity development path (Munasinghe 1995). Figure 2.3 shows how a country's emissions might change with its level of development, as illustrated by the proxy of GDP per capita. In the initial stages, emissions tend to increase for a number of reasons – economies tend to be built around more energy-intensive primary sectors, and the fuel mix may include fossil fuels, as with coal in South Africa's case. If South Africa's development path for the electricity sector were purely growth oriented – without any change in the fuel mix on the supply side, or efficiency on the demand side – then emissions would increase.

Figure 2.3 *Emissions paths relative to development level and possibility of 'tunnelling'*



Source: Munasinghe (2002: 126)

South Africa, with high emissions per GDP and per capita, is already high on the curve AB. The main reasons for this emissions profile – and a similar picture for local pollutants – are due to the coal-dominated fuel mix, energy-intensive primary and secondary economic sectors and relatively inefficient energy use (see Chapter 3 for further discussion). Depending on how one defines a safe limit (not quantified in this heuristic diagram), South Africa perhaps already lies above such a limit, on segment BC. South Africa's per capita emissions were 6.91 t CO_2 (1.88 t C) per person in 2000, which is well above the global average of 3.89 t CO_2 (1.06 t C) (IEA 2002a). Even more than for other developing countries, South Africa needs to de-couple emissions from economic growth. The main opportunities for de-coupling lie in using energy more efficiently, and in changes in the fuel mix. While coal continues to be used, increased beneficiation – adding more value within the country – will be needed, as well as reducing emissions through 'cleaner coal' technologies. In the longer term, changes to less energy-intensive economic sectors – typically secondary and tertiary sectors – can reduce emissions further, at a time when per capita incomes are also higher.

To stabilise the climate – which is the ultimate objective of the UNFCCC – the global average needs to decrease. What is needed is a technological, infrastructural and institutional transition to a sustainable electricity economy in South Africa that also reduces GHG emissions. It is for this reason that the issue of climate change mitigation is approached from the perspective of energy for sustainable development.

Conclusion

The approach taken in this book puts development objectives first, focuses the analysis on means of making development more sustainable, and considers reductions of GHG emissions as co-benefits. The aim of this chapter was to examine the relevant literature on sustainable development, energy and climate change.

A working definition of sustainable development embraces the economic, social and environmental dimensions. *Sustainable energy development* means that a set of development indicators is increasing over time, contributing to economic welfare. The increase is not threatened by feedback from either biophysical impacts or social disruption, making it durable or sustainable. Chapter 7 will define in more detail indicators to evaluate whether policies make energy development more sustainable.

The literature on sustainable development and climate change focused on issues of development, equity and sustainability. An important finding underpinning the approach taken in this book is that reducing emissions in the reference scenario may be as important as climate change policy. Making energy development more sustainable will have co-benefits in terms of climate change mitigation. Pursuing a goal motivated by development policy is more appropriate for countries like South Africa where development objectives are defined around basic needs – issues such as reconstruction and poverty alleviation.

Notes

1 For more extensive overviews of the concept of sustainable development, its history and the debate around it, see, for example, Pezzoli (1997), Guha and Martinez-Alier (1997) and Robinson (2004).

2 Energy poverty is taken in this book to mean the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development. For discussions of energy poverty in the African and South African context, see Karekezi (2002), Eberhard and Van Horen (1995), Mehlwana (1998) and Davidson and Sokona (2002).

3 The other principles are equity, common but differentiated responsibilities, precaution, cost-effective measures and support for an open international economic system (UNFCCC 1992).

4 Annex I Parties are countries included in Annex I to the Convention. They include OECD countries and economies in transition, i.e. Eastern European countries.

5 The difference in emissions between the reference case in A1FI and 550 ppmv is much larger than the corresponding difference between B1 reference emissions and a path stabilising at the same level.

3 Starting from development objectives

The broader context

This chapter outlines electricity development objectives for South Africa. It does not relate these explicitly to climate change, but rather starts from an analysis of the energy sector and its relationship to broader development. The broad development objectives of the country are reconstruction, development and poverty alleviation. These development aims are encapsulated in three successive policy frameworks: the 1994 RDP, the 1996 Gear strategy, and the most recent 2006 Accelerated and Shared Growth Initiative for South Africa (AsgiSA) (see ANC 1994; AsgiSA 2006; DTI 1996).

South Africa's energy development path is assessed not only in terms of its own objectives, but also in terms of sustainability in its economic, social and environmental dimensions. To be sustainable, electricity development objectives must contribute to the broader developmental goals of South African society. The chapter therefore assesses the historical contribution of the electricity sector to social and economic development, and considers the impacts of electricity supply and use on the environment. In so doing, it provides a starting point for analysis of climate change mitigation that is firmly rooted in understanding the objectives of the energy sector on its own terms. Considering the history and current status of the electricity sector through the lens of sustainable development sets the framework for stories about how electricity development can become more sustainable.

Development objectives in South Africa

South Africa's development objectives have been shaped deeply by apartheid – a history of racial oppression and patterns of economic exploitation. Apartheid systematically underdeveloped black working-class communities and left a deep legacy of backlogs of basic services in rural and urban areas.[1] A central driver for policy since 1994 has been the redress of the imbalances of apartheid and the promotion of socio-economic development of poor communities. A core document capturing the major objectives is the RDP. However, the imperatives of reconstruction and development have been in tension with a macroeconomic framework that emphasises economic growth as the driver of development – the Gear strategy. Sectoral targets have had to be pursued in a changing macroeconomic framework.

Many of the detailed socio-economic development objectives were set out in the African National Congress's RDP (ANC 1994). It outlined job creation through public works and meeting a range of basic needs as key priorities. Quantified goals were set for delivery of several basic services. For instance, the RDP proposed addressing the housing backlog of some 2 to 3 million houses by aiming to build 300 000 units each year for the first five years. In the same period, 30 per cent of the land was to be redistributed. In providing basic services of water and sanitation, a short-term target of 25 litres of water per person per day was identified. In the energy sector, the main aim of the RDP was 'electricity for all'. The target of connecting 250 000 households per year is one of the few that has been exceeded (Borchers et al. 2001).

These aspirational goals serve to illustrate the importance of socio-economic development, conceived around delivery of basic services, in the broader context of South African policy. While the status of RDP has become uncertain and lives in tension with macroeconomic policy, these overall development objectives continue to provide an important context for energy policy as well. As the country has gained experience with implementation, new challenges – technical, social, economic – have arisen and targets have had to be reformulated and refined.

The energy sector has performed well – relative to other sectors – in meeting such targets. Significant progress has been made in extending access to electricity in particular, although affordability and productive use remain difficult issues. Yet more remains to be done, including the challenge of delivering energy in a sustainable manner. Sustainable development needs to take into account not only the development objectives of the RDP, but also the economic imperatives of Gear.

Energy and development

The Gear framework set macroeconomic policy from approximately 1997 onwards. As the name suggests, Gear emphasises growth, employment and redistribution. Accelerated economic growth is a key objective of government's macroeconomic policy. Key aims have been to reduce the budget deficit (which grew to 7 per cent of GDP under the apartheid government), accelerate tariff reduction, tighten monetary policy, reach inflation targets (between 3 and 6 per cent), and limit private and public sector wage increases (DTI 1996).

While explicit development goals are commonly associated with the RDP, the long-term vision of Gear includes a number of economic and social goals:

- a competitive, fast-growing economy which creates sufficient jobs for all work-seekers;
- a redistribution of income and opportunities in favour of the poor;
- a society in which sound health, education and other services are available to all; and
- an environment in which homes are secure and places of work are productive.

Gear thus – at least in principle – included some of the social development objectives of the RDP. However, its focus on explicitly macroeconomic and social goals is referenced to the earlier document, the RDP.

A major component of government's macroeconomic strategy is the privatisation of state-owned enterprises. The main focus of these efforts is the four big parastatals: Eskom (electricity utility), Transnet (transport), Telkom (telecommunications) and

Denel (arms). In the energy sector, the corporatisation of Eskom has already taken place, changing it from a parastatal to a public company. How this played out in energy development, and especially in the particular model of corporatisation for Eskom, is examined in Chapter 4.

The focus on privatisation has more recently swung back, in the context of a re-emphasis on the notion of the 'developmental state'. The notion is not new (Woo-Cumings 1999) and was earlier used by Ben Fine (Fine 1999), who coined the phrase 'the minerals-energy complex' to define South Africa's political economy. More recently, however, political shifts away from privatisation have been reflected in literature around politics, economic development and service delivery (Edigheji 2006; Fakir 2007; Swilling & Van Breda 2006). President Mbeki's 2008 State of the Nation address made clear that

> [t]he developmental state should maintain its strategic role in shaping the key sectors of the economy. This means that we need to continue this year to strengthen the role of state-owned enterprises and agencies in advancing our overarching industrial policy and economic transformation objectives. (Mbeki 2008)

A new government development policy framework (AsgiSA 2006) responded to the failures of earlier policies in these areas by proposing a 'national shared growth initiative' to counter the exclusion from the formal economy of the bottom third of the population. The initiative was proposed in response to a set of problems not addressed by the earlier frameworks, including:

- a strong currency, which undermined the competitiveness of non-commodity sections of the economy;
- backlogs in national infrastructure, which undermined both basic service delivery and high-end economic growth; and
- a shortage of skills, lack of support for small businesses, and economic concentration in the economy, leading to barriers to entry into various markets in the economy and the exclusion of a significant proportion of the population from the formal economy.

In response to these constraints, AsgiSA proposed a large-scale state-led infrastructure development programme, specific sectoral development plans (including business process outsourcing, tourism, biofuels and agro-processing), national skills development, an overhaul of regulation and policy-making, and measures to eliminate the 'second economy' (that is, to create opportunities to participate in the formal economy for those excluded from it). Growing and diversifying the economy, alleviating poverty and lowering unemployment remain key development goals. Clearly, the state seeks to diversify the economy away from the apartheid-era development path based on the energy-intensive 'minerals-energy complex', but these sectors represent one of the South African economy's key areas of international competitiveness and still form the basis for a large proportion of the economy and an even more important share of exports. The sectors are also currently attracting significant local and international investment.

Reconciling sustainable development goals – such as mitigating GHGs, alleviating poverty and creating employment – with the current structure of the economy is one of the main challenges which South African policy-makers face. Thus, in South Africa the focus of the tension between development objectives and climate change mitigation objectives is the energy system, as well as the point at which this tension can be resolved through innovative policies and measures.

The policy environment in the energy sector

The major objectives of government policy for the energy sector are spelled out in the 1998 White Paper on Energy Policy (DME 1998a):

- increasing access to affordable energy services;
- improving energy governance;
- stimulating economic development;
- managing energy-related environmental impacts; and
- securing supply through diversity.

Electrification has been a major way of extending access, and universal access to electricity continues to be a goal. Historically, provision of electricity in South Africa was limited to established towns and areas of economic activity. In 1993, only some 36 per cent of the total population had access to grid electricity. Initiated by Eskom in 1991 under the slogan 'electricity for all', electrification was included as an RDP programme after the 1994 elections.

The first phase of the National Electrification Programme (1994–99) was implemented by Eskom and municipalities. It was financed internally at a total cost of about R7 billion (Borchers et al. 2001: 1), increasing electrification to about 66 per cent nationally by 1999 (46 per cent in rural areas, 80 per cent in urban areas) (NER 1999). The aim of Phase I was to provide access to electricity for an additional 2.5 million households, mainly in previously disadvantaged and rural areas, as well as for all schools and clinics without electricity. These targets were met and exceeded, with a total of 2.75 million connections in Phase 1 (Borchers et al. 2001: iii) and an estimated 3.75 million connections by 2004. During 2003, a further R1.1 billion was spent on electrification, now financed by the government through the Department of Minerals and Energy (DME). However, a third of the country's population still remains without electricity, with rural areas being the most difficult and costly to electrify. Average costs per connection have declined over time due to learning-by-doing and diminishing infrastructure costs for Eskom (Borchers et al. 2001).

Increasing access to affordable energy services has to a large degree been interpreted as access to electricity, even though other fuels play important roles as well, for example liquefied petroleum gas (LPG) for cooking and liquid fuels for transport. Recognising the importance of providing energy services to rural areas, an off-grid rural concessions programme was launched in 1999, aiming to provide up to 50 000 solar homes systems (SHSs) in each of seven concession areas across the country (Kotze 2001). Proposals have been made to extend the concept to a package that would also include LPG for cooking and other uses. Other energy goals in the RDP are improved rural electrification, a low-smoke coal programme, energy efficiency and the regulation of liquid fuels.

A major change in the governance of the energy sector is the reform of the electricity industry. Broader national development policy, as outlined above, interacts with global trends to reform the electricity sector. The way in which restructuring happens in the sector will have a significant impact on the delivery of services, as well as on the future role of energy efficiency and renewable energy (Winkler & Mavhungu 2001). Opportunities exist for independent power producers (IPPs) to sell renewable energy (DME 2003b), but entry into the market is difficult (Davidson & Turkson 2001; DME 2000a).

Major changes in governance are also taking place in the liquid fuel sector, with the establishment of a National Gas Regulator. The first pipeline from Mozambique began delivering natural gas in the first half of 2004 (Sasol 2004). The pipeline can supply 120 million gigajoules (GJ) per annum and potentially raises the contribution of natural gas to primary energy supply from 1.5 per cent to just over 4.0 per cent.[2] The natural gas is marketed by Sasol in Gauteng and KwaZulu-Natal to industries, with a domestic market operated by eGoli Gas. The option of introducing liquefied natural gas (LNG) into South Africa is presently being examined (CEF 2005). The Petroleum Products Amendment Act (No. 2 of 2005) changed the licensing rules for petrol stations to give the government more influence, and the Petroleum Pipelines Act (No. 60 of 2003) established tariffs and access rules for oil and gas pipelines. These were the first major changes in petroleum sector regulations in many years and are revisions of regulations rather than full-scale deregulation of the oil industry.

Energy-related environmental impacts are governed by environmental legislation. Of particular note are the National Environmental Management Act (No. 107 of 1998) and, for air pollution, the Atmospheric Pollution Prevention Act (No. 45 of 1965). The Department of Environmental Affairs and Tourism (DEAT) has published sulphur dioxide standards for comment, as part of an initiative to establish a National Ambient Air Quality Standard (RSA 2001). A Vehicle Emission Strategy (DEAT & DME 2003) could make a major contribution to improved air quality, since transport energy has been identified as a major source of local air pollutants in cities such as Cape Town (Wicking-Baird et al. 1997). Institutional requirements are probably the key constraint to effective implementation – the lack of people to effectively enforce existing regulations. Coordination and effective communication between different national departments (DME, Transport and DEAT) as well as between different levels of government will also be necessary. Without compliance and enforcement mechanisms, regulations are not meaningful. Accurate monitoring of emissions may soon be required through the regulations specified in the Air Quality Act (No. 39 of 2004), as well as ensuring that such information is widely disseminated.

Diversity of supply is a major goal of energy policy. The energy minister made clear that South Africa intends 'to use every energy source optimally: coal, gas, oil, nuclear and renewable energy' (Mlambo-Ngcuka 2003). Starting from a coal-dominated base, the initial focus in terms of securing supply through diversity has been on importing natural gas from Mozambique and possibly Namibia, as well as more recent finds off the South African coast (*Business Day* 3 March 2000[3]; *Business Day* 3 April 2000[4]; DME 2001a). Gas has been imported by pipeline from Mozambique since 2004 but its preferred use has been for feedstock at Sasol's chemical and synfuel plants (Sasol 2004). The first gas was delivered via a pipeline from the Pande and Temane fields in Mozambique to Sasol's plant in Secunda. These investments – US$1 200 million in the Mozambique project alone (Venter 2001: 16) – could promote a significant shift away from coal as a primary energy source, and provide feedstock for high-value-added chemical and synfuel plants.

Renewable energy sources are another major option for increasing diversity. The focus has been primarily on increased imports of hydroelectricity from within the Southern African Power Pool (SAPP), assuming there is political stability in the country hosting the possible source. Despite some ongoing conflicts over the price of importing electricity, the region's utilities are working on a combined regional power expansion plan. Eskom has identified a more than 9 000 MW potential for regional imports, even without the massive potential of the Grand Inga scheme in the Democratic Republic of Congo. Grand Inga could potentially provide capacity of up to 100 000 MW in the long term and over 40 000 MW in the medium term (Eskom 1997). Regional cooperation on energy development is also a major drive within Nepad (New Partnership for Africa's Development).

In promoting greater diversity in supply, increasing the percentage of renewable energy in the electricity-generation mix is a particular goal. In 2003, the DME published a White Paper on Renewable Energy. The new policy document intends to

> give much needed thrust to renewable energy; a policy that envisages a range of measures to bring about integration of renewable energies into the mainstream energy economy. To achieve this aim Government is setting as its target 10 000 GWh (0.8 Mtoe [million tons of oil equivalent]) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro. The renewable energy is to be utilised for power generation and non-electric technologies such as solar water heating and bio-fuels. This is approximately 4% (1 667 MW) of the projected electricity demand for 2013 (41 539 MW). This is in addition to the estimated existing (in 2000) renewable energy contribution of 115 278 GWh/annum (mainly from fuelwood and waste). (DME 2003c: ix)

The last sentence makes it clear that this amount is additional to current use of renewable energy, most of which is biomass. In contrast to earlier drafts, the focus is not exclusively on renewable energy for electricity generation, but also for solar water heating and biofuels. However, the total energy is then converted to a percentage of electricity demand (not total energy demand). Biomass data are very unreliable, since fuel-wood and waste are mostly not traded commercially, so that the error in the data on biomass energy could be larger than the target.

The energy minister's 2003 budget speech indicated that renewable energy policy would 'lead to the subsidization of Renewable Energy and develop a sustainable market share for clean energy' (Mlambo-Ngcuka 2003). Following the approval of policy by Cabinet, the DME is now developing a strategy to achieve the target. Several studies (some commissioned directly by the government, others by the NGO community) have analysed in some detail aspects of renewable energy policy, including economic and financial analysis (DME 2004a); developing market rules for renewable energy, in particular IPPs (Sad-elec 2003); policies and measures for renewable energy and energy efficiency (EDRC 2003a); and the potential of renewable energy technologies (RETs) to create jobs (AGAMA 2003). NGOs have called for significantly higher targets than the 4 per cent in the final policy document, namely '10% of electricity generation by renewable energy technologies by 2012 and 20% by 2020' (Energy Caucus 2002: 7). However, analysis indicates that achieving the more modest government target by 2013 will require substantial additional investment (Alfstad 2004a).

Government intends to take the results of these national-level studies and develop practical projects that bring together developers and financiers (pers. comm. Otto 2004[5]). The design of systems for an office to administer subsidies for renewable energy projects is under way. Subsidies are expected to be once-off for three years (2004–06), after which the approach will be evaluated.

Assessing progress against energy development objectives

The five major energy policy goals spelled out in the DME's 1998 White Paper remain current, with some changes in emphasis over time. In the budget speech for 2005, the energy minister interpreted these goals in the following way:

- 'attaining universal access to energy by 2014;
- access, affordable and reliable energy especially for the poor;
- diversifying primary energy sources and reducing dependency on coal;
- good governance which must also facilitate and encourage private sector investments in the energy sector;
- environmentally responsible energy provision' (Mlambo-Ngcuka 2005).

The minister has consistently linked all these to the overall government goal of 'pushing back the frontiers of poverty' (Mlambo-Ngcuka 2003).

Overall progress against the five major objectives of energy policy was assessed in a 2002 study (see Table 3.1). Within these objectives, different policy priorities emerged and progress was assessed against these more detailed priorities.

Table 3.1 *South African energy policy priorities and progress*

Objective	Priorities	Progress to date
Increasing access to affordable energy services	• Electrification policy and implementation • Address off-grid electrification	Initiate second phase of electrification programme, including renewable energy for off-grid electrification
	Affordability	• Zero-rating of VAT on paraffin • Poverty tariff
	• Facilitate management of woodlands • Promote improved fuel-wood stoves	No activity
	Establish thermal housing guidelines	Voluntary guidelines only
Improving energy governance	Promulgate electricity regulatory Bill	Postponed to 2002
	Manage deregulation of oil industry	No petroleum regulator; Petroleum Products and Pipelines Bills in 2002
	Implement new regulation of nuclear power	Nuclear regulator established
	Restructure state energy assets	• Eskom Conversion Bill passed • PetroleumSA formed • iGas formed
	• Restructure DME budget • Establish energy policy advisory board • Establish information systems and research strategy	Limited activity
Stimulating economic development	Encourage black economic empowerment (BEE) in energy sector	Two multinational oil companies have sold 25% of business to BEE firms
	Manage electricity distribution industry restructuring	Plan for regional electricity distributor agreed; implementation in 2002
	Remove energy trade barriers and facilitate investment in energy sector	Only Gas Bill to encourage investment in natural gas
	Introduce special levies to fund regulators and other energy agencies	Implemented in all sub-sectors except nuclear
	Introduce competition in electricity	Outline of long-term plans agreed by Cabinet
	Establish cost-of-supply approach to electricity pricing	Cost-of-supply and wholesale electricity tariff piloted
	Promote energy efficiency and voluntary appliance labelling programme	Limited activity outside of commercial building standard
Managing energy-related environmental impacts	Improve residential air quality	• Pilot programmes to improve air quality through low-smoke fuels • Proposals on ambient air quality standards under debate
	Monitor reduction on candle/paraffin fires resulting from electrification	Hazards still very significant
	Introduce safety standards for paraffin stoves	Under discussion
	Develop policy on nuclear waste management	Under discussion

→

Objective	Priorities	Progress to date
Managing energy-related environmental impacts	Investigate options for coal discards	Significant research, but no programmes
	Investigate environmental levy	Not investigated
	Evaluate clean energy technology	Participation in climate change debate
Securing energy supply through diversity	Develop SAPP	SAPP regional coordination centre established and some joint planning
	Pursue international and regional cooperation	Southern African Development Community (SADC) Regional Regulator's forum and Nepad
	Develop gas markets	Mozambique gas to Sasol, and Namibia also under discussion
	Stimulate use of new and renewable energy sources	Piloting several programmes, Renewable Energy White Paper in 2002
	Stimulate energy research	Declining research funds

Note: VAT = value added tax
Source: Spalding-Fecher (2002a)

The table makes clear that the sectoral goals set for energy by the RDP in 1994 have had to be refined and modified for policy and technical reasons. Experience with electrification showed that while the targets of physical connections were met and exceeded, additional policy – the poverty tariff[6] – was needed to make the use of electricity affordable. Like all development targets, energy objectives had to be achieved within a changing macroeconomic framework.

Overall, although the sector has done relatively well, substantial work remains to be done and a high standard of sustainability has not been reached.

The role of electricity in development

Energy in general and electricity in particular has been central to South Africa's development path in the past. While energy on its own is not sufficient for development to occur, it is certainly a necessary ingredient. Energy and particularly electricity will continue to be shaped by future social and economic development.

Energy and electricity development in South Africa

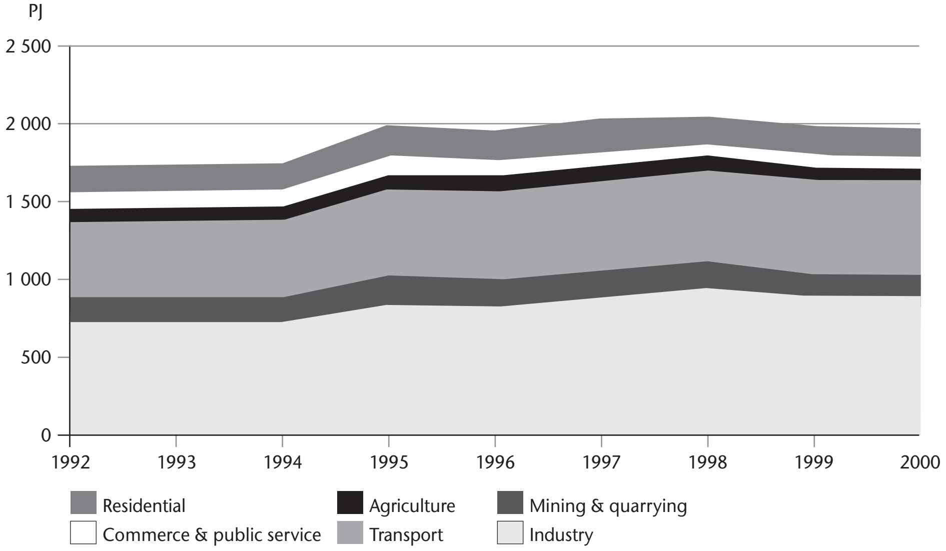
The South African energy sector has historically been at the centre of the country's development. The origins of the electricity supply industry in the first years of the twentieth century, for example, were driven by the needs of the booming mining industry. Energy was a critical ingredient in major investments in mining. Electricity supply, too, was shaped by the demand from the mining industry as it emerged in the early twentieth century. The mining sector in turn produces coal, South Africa's predominant fuel[7] for electricity generation and direct use in industry.

As manufacturing became more important in the economy than mining and agriculture, energy continued to be a major driver of development. Much of the manufacturing sector is also linked to mining activities through minerals beneficiation and metals production. Mining and the various processes of beneficiation are all energy-intensive. In the South African context, the availability of inexpensive coal and electricity was critical to the establishment of these industries. The 'minerals-energy complex' (Fine & Rustomjee 1996) fundamentally formed the energy economy of the country.

In the 1950s, the then apartheid government decided to develop a synthetic petroleum industry and local nuclear capacity, reflecting concerns for energy security. With local fuels it could meet demand for liquid fuels and lessen its dependence on energy imports. The 1960s and 1970s saw a large investment in electricity generation, resulting in excess capacity through the next two decades (see Figure 3.7).

Under the democratic government after 1994, the focus shifted from supply to addressing demand, and particularly broadened to include household access to electricity and making energy services more affordable for the poor. The earlier period focused primarily on economic development, in the sense of the growth of mining and manufacturing industries. Productive activity was central to energy development.

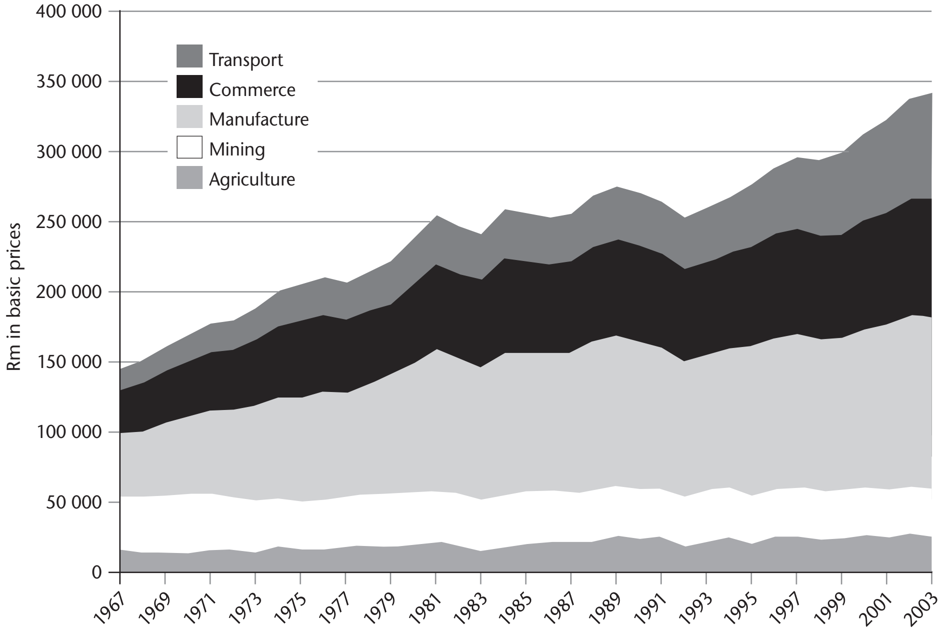
Figure 3.1 *Energy demand, 1992–2000*



Note: Does not include consumption of renewable energy and waste, due to data uncertainties.
Source: Based on data in energy balances (DME 2002a)

The most demand for energy has come from industry, mining and transport. Demand from two key economic sectors, industry and transport, has been the major source of recent growth across all energy carriers (see Figure 3.1). Some growth can be seen in the transport sector, while mining production declined slightly towards the end of the past decade. These sectors make major contributions to the economy, as seen in Figure 3.2. The manufacturing and commercial sectors have increased in importance over time, with mining and agriculture remaining fairly constant in real terms and mining declining in recent years. If earlier time series were available, they would show mining and agriculture contributing most economic output in the early 1900s.

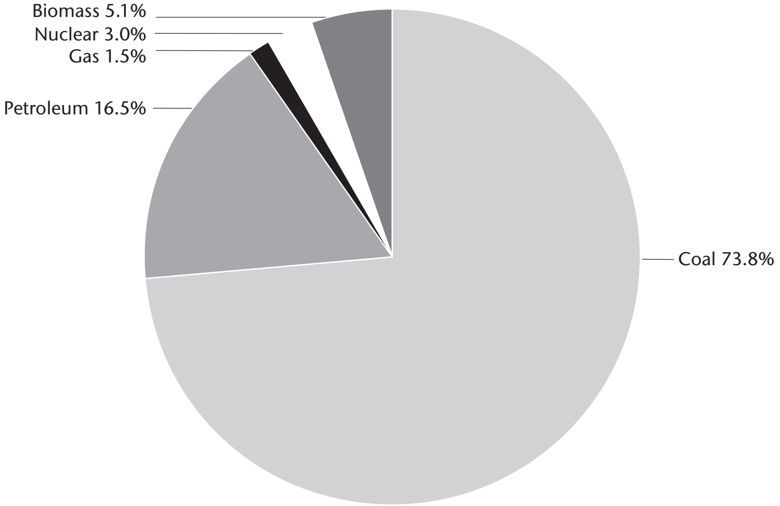
Figure 3.2 *Sectoral contribution to economy, 1967–2003*



Notes: The figure includes only selected primary and secondary sectors.
Numbers on the left axis represent Gross Value Added at basic prices of the sector.
Source: SARB (various)

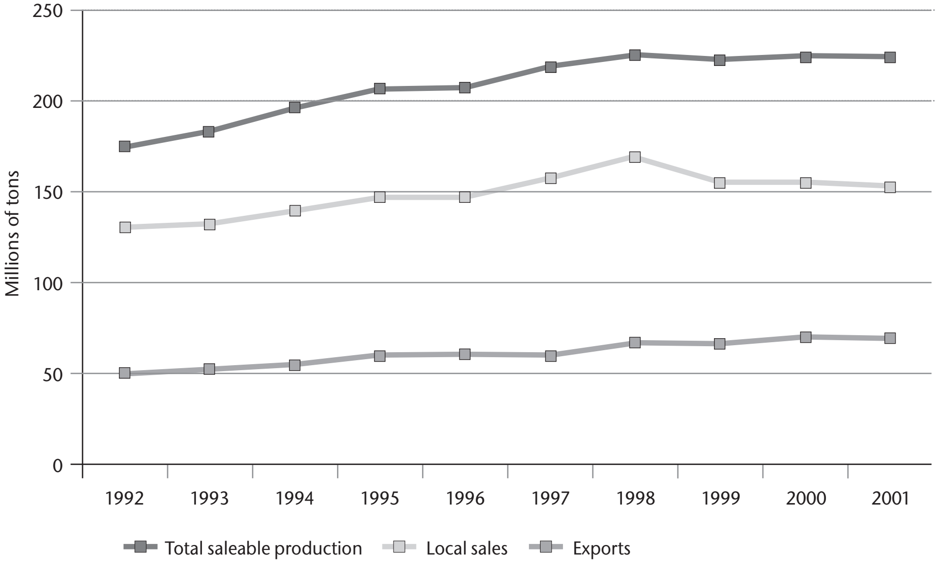
Most of the energy used in the major economic sectors is produced from coal. Figure 3.3 illustrates the coal dependence of the South African economy, with 73.8 per cent of total primary energy supply (TPES) coming from coal (DME 2001a). This compares to a share of 20.0 per cent for Organisation for Economic Cooperation and Development (OECD) countries and a world average of 24.0 per cent (IEA 2001).

Figure 3.3 *Share of total primary energy supply, 1999*



Source: DME (2001a)

Figure 3.4 *Total saleable production, local sales and exports of South African coal, 1992–2001*



Source: DME (2002b)

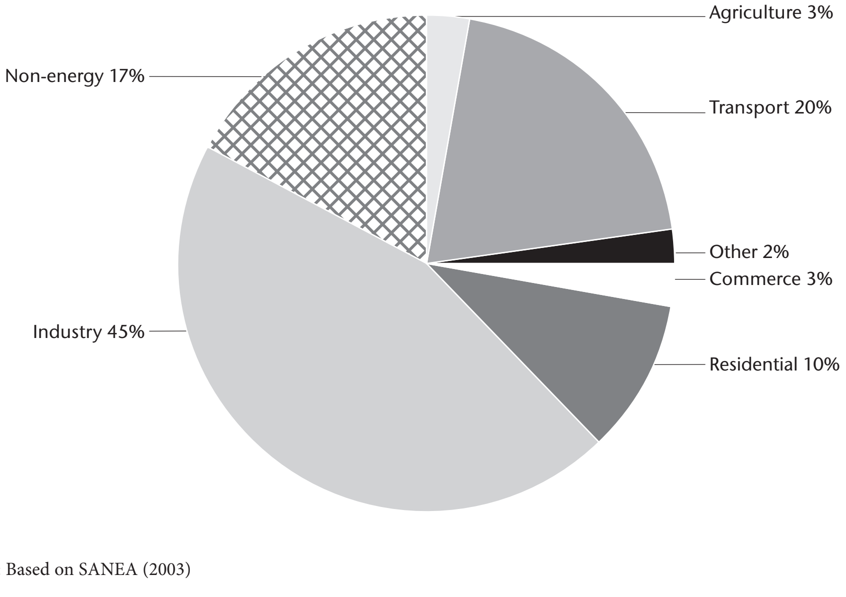
South African coal reserves are large, with the best current estimate being 38 billion tons (ERC 2004a: 36). This gives South Africa the world's sixth biggest reserves after

China, the United States, India, Russia and Australia. Annual production of coal is around 230 million tons per year (see Figure 3.4), giving a life of about 165 years of production at current rates. Pinheiro's detailed technical analysis gives an estimated life of 139 to 151 years, assuming that coal producers not only supply coal for electricity generation but also find profitable markets for their products (Pinheiro 1999: 31). In 2001, Eskom burned 94.1 million tons of coal in its power stations (Eskom 2001: 126).

The high levels of energy and electricity consumption in South Africa, based as they are largely on coal, have led to high GHG emissions relative to other developing countries (discussed later in the chapter). In the official GHG inventory (part of South Africa's initial national communication to the UNFCCC), the energy sector – both production and use – contributed 78 per cent of GHG emissions in 1994, in absolute amounts 297 564 Gg[8] out of 379 842 Gg CO_2-equivalent (RSA 2004: 21). Most of South Africa's GHG emissions are related to the production and consumption of energy. Electricity generation contributes the largest part of the emissions from 'energy industries' – over 40 per cent of the total GHG emissions, almost exclusively in the form of carbon dioxide.[9]

Broken down by the economic sectors which consume final energy, Figure 3.5 illustrates the dominance of the industrial and transport sectors. 'Non-energy' refers to resources that could be used for energy but which are converted to other products, like coal into chemicals and wood into paper (SANEA 2003). Clearly, major economic and social development would not be possible without this energy.

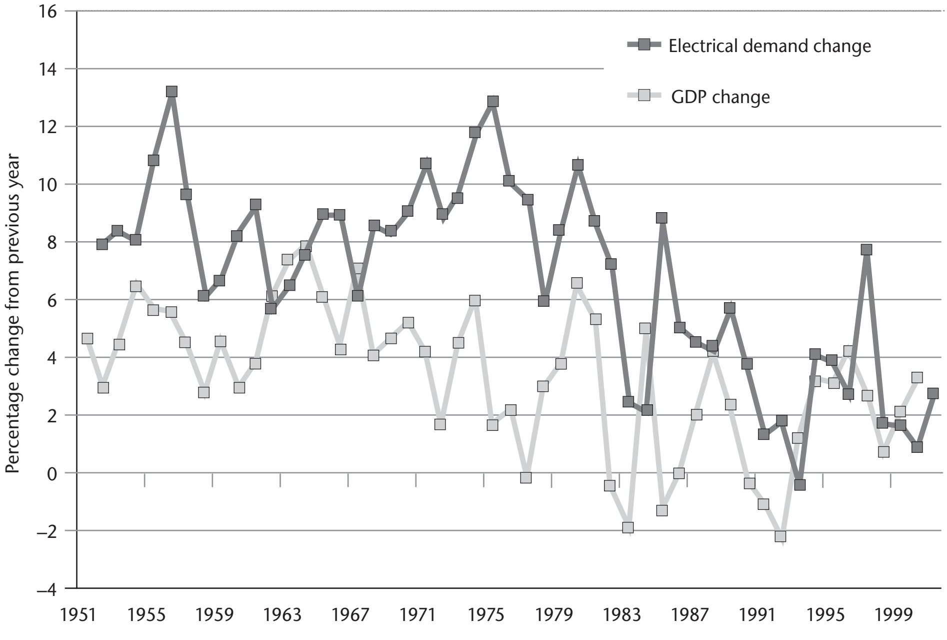
Figure 3.5 *Share of final energy consumption, 2000*



Source: Based on SANEA (2003)

The link between electricity and economic development is shown in similar growth rates. Growth rates for electricity consumption and economic output (approximated by GDP growth rates) have been roughly correlated, as shown in Figure 3.6. Total electricity sales are a good proxy for consumption, and grew fairly consistently in the second half of the twentieth century. The figure shows the percentage change from the previous year, with higher growth rates of between 6 and 13 per cent for the 1950s to the 1970s, but between 1 and 4 per cent for the 1980s to the 1990s. Economic growth was noticeably lower than electricity demand growth around the 1970s, although in general at lower percentage rates than electricity.

Figure 3.6 *Percentage changes in Eskom electricity sales and changes in real GDP at market prices*



Sources: Eskom (1987, 1996); NER (2000); SARB (2002)

The focus of energy development has recently broadened to include social development. Improving the quality of life for South Africans by ensuring access to energy services is one part of this. The residential sector has seen growth in access to electricity in particular, as noted above, but access to transport services is important in relation to the liquid fuel sector. Energy for economic development remains central, however, including the delivery of energy that can enable productive activity, particularly in the industry, commerce and agriculture sectors. The history of the development of the electricity sector provides the backdrop for understanding its current status and future potential.

Development of the electricity supply industry

The pattern of electricity demand was briefly outlined above (see Figure 3.1). By 1948, the electricity supply industry was consolidated into a large and powerful state-owned, vertically integrated monopoly, Escom (renamed Eskom in 1987). Massive power station projects were initiated in the 1960s and 1970s (mostly coal-fired stations, but also ones using local nuclear capacity) in response to high economic growth and an assumption of continued rapid increases in electricity demand – up to 16 per cent growth in peak demand between 1972 and 1982 (Eberhard 2003). By 1973, the transmission grid was interconnected and controlled centrally. As in other sectors (transport, water, telecommunications, iron and steel, synfuels, nuclear energy), the state assumed a dominant role and owned Eskom as a parastatal. With the isolation of the apartheid government, energy security became an important driver of policy and contributed to the development of synthetic fuels, uranium production and nuclear power, as well as the overcapacity of power plants (Steyn 2001).

By the 1980s, economic growth had slowed down but the long lead times of building power stations meant that the projects continued. This left the national utility with large excess capacity in the 1980s and 1990s. Construction of new plants was put on hold and plans for the final station eventually cancelled (Eberhard 2003). Older plants with about 5 000 MW capacity were 'mothballed'. Eskom promoted growth in demand, particularly in minerals beneficiation in aluminium and ferrochrome. Nonetheless, maximum generating capacity still exceeded peak demand by 63 per cent in 1992 (Steyn 2001). Table 3.2 shows the gap between licensed capacity and peak demand as 'excess capacity' between 1975 and 2000. The net maximum power produced was lower than licensed capacity over the period, but still exceeded peak demand by a substantial margin.

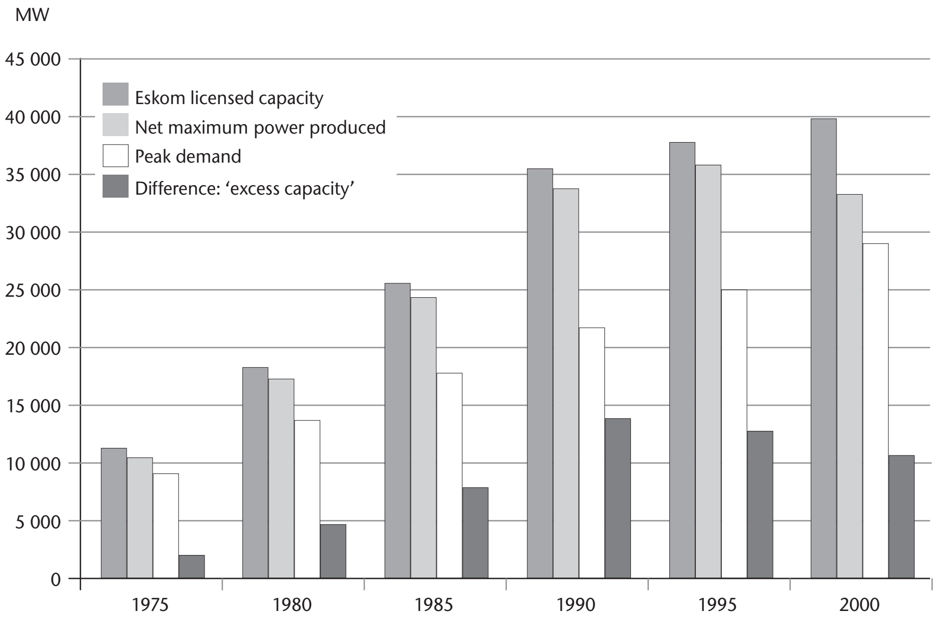
Table 3.2 *Gap between capacity and peak demand for Eskom*

	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: 'excess capacity'	2 057	4 681	7 864	13 810	12 707	10 682

Sources: Eskom (1987, 1996); NER (2000)

Excess capacity has helped to keep electricity prices low, although this excess capacity has been exhausted as evident from supply shortages in the Western Cape in 2006 and nationally in 2008. This excess capacity is illustrated as the difference between total licensed capacity and peak demand in Figure 3.7.

Figure 3.7 *Eskom licensed capacity and peak demand (MW)*



Sources: Eskom (1987, 1996); NER (2000)

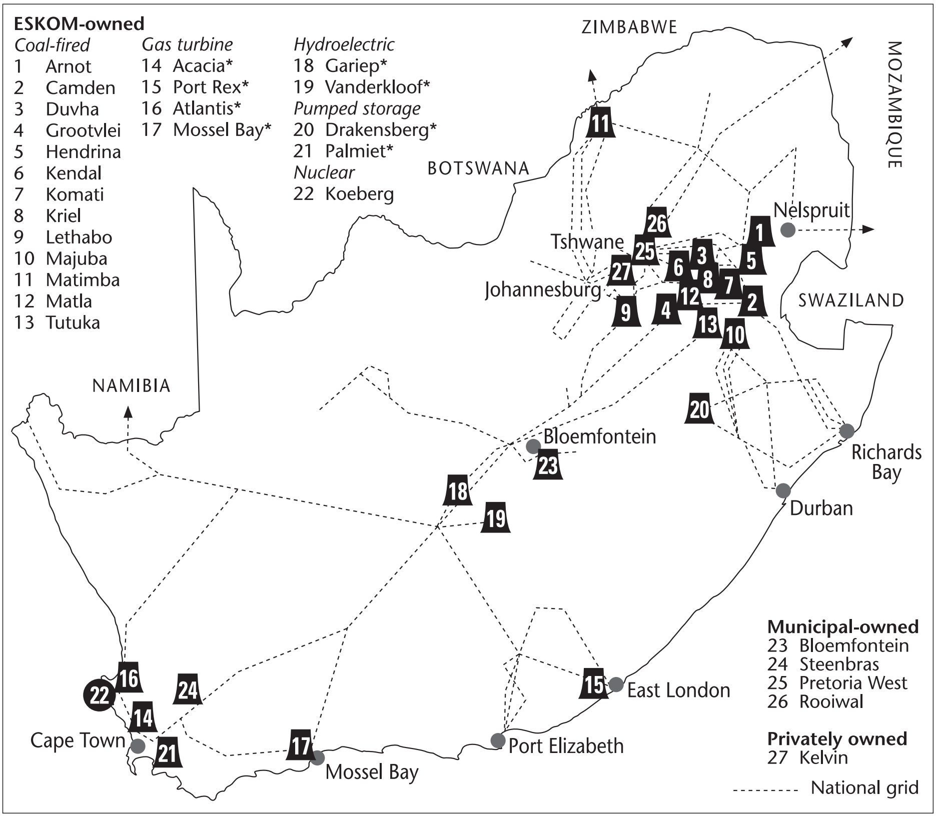
With little need for new investment in recent decades, debt has been reduced as most of the capacity has already been paid off. When new investments have to be made, costs and electricity prices are expected to rise. The presence of low energy prices, including coal-generated electricity, has been one of South Africa's key competitive advantages and continues to drive much new investment in industry (Eberhard & Van Horen 1995; Visser et al. 1999). It has, however, given little incentive for the efficient use of energy and has contributed to local and global environmental problems (Davis & Steyn 1999; Spalding-Fecher, Afrane-Okese et al. 2000; Van Horen 1996b).

Current status of electricity sector

Most generation and transmission of electricity in South Africa is derived from Eskom. The utility generated 95.9 per cent of electricity sent out in 2002, with municipalities and private autogenerators[10] contributing 0.6 per cent and 3.5 per cent respectively. The total quantity of electricity generated in 2002 was 203.6 TWh (NER 2002a).

South Africa's generating technology is based largely on coal-fired power stations, mostly concentrated near and to the east of Johannesburg – close to the main coal-mining areas as well as the major demand centre. To avoid transport costs, all the large coal power stations are concentrated around the coalfields in Mpumalanga, Gauteng and Limpopo province (see Figure 3.8).

Figure 3.8 *South Africa's power stations by fuel and ownership*



Notes: Only plants > 100 MW shown.
*Used for peaking and emergency.
Source: Updated,[11] based on Trollip (1994)

At the end of 2000, there were 50 power stations in the country, of which 20 were coal-fired, accounting for 90.0 per cent of the total licensed capacity of 43 142 MW (including capacity in reserve and under construction). Three older coal stations were put into reserve when there was excess capacity. They constitute 3 556 MW but were to be 'de-mothballed', starting with Grootvlei, in 2007 (NER 2004a: III). Net maximum power produced was lower than licensed capacity at 35 324 MW. The only non-coal stations of significance are the Koeberg nuclear station (4.6 per cent of operational capacity) and two pumped storage facilities (collectively 4.0 per cent) (NER 2001a). Stations that are located outside of the north-east, where most coal-fired power stations are concentrated, assist with grid stability in other parts of the country.

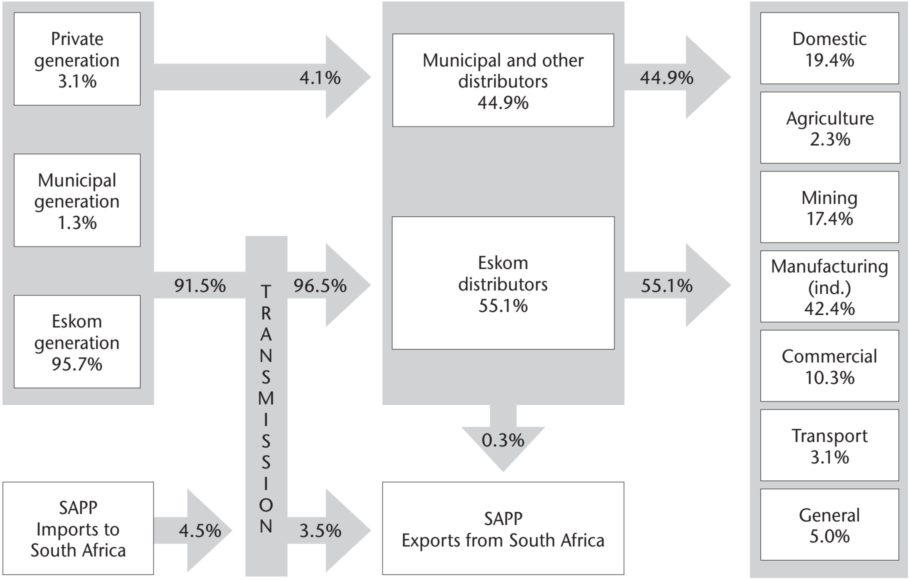
Table 3.3 shows the share of electricity sent out by fuel type (note that percentages of capacity and electricity generation can differ, depending on load factors).

Table 3.3 *Net electricity sent out (MWh) by fuel type, 2001*

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

Notes: Negative values: Pumped storage uses more electricity in pumping water up than it generates, and hence is a net consumer. For gas (using aeronautical diesel fuel in jet turbines), Acacia station consumed more for own use in its generation process than it generated in 2000. This is not always the case.
Empty cells imply that particular owners do not operate that type of power plant.
Source: NER (2001a)

Figure 3.9 *Energy flow through the electricity supply industry in South Africa*



Note: The original diagram gives no percentages for imports and exports. For 2000, however, 5 294 GWh were imported from SAPP utilities and 3 967 GWh exported. As a percentage of gross energy sent out, of 198 206 GWh imports constituted 2.6 per cent and exports 2.0 per cent. It is not exactly clear how this would change the percentages above, but the impact of 1 327 GWh difference between imports and exports is unlikely to result in changes in front of the decimal point.
Source: NER (2001a)

The flow of electricity from production, through distribution and to end-use customers is shown in Figure 3.9. In addition to domestic resources, imports (primarily hydroelectricity) are shown. Note that the shares for different sectors in this figure are for electricity only, while those in Figure 3.1 are for all energy.

Economic and institutional aspects

How sustainable is South Africa's energy economy? To answer this question, one needs to consider how financially sustainable the sector is, but also what contribution it makes to overall economic development. Sustainability in the energy sector is not only about the internal dynamics of the sector, but also about its relationship to the broader economy.

One of the features of South Africa's energy economy that receives much attention is the relatively low price of electricity. There are multiple reasons for this and the price is low from a utility perspective rather than being affordable for all customers.

As a parastatal for most of its life, Eskom received support from the government over the years. While it has contributed significantly to social development (notably electrification), this has been made possible by a range of factors – low coal prices, utilising power station technologies that maximise economies of scale and exploit the lowest value (and cost) of coal, exemption from taxation and dividends, financing subsidies and overcapacity (Clark 2001a; Eberhard 2000; Steyn 2000).

South Africa has taken advantage of large economies of scale in coal mining and power generation, and the power stations are situated near the mines and benefit from long-term coal contracts (Chamber of Mines 2001). Municipal distributors and large industrial and mining customers account for more than 80 per cent of Eskom's sales, which reduces overhead costs per unit of sales (NER 2000). Given that power plants need to be near coalfields to avoid transport costs, electricity generation is concentrated in the north-east of South Africa. Electricity has to be transmitted to other major centres such as Richards Bay, Durban and East London.

Investments have effectively been subsidised with public money, for example through the Reserve Bank providing forward cover protecting Eskom against changes in exchange rates. As a parastatal, Eskom did not have to pay tax and dividends, even after these investments had been paid off. The estimated benefit to Eskom was R22 579 million between 1986 and 1998 (Steyn 2000: 7). Even with this subsidy, Eskom's debt burden was high in the 1980s. Large investments made in previous decades led to significant overcapacity, so that Eskom has been able to pay off these debts, reduce financing costs and price electricity at a very low marginal cost (Davis & Steyn 1998; Eberhard 2000; Van Horen & Simmonds 1998).

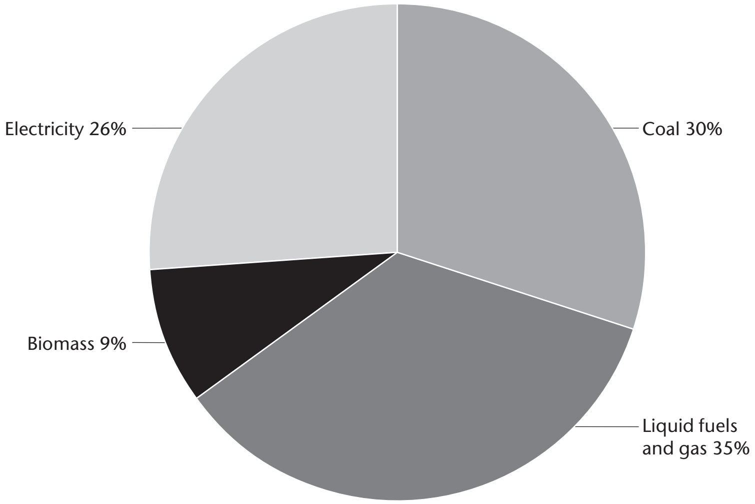
Eskom's high debt-equity ratio[12] in 1986 at 2.93 declined to 0.85 in 1998 (Steyn 2000) and was reduced further by 11.5 per cent per year to 0.63 in 2000 (Eskom 2000). In a commercial firm, lower debt repayments would have been replaced by higher payments of dividends to shareholders, but this did not happen with Eskom as a public company. With the capital costs having been paid off, consumers are currently paying only for energy costs.

Over-investment in coal-fired power plants in the 1980s led to excess capacity, so that Eskom has not had to invest significantly in new power stations for some years, which reduces overall costs. In fact, three power stations have been 'mothballed' and the debt for constructing power plants has largely been paid off. As noted, when new investments have to be made, costs and electricity prices will rise. Eskom expects that hundreds of billions in new investment will be required over the next 25 years (*Business Day* 12 July 2001[13]), for an estimated capacity of 15 000 to 25 000 MW (*Business Day* 17 July 2001[14]). In 2008, the finance minister indicated that Eskom's capital expenditure for the following five years would require R343 billion, of which 73 per cent would be for new electricity-generating capacity (Manuel 2008: 13).

The overall effect is that the price of electricity does not reflect true costs (the value of the inputs used to produce electricity) – the full capital costs are not reflected (tariffs are not 'cost-reflective'), nor are externalities priced. Cheap electricity has had a large opportunity cost to South Africa as a whole.

With the restructuring of the electricity supply industry, investment will not come exclusively from Eskom; IPPs can enter the market. Eskom has been corporatised and up to 30 per cent of its assets may be sold off. While previously exempt from tax, Eskom will have to pay tax and dividends in future – the passing of the Eskom Conversion Act (No. 13 of 2000) made provision for future tax payments. The value of Eskom's assets for tax purposes was specified in the Act at R41 827.8 million at 1 January 2000 (DPE 2000: 8).

Figure 3.10 *Share of final energy demand by energy carrier*

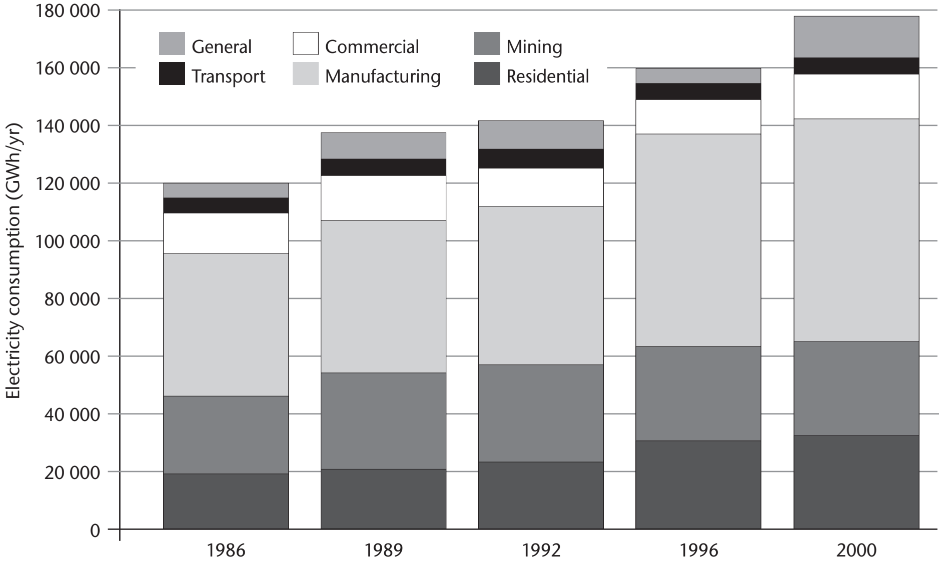


Source: Based on data from DME (2002a)

Having considered several internal dynamics affecting the economics within the energy sector, the chapter now looks at the contribution of energy – and electricity in particular – to the broader economy and its various sectors. To understand the role of electricity in productive activity, it is useful to put electricity in the context of other major energy carriers. Figure 3.10 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.

Electricity makes up 26 per cent of final energy demand in South Africa, following coal and liquid fuels (DME 2000b). This share underestimates the role that electricity plays, however, as a high-quality energy carrier and as a critical input to key economic sectors and productive activity. At the point of final demand, electricity is efficient to use – the thermal losses have already occurred upstream in the power stations and lines. Similarly, pollutants from electricity generation are emitted where the coal is burned, but at the point of use electricity is a clean 'fuel'. Other fuels, by contrast, are typically burned directly in industrial equipment – or indeed in household appliances. Efficiency losses and pollution occur on site.

Figure 3.11 *Electricity demand, 1986–2000*



Sources: Davis (1998); NER (2000)

To understand the contribution of electricity to economic sectors, we need to investigate what electricity is used *for* and how these uses contribute to productive activity. Figure 3.11 shows the trends in electricity consumption for major economic sectors from 1986 to 2000 (ignoring other energy carriers). The growth in aggregate demand is clearly evident. By 2000, manufacturing and mining together made up more than half of electricity demand, and both sectors were also major contributors to economic growth and exports. Together with the transport and commercial sectors, all are essential to production and together account for about three-quarters (74 per cent) of final energy consumption.

The input–output tables for the South African economy were used to establish the sectors in which electricity contributed the highest share of input costs. Table 3.4 is based on the 1995 input–output tables and identifies sectors with above national average (7 per cent) share of electricity as intermediate input cost. The mining and minerals beneficiations sectors are at the top of the list, with cement and chemicals also paying a major share of their input costs to electricity.

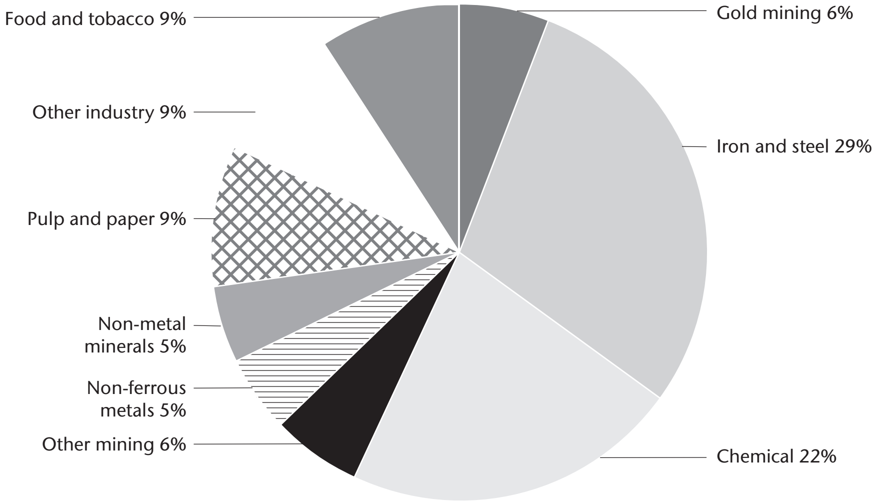
Table 3.4 *Electricity-intensive sectors of the South African economy*

SIC sector	Sector description	Electricity costs as percentage of total intermediary input costs
2400	Gold mining	31.8
3710	Iron and steel basic industries	18.9
3610	Pottery	18.1
3720	Non-ferrous metal basic industries	17.1
2800	Other mining (diamonds and other)	16.7
4200	Water supply	14.9
3692	Cement	14.9
3511	Industrial chemicals	14.6
3691	Bricks	12.2
3513	Synthetic resins	11.9
2100	Coal mining	11.8
3620	Glass and glass products	11.7
9800	Other services, non-profit seeking	10.3
8310	Real estate	9.5
7100	Transport and storage	9.0
3411	Pulp and paper	8.5
6300	Catering and accommodation services	7.3
	Average for the South African economy	6.8

Note: SIC = standard industrial classification
Source: Consult 101, EC & IDC (2001)

The contribution to productive activity can be understood in more detail by considering characteristics of the major electricity-using sectors. The sub-sectors that consume the most energy are mining, iron and steel, and chemical industries (see Figure 3.12).

Figure 3.12 *Final industrial energy consumption by sub-sector, 2001*



Note: 2001 total: 1 302 PJ
Source: SANEA (2003)

Industry (including both mining and manufacturing) is perhaps the classical sector of productive activity. The sector includes energy- and electricity-intensive industries, for example minerals beneficiation like aluminium smelting as well as mining itself. It uses primarily coal (57 per cent of its final energy demand) and electricity (35 per cent) (DME 2002a).

Few productive activities are possible without transport. Unsurprisingly, electricity plays a relatively small role in a sector dominated by liquid fuels, notably petrol and diesel. Petroleum products account for 97 per cent of consumption; electricity is mostly used in rail transport. While rail is important to production, it is overshadowed by road transport.

Electricity is the predominant form of energy carrier in the commercial sector. Government and office buildings, financial services, information technology, educational institutions and recreational sub-sectors primarily use electrical appliances, for example lights, air conditioning, heaters and office equipment. The services offered by the commercial sector are an increasingly important part of GDP. If energy-efficiency standards were made mandatory for commercial buildings, significant savings – of electricity and money – could be made.

While agriculture has declined in terms of economic output (as approximated by GDP),[15] the sector remains important for food production and as a source of rural employment. Except for isolated studies (Auerbach & Gandar 1994), data on agricultural energy use are poor for commercial farms and almost non-existent for dense rural settlements and 'subsistence farming'. Most energy in this sub-sector is used for land preparation and water pumping, with minor contributions from crop processing, transport and lighting. The larger energy users are commercial farms, which are tending to increase in size but decrease in number. Energy is used primarily in the form of diesel, followed by electricity and coal (ERC 2003; SANEA 2003).

In summary, then, the electricity sector is characterised by relatively low tariffs. Although electricity is not the largest energy carrier in South Africa, it makes an essential contribution to the full range of productive and income-generating activities. The sector has contributed to economic development through the provision of low-cost and reliable electricity supply.

Turning to social dimensions, the residential sector takes centre stage. Figure 3.11 illustrates that the residential sector makes the third largest contribution to electricity demand. The share of electricity demanded by this sector has grown in the last decade, as targets for development have been pursued in energy and other sectors. The following section considers in more detail how electricity relates to social development.

Social dimensions and the residential sector

One of the most ambitious goals of the RDP was to connect a quarter of a million households to electricity each year. Achieving this goal has made a major contribution to social development. Has this contribution been achieved in a sustainable manner and can it be extended more broadly and deeply?

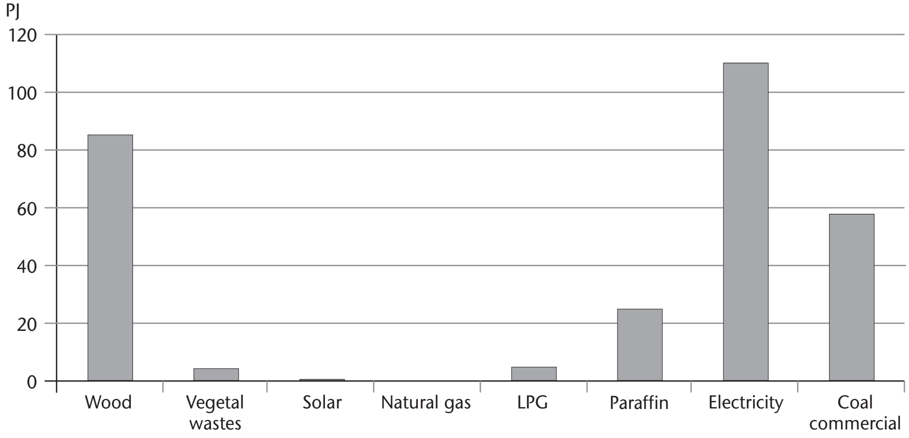
Electricity services are important in improving the quality of life of the previously disadvantaged majority. As described above, electrification has been a key means of delivering access to commercial energy services, increasing the share of connected households from roughly one-third to two-thirds during the 1990s. By the same token, however, every third household is still without electricity – every second one in rural areas. So while major strides towards social sustainability have been made, more remains to be done. And the experience of electrification has shown that numbers of connections are not the only parameter. Finally, the question of affordability of energy services raises a critical question of sustainability in its social dimension.

Electrification and multiple fuel use

The National Electrification Programme, described earlier, has been the major vehicle thus far for meeting the target of universal access to affordable energy services. It has contributed to improved quality of life in several ways, including increased access to a modern energy carrier, improved healthcare in clinics, and adult education classes in the evenings at schools. Small retailers are able to extend their business hours and use electrical appliances. Reduced use of coal in Gauteng improves indoor air quality, while less use of paraffin in the Western Cape reduces the risk of fires. Access to electricity has increased not only for richer households, but also for poorer ones – 31 per cent of those earning less than US$1 per day had access to electricity in 2000, compared to 20 per cent in 1995 (SARPN 2005: 13).

However, multiple fuel use has persisted despite electrification (Borchers et al. 2001). Energy use in poor households continues to be characterised by the use of fuels such as paraffin, coal, fuel-wood and LPG (see Figure 3.13).

Figure 3.13 *Final residential energy demand by energy carrier, 2001*



Note: 2001 total: 288 PJ
Sources: Based on SANEA (2003) and ERC (2003)

Patterns of household energy demand differ significantly in rich and poor, and urban and rural households (Mehlwana 1999b; Mehlwana & Qase 1998; Simmonds & Mammon 1996). Middle- and high-income households use a much higher share of electricity. For poor households, the issue is not simply one of physical connection; access is also limited by affordability. Not only are poor areas often the last to be electrified (ERC 2004a), but many poor households use electricity primarily for lighting and entertainment, not for cooking and space heating. The continued use of multiple fuels many years after electrification highlights the importance of making affordable the use of modern energy for cooking, lighting, space heating and media. Electrification is desirable for its social benefits, but needs to be affordable both for the utility and for customers.

There is a distinct rural–urban divide in electrification rates and across income groups. The national average electrification rate in 2003 of 69 per cent obscures the fact that almost half the rural population (54 per cent) remains without grid electricity and other convenient fuels, while 79 per cent of urban households are connected to the grid (NER 2003a). Very poor households (quintile 1) in rural areas have the lowest electrification rates at 41 per cent (see Table 3.5). The largest difference between rural and urban households is found in the second quintile.

Table 3.5 *Estimated electrification levels of rural/urban households, by income quintile (%)*

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

Sources: UCT (2002), based on data from October Household Survey (Stats SA 1999)

As discussed above, Eskom's industrial and residential electricity tariffs are among the world's lowest (SANEA 1998), made possible by economies of scale, effective subsidies, low debt ratios and non-payment for external costs. From the perspective of poor households, however, electricity remains expensive, especially when used for cooking and heating. High cut-off rates and community protests against cut-offs illustrate the problem of affordability.

'Low tariffs' and affordability

Even for electrified households, the benefits from cooking and heating with electricity were lower than expected by planners, due to affordability. A physical connection to the grid does not ensure that the electricity is actually used; finance is also required. Instead of the planning estimate of 350 kWh per month, consumption remained between 100 and 150 kWh per household per month. Low levels of consumption together with other factors – high operating costs, high levels of losses and high cost of capital (NECC 2000) – have meant that electrification has not been financially viable and requires major cross-subsidies (Borchers et al. 2001).

However, the non-use of electricity (for cooking, etc.) among electrified low-income households is quite surprising, given current costs. Recent case studies show that 56 per cent of households in South Africa connected to the national grid in Eskom-licensed areas consume less than 50 kWh of electricity per month (Prasad & Ranninger 2003) (see the discussion relating to a poverty tariff in Chapter 4).

Off-grid electrification programme

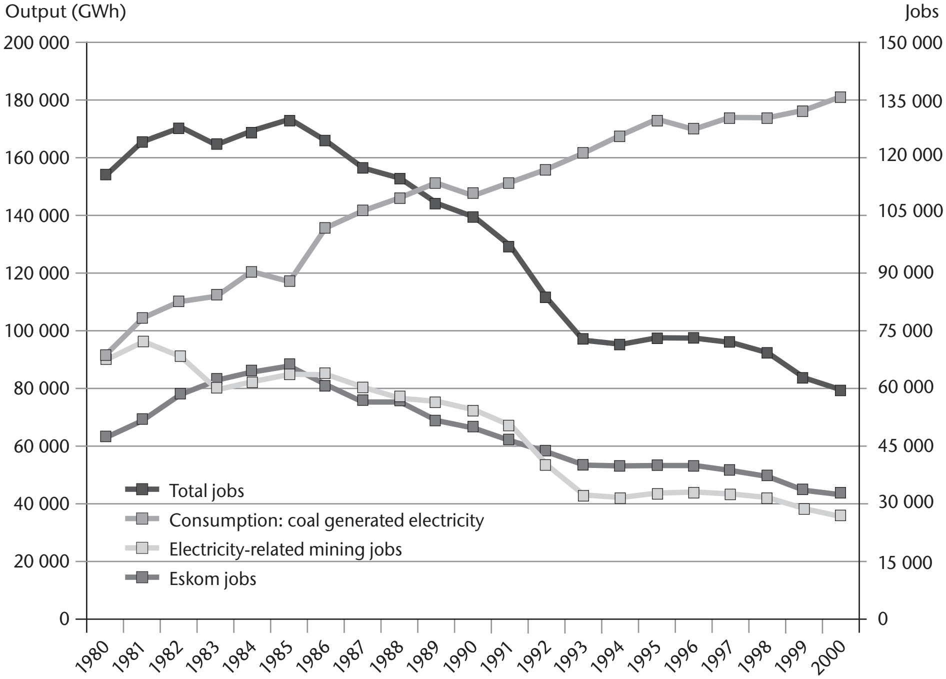
Remote rural areas are more costly to electrify than denser urban settlements closer to the grid. Building on a school and clinic off-grid electrification programme and an Eskom–Shell joint venture which installed 6 000 SHSs, a major off-grid electrification programme began in 2002 (Afrane-Okese 2003). The programme targeted 350 000 homes for SHSs. Operational challenges early in the programme led to a shift from a concession approach to a fee-for-service model (Afrane-Okese 2003).

Seven concessionaire companies were to provide non-grid electricity services for an agreed fee to be paid by the customer – the fee for service. The companies would retain ownership of the systems they installed and service them regularly. The government provided the concessionaires with a capital subsidy of R3 500 per system. Initially, a flat monthly fee of R58 was paid for the service, regardless of the amount used. A solar panel provides on average 62 kWh per year, so that even after the capital subsidy and the poverty tariff, customers were paying 193c per kWh. This is five times the amount a grid-connected customer pays without any subsidy (Spalding-Fecher 2002b). In reaction to this discrepancy and the poverty tariff, government agreed to a monthly service subsidy of R48 as the equivalent of the poverty tariff to grid-connected customers. The subsidy was paid to concessionaires, leaving households paying R10 per month. However, problems with this approach led to the withdrawal of the subsidy. The fluctuation of tariffs led to the near collapse of the off-grid programme in early 2004. By mid-2005, some companies providing a service were in operation, with three service providers having signed agreements to instal 8 000 systems each (pers. comm. Banks 2005[16]).

Electricity and job losses

As shown in Figure 3.14, employment in Eskom and electricity-related mining has declined, even as consumption of electricity (predominantly coal-based) has increased. Coal mining shed more than half its jobs, from about 100 000 in 1986 to 49 000 in 2001 (SANEA 2003: 36). In Figure 3.14, a share of job losses in coal mining is attributed to electricity generation (AGAMA 2003), based on the 53 per cent of non-export coal being consumed for electricity generation (DME 2002a).

Figure 3.14 *Employment in coal-based electricity generation in South Africa, 1980–2000*



Sources: AGAMA (2003). Underlying data from DME (2002a, 2002c); Eskom (1989, 1996); NER (2001a)

Increasing mechanisation and capital-intensive production meant that the consumption of electricity and production of coal increased in the respective industries at the same time as employment was reduced (AGAMA 2003). The job losses in Eskom may not take into account increasing outsourcing of some services. As shown in Figure 3.7, excess capacity increased through the 1980s and peaked in the mid-1990s, suggesting that some job losses may have been in constructing power plants. Perhaps the remaining challenge for electricity's contribution to social development is that of job creation.

This section has shown how the electricity sector has contributed to social development through increasing access on and off the grid. Issues of affordability, while not easily resolved, have been partially addressed by the policy of a poverty tariff. Yet the production and consumption of electricity has significant environmental impacts. It is to this dimension of sustainable development that the chapter now turns.

Environmental impacts

The electricity sector has undoubtedly made major contributions to economic and social development. South Africa's heavy dependence on coal (see Figure 3.3) means that the way in which electricity is supplied and used has major environmental implications. Changing the fuel mix for electricity generation, and introducing safer, cleaner fuels for use in households, transport and industry, remain major challenges.

At the point of use, electricity is a clean energy carrier. This is not true of many other energy carriers, resulting in substantial energy-related environmental impacts not related to electricity. Paraffin use has severe health and safety impacts (poisoning from ingestion, burns and deaths from fires, destroyed housing) and is widespread in the Western Cape (Biggs & Greyling 2001; Lloyd 2002; Mehlwana 1999a). In Gauteng, where locally available coal is burned indoors, respiratory disease resulting from indoor air pollution is prevalent (Qase et al. 2000). In rural areas, indoor wood fires have similar effects, as pollutants are confined in the house (see Spalding-Fecher, Afrane-Okese et al. 2000; Van Horen 1996a). Switching from wood, paraffin, coal, candles, batteries and various other fuels to electricity may have environment benefits at the local level (Spalding-Fecher 2000a, 2005).

Local air pollution

Environmental impacts occur upstream in the generation of electricity and the mining of coal. The impacts of electricity supply can be considered on two levels, the local and the global environments. Indoor air pollution is generally associated with other energy carriers. Electricity can displace these fuels in theory and contribute to a healthier indoor environment. But with the persistence of multiple fuel use even after electrification (discussed earlier), serious environmental health issues remain.

Outdoor air pollution is largely contributed to by the burning of coal (often of a poor quality) for electricity production and by brown haze from the transport sector. Coal-fired power plants generate 93 per cent of South Africa's electricity (NER 2001a) and this fuel mix changes only slowly, as investments in this sector have lifetimes of 30 years and more. Investments made in energy technologies today lock the country into a particular path for a generation. A key issue for the environmental sustainability of the electricity sector is the mix of energy technologies that will be used to meet growing demand – renewable energy, nuclear power, petroleum, coal, natural gas and others (see Chapter 4).

South African coal has high ash, low sulphur and low calorific value. While Eskom has developed considerable expertise in burning poor-quality coal (including coal with a heating value lower than 16 MJ per kilogram), it has not installed the costly equipment – such as flue gas desulphurisation (FGD) and bag filters – to reduce emissions. Coal-fired power stations produce large amounts of pollutants, including local pollutants such as particulates and sulphur as well as the GHGs (contributing to anthropogenic climate change) nitrous oxide and carbon dioxide.

Table 3.6 *Emission from Eskom power stations, 2001*

Pollutant	**Kilotons**
Particulate emissions	59.64
Sulphur dioxide (SO_2)	1 500
Nitrogen oxide (NO_x) as nitrogen dioxide (NO_2)	684
Nitrous oxide (N_2O)	2 154
Carbon dioxide (CO_2)	169 300

Note: kiloton = one thousand tons
Source: Eskom (2002a)

Probably the major local environmental impact associated with electricity is on outdoor air pollution. The pollutants listed in Table 3.6 contribute to health impacts such as respiratory ailments (Spalding-Fecher & Matibe 2003). Sulphur emissions are associated with acid rain, and particulates have impacts on visibility in Mpumalanga where most of the coal-fired stations are located. Mining the coal is associated with dust and methane (CH_4) and social impacts include injuries and deaths.

Water consumption per unit of electricity has been reduced by newer stations, which are dry-cooled. Kendal and Matimba stations require 0.1 litres of water per kWh, compared to 1.8 litres to 22.0 litres per kWh for wet cooling through the conventional cooling towers. However, with the wet-cooled stations still in operation, total water consumption has increased slightly, from 225 699 Ml in 1997 to 239 233 Ml in 2001 (Eskom 2002a).

Global GHG emissions

In terms of global environmental impacts, South Africa is one of the most carbon emissions-intensive countries in the world, due to the energy-intensive economy and high dependence on coal for primary energy. South African per capita emissions are higher than those of many European countries and more than three-and-a-half times the average for developing countries (see Table 3.7).

Table 3.7 *Energy sector CO_2 emissions, various measures and time frames*

	CO_2/cap.	**CO_2/GDP**	**CO_2/GDP PPP**	**Cumulative energy CO_2 emissions from 1950 to 2000**	
	tons/capita	*kg/1995 US$*	*kg/1995 PPP US$*	*Mt CO_2*	*% of world total*
South Africa	6.65	1.65	0.75	10 165	1.29
Africa	0.89	1.16	0.45	13 867	1.75
Non-OECD	1.65	1.33	0.45	318 117	40.23
OECD	10.96	0.44	0.56	472 635	59.77
World	3.89	0.68	0.56	790 753	100.00

Notes: Percentages in the last column do not add up to 100 as rows are not mutually exclusive (for example, South Africa is part of Africa).
PPP = purchasing power parity
Mt CO_2 = million tons of carbon dioxide
Sources: IEA (2004a); WRI (2003)

South Africa is a semi-industrialised country with an emissions profile that in some respects is not typical of other developing countries. Some key characteristics of its economy and energy sector are not favourable in terms of GHG emissions.

Among major developing countries, South Africa's emissions intensity is relatively high in that it emitted 0.75 kilograms of carbon dioxide per US$ GDP (PPP)[17] in 2002 (IEA 2004a), compared to an average of 0.45 kilograms of carbon dioxide per US$ GDP (PPP) for non-OECD and African countries. South Africa is also well above the OECD and world averages (see Table 3.7). Similarly, emissions per capita are high at 6.65 tons of carbon dioxide (t CO_2) per capita, four times higher than the non-OECD value of 1.65 t CO_2 and higher than several OECD countries (IEA 2004a).[18] The values including other GHG emissions are higher, since the International Energy Agency's (IEA's) statistics are only for carbon dioxide from fuel combustion.

South Africa's share of historical cumulative emissions (1950–2000) including *all* gases and sources is somewhat lower (1.17 per cent) than its share of 2000 annual emissions (1.51 per cent), reflecting more recent industrialisation than in the north (Winkler, Spalding-Fecher & Tyani 2001).

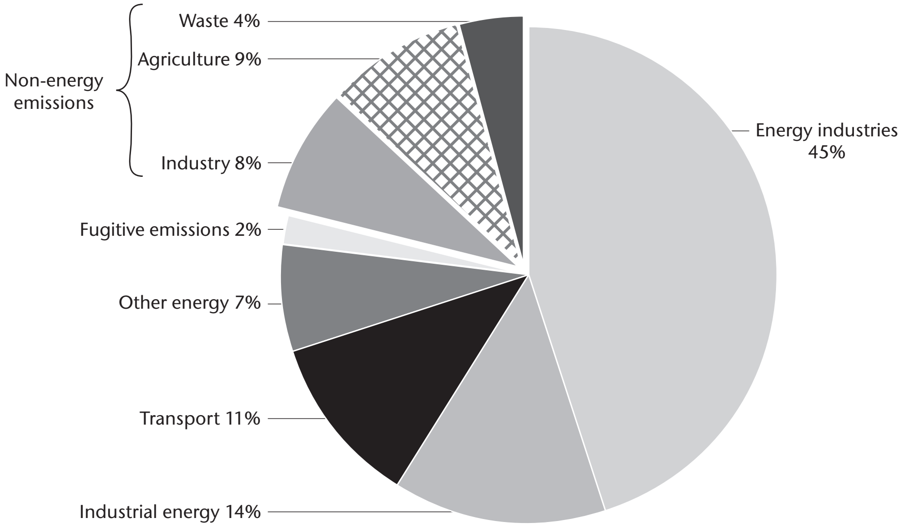
While South Africa's GDP per capita[19] lies below the world average (US$3 160 per capita compared to the global average of US$4 890 per capita[20]), this figure hides the gap between black and white, and rich and poor, within the country.

Reliance on coal energy sources is the main reason behind South Africa's high emissions. On the supply side, major sources of GHGs associated with electricity are coal mining and power generation. Other major emission sources from energy – but not electricity – include oil refining, production of synthetic liquid fuels, gas extraction, wood burning and the burning of coal and oil to produce heat. On the demand side, high emissions stem from energy-intensive industries such as iron and steel, aluminium, ferrochrome and chemicals – the same sectors that make up a large share of South African exports. Energy is not used efficiently in these sectors, by international comparison (DME 2003d; Hughes et al. 2002).

South Africa's emission profile means that its responsibility to mitigate is higher. It also implies that major changes in energy systems will be needed over time, given the high proportion of energy-related GHG emissions. According to South Africa's draft Initial National Communication, total emissions of carbon dioxide, methane and nitrous oxide were 379 842 Gg[21] CO_2-equivalents in 1994 (RSA 2004: 21). This converts to 103.6 million tons of carbon, which can be attributed to the major sectors of energy, industry, agriculture and waste.

The energy sector, including energy production and use, contributed 78 per cent of GHG emissions (297 564 Gg CO_2-equivalent), agriculture 9 per cent, industrial processes 8 per cent and waste 4 per cent (one percentage point missing due to rounding). Comparing the three GHGs in the inventory, carbon dioxide contributed by far the most, 83 per cent in 1994. Methane contributed 11 per cent and nitrous oxide 5 per cent. This analysis focuses on carbon dioxide emissions, given their predominance.

Figure 3.15 *South Africa's GHG inventory by sector, 1994*



Source: RSA (2004)

As Figure 3.15 shows, the energy sector is a key source of emissions and includes a number of critical energy-related activities: energy industries (45 per cent of total gross emissions), energy used in industry (14 per cent), energy used in transport (11 per cent), fugitive emissions from fuels (2 per cent), and other energy-related activities (7 per cent).

The future of energy development in South Africa is integrally related to climate change mitigation. Having placed South Africa in the international context in this respect, the chapter concludes by comparing the country to others in relation to energy.

Conclusions: Comparing and assessing

To assess how far South Africa has come in terms of energy development, some comparison to other countries is helpful. Other developing countries have the same broad challenge of development, but different energy and electricity sectors. Looking at levels of energy consumption, access to electricity and energy intensity are particularly relevant to energy development paths.

Compared to other developing countries, South Africa's TPES per person is relatively high (see Table 3.8). The exceptions are other rapidly industrialising countries, with some, such as South Korea, having higher consumption per capita. Total electricity consumption for South Africa is high, particularly in the African context. The two-thirds of South Africans with access to electricity consume close to 50 per cent of Africa's electricity, while making up only 5 per cent of its population.

Table 3.8 *Energy and electricity consumption, 2000*

	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

Notes: TPES is shown per person, while electricity is in total consumption for whole countries or regions.
Toe = tons of oil equivalent; TWh = terawatt-hour
Source: IEA (2002a)

South Africa's high energy consumption levels, particularly of electricity, are mainly because of its strong industrial base. However, this also reflects electrification rates that are now exceeding the average for developing countries (see Table 3.9).

Table 3.9 *Electrification rates, 2000*

	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	134.2	2 930.7
OECD	99.2	8.5	1 108.3
World	72.8	1 644.5	4 390.4

Source: IEA (2002b)

These relatively high levels of consumption also reflect a high energy intensity – that is, a high energy input per unit of gross national product. The Integrated Energy Plan acknowledged that by 'international standards, South Africa has a high energy intensity' (DME 2003d: 7). South Africa's history, shaped as it is by the minerals-energy complex, has seen the abundance of mineral deposits converted to low energy costs, but also an emphasis on primary extraction and processing. These economic activities are highly energy intensive. The changes of GDP and final energy consumption are reported in Table 3.10.

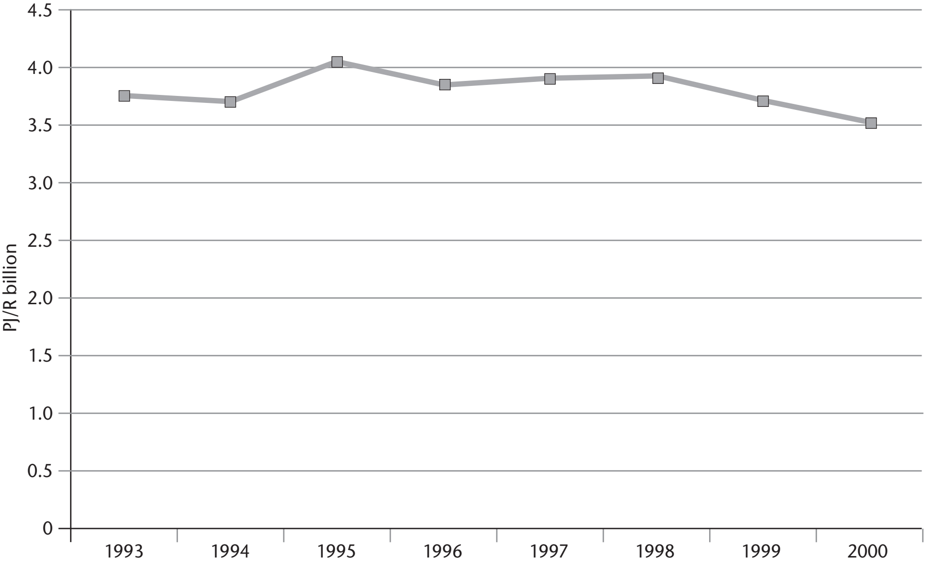
Table 3.10 *National energy intensities, 1993–2000*

	Unit	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

Source: DME (2003d)

Figure 3.16 graphs South Africa's energy intensity between 1993 and 2000. Post-1995, GDP rose and final energy consumption fell, resulting in a lowering of energy intensity over that period. Improving energy intensity has been related to achieving the MDGs in South Africa, measured in energy per unit of GDP (SARPN 2005).

Figure 3.16 *Changes in energy intensity, 1993–2000*



Source: Based on DME (2003d)

This chapter has considered the development objectives for electricity nested within the broader energy sector and framed by the overall development objectives of the country. Reconstruction and development in the energy sector have to a significant degree been interpreted as universal access to electricity – and the country is roughly halfway towards achieving this goal. Electricity has contributed to social development through increasing access on and off the grid.

Yet sustainable development of the electricity sector does not begin and end with access to electricity. Dealing with the legacy of apartheid and the systematic underdevelopment of large sections of the population remains challenging. Issues of affordability, while not easily resolved, have been partially addressed by the policy of a poverty tariff.

In terms of economic development, the electricity sector has provided relatively low tariffs – although, as examined in this chapter, there are multiple reasons for this. Electricity makes an essential contribution to the full range of productive and income-generating activities.

Achieving economic development and delivering basic social services is complicated by the tension with macroeconomic parameters, as well as the ongoing challenge of achieving all this while limiting environmental impacts. The emissions intensity of the energy and electricity sectors, both strongly shaped by coal, means that environmental sustainability is particularly challenging for South Africa. The next chapter examines policy options that might help to meet this challenge.

Notes

1 Given South Africa's history of apartheid, racial categories remain significant. In presenting statistical information related to household energy use, categories of 'black', 'white', 'coloured', 'Indian' and 'African' are used as found in the literature. In defining household types, however, income categories ('richer' and 'poorer') are found to be more relevant.

2 See http://www.dme.gov.za/home.asp?menu=main.

3 D Marrs, 'Sasol takes over stakes in Temane gas field'.

4 D Marrs, 'Cape power station likely after gas find'.

5 A Otto, Principal Energy Officer: Renewable Energy, Department of Minerals and Energy.

6 Official names include the electricity basic support services tariff (EBSST).

7 Coal is currently most widely used, as illustrated in various graphics in this chapter. In terms of the total resource, however, it is smaller than uranium and certainly than solar energy, which is renewable each year.

8 One Gg equals 1 000 tons, so multiply Gg by 1 000 to get a million tons. To adjust tons of carbon dioxide to tons of carbon, multiply by a factor of 12/44 or 0.2727.

9 Eskom reported emissions of 2 154 tons of nitrous oxide in 2001, compared to 169.3 million tons of carbon dioxide (Eskom 2002a). Converted by the Global Warming Potential of nitrous oxide, this means that nitrous oxide accounts for 0.4 per cent of CO_2-equivalent emissions, a factor that has remained constant since 1997.

10 Autogenerators are industries that generate electricity for their own use, including Sasol, sugar companies and the pulp and paper industry.

11 Updated for this book by Tim James, Energy Research Centre, University of Cape Town.

12 A debt-equity ratio of 1.00 would show equal debt and equity. In other words, only half of the liabilities of the company would be financed by borrowing (debt), the rest from other provisions such as capital development funds, loans redeemed and other capital receipts that reflect the use of retained earnings of the company to support assets. A ratio greater than 1.00 shows more reliance on debt to finance operations; below 1.00 the operations are financed from retained earnings.

13 R Chalmers, 'SA needs to invest in the generation of its electricity'.

14 R Chalmers, 'SA must get it right first time'.

15 As first mining and then manufacturing increased their influence in the economy, agriculture declined in its share of economic output, contributing 9.1 per cent of GDP in 1965, for example, but only 4.0 per cent by 1998 (NDA 2000).

16 D Banks, Remote Area Power Supply consulting.

17 US$ using 1990 prices and exchange rates.

18 A previous version of the International Energy Agency data, for 1998, showed a more dramatic difference, with South Africa at 1.81 kilograms of carbon dioxide per US$ GDP (PPP), compared to a non-OECD average of 0.70 kilograms of carbon dioxide. One reason for the difference may be a change from 1990 to 1995 as the base year.

19 GDP per capita is not directly part of the emissions profile, but a key characteristic shaping a country's ability to pay for mitigation and adaptation.

20 Reported as gross national product per capita using exchange rates, based on 1999 dollars, by the World Bank Atlas method (World Bank 2000). South Africa was ranked 86th by this method; 69th when PPP is used.

21 See note 8.

4

Options for energy policy

This chapter[1] examines the policy options that can move South Africa's electricity sector from its current position towards a more sustainable development path. While there are constraints to policy choices in the electricity and residential sectors – notably privatisation and non-negotiable policy commitments – it is possible for South Africa to shift towards greater sustainability. Policy options need to start from the current reality of energy and development (described in Chapter 3), but identify key levers that can move the sector towards a more sustainable future. Scenario planning for the electricity sector involves the creative tension between current reality and future possibility.

An essential input to the scenario modelling of the following chapters is a suite of policy options that could enhance sustainable development in the electricity sector. Scenarios (essentially combinations of policy options) will allow evaluation of the implications of electricity policy for sustainable development in all its dimensions – economic, social and environmental.

Important policy and technology choices to be examined in this chapter include energy efficiency in the near term; investing in a cleaner, more diverse fuel mix; and new industrial policies to make the economy less energy intensive over time. Different instruments falling into two broad types – economic and regulatory – can be used to achieve policy objectives. To reduce the environmental impacts of electricity, for example, taxes can be used to internalise external costs or regulatory standards can be set. Such specific policy and technology options within the broader choices are described in this chapter, laying the basis for modelling policy options in future scenarios in the chapters that follow.

Extended affordable access to modern energy services is a policy imperative which other initiatives will have to follow. As outlined in Chapter 3, affordable access to energy services has been advanced primarily through electrification, both through on- and some off-grid programmes. Any scenarios for the electricity sector will need to contribute to affordable access to electricity.

The energy policy (DME 1998a) goal of improving governance – including the introduction of competition – sets constraints for electricity policy options. Privatisation is not the only aspect of governance, but it is the one that determines the macroeconomic framework for other policies. Indeed, the role of the regulator is likely to change with the restructuring of the distribution industry, and possible privatisation on the supply side (Eberhard 2003). From licensing and setting tariffs for a virtual monopoly, the role would shift to setting rules for a competitive market. This chapter considers the prospects of power sector reform and the implications for electricity policy that promotes sustainability.

Current electricity policy shares the five major goals of the White Paper on Energy Policy (DME 1998a) (see Chapter 3 for details). Access to electricity is a particularly strong policy imperative. Future policy options for the electricity sector will be framed by governance arrangements in the sector, with the future of privatisation setting major parameters. Some of these options contribute to reducing the environmental impact of energy supply and use. Major policy shifts are possible in changing the energy economy, but are also a long-term process. Forward-looking policy will seek security by diversifying the fuel mix, examining various fuel and technology options.

Affordable access to electricity

Universal access to affordable electricity remains a cornerstone of policy for the sector and is treated as a 'given' in considering policy choices. In urban areas, close to 100 per cent of households may be connected. The challenge for the future will be to achieve universal access in rural areas, where almost half[2] of the households were still without access to grid electricity by 2003 (NER 2003d: 32). Government's commitment to achieving universal access has been reiterated in many policy speeches (Mbeki 2004a; Mlambo-Ngcuka 2002a, 2003, 2004). With the rationalisation of the electricity distribution industry (EDI), electrification will be carried out by the six new regional electricity distributors (REDs) – still combining Eskom and municipal distributors, but in a new institutional configuration. The aim is to consolidate the EDI. Cape Town launched the first RED in mid-2005, but by the end of 2006 it seemed impossible to transfer assets into the new entity, the regulator retracted the distribution licence and the city wound up RED One. Outstanding policy issues – including transfer of assets, effective leadership and the constitutional authority over 'electricity regulation' – are to be resolved by an intergovernmental forum on EDI restructuring, which will assist in drafting an EDI Restructuring Bill (Eberhard 2007).

Electrification policy

One challenge for the policy of electrification lies in the fact that the areas where electrification is cheaper – urban areas and denser settlements – were electrified first. Even in this context, electrification is not viable in financial terms (Borchers et al. 2001). As the programme reaches the 'deep rural' areas, longer distribution lines are needed to connect more widely dispersed customers with lower consumption, and the cost per connection increases. The prospects for the off-grid concessions programme, despite its heavy subsidies for SHSs, are currently not good (see Chapter 3).

Financing of continued electrification will most likely remain an important policy issue. Government has already decided that the second phase of electrification will not be funded by Eskom and channelled to municipalities, but will be paid for directly by national government departments. In principle these funds might be balanced by the taxes and dividends which the corporatised Eskom started to pay from 2003 (Eskom 2005). However, electrification will now have to compete with other social expenditure in the budget for the first time. The medium-term expenditure framework allocated R1.1 billion to electrification in 2005/06 out of a total departmental budget of R2.1 billion (DME 2004b) (see 'Policy on electricity prices, tariffs and taxes' later in this chapter). Electrification funding is smaller than planned expenditure on housing, at an average of R4.5 billion per year for 2004–07, and comparable to capital programmes for basic water and sanitation of R1 billion per year (National Treasury 2003a: 180, 226). Operation of water services, however, requires another R900 million per year.

Financing of the costs of connecting households is an issue for financial policy. Another is whether there will be ongoing subsidies for the provision of basic services. For electricity, the poverty tariff has been the primary response to affordability so far (see below and Chapter 3).

Tackling affordability

Even for households that have been connected to the grid, the affordability of using electricity remains a major issue. Since July 2001, some municipalities across the country have introduced free electricity, varying from 20 kWh to 100 kWh per month (Fowles 2004: 28). In an attempt to address the question of affordability, national government committed itself in 2003 to supplying 50 kWh of free electricity per household per month (DME 2003e).

The poverty tariff stipulates a uniform EBSST of 50 kWh at zero cost to all grid-connected poor customers.[3] While reducing the energy burden of poor households, the lifeline tariff is considered sufficient for lighting, ironing, water heating, television and radio (National Treasury 2003a), and could make cooking and heating with electricity more attractive. By subsidising the use of electricity for some basic needs, government is seeking to increase the social benefits of electrification (Gaunt 2003).

President Mbeki noted that the poverty tariff was not achieving its aims 'if the benefits of free basic electricity are accruing mainly to those who are relatively well off' (Mbeki 2005). A key challenge of a poverty tariff is identifying the poor, since means testing is administratively expensive. One policy option that has been proposed is a 'weak-grid approach' using a lower-capacity grid, for example a 2.5 A supply rather than typical urban 20 A or 60 A (UCT 2002). Such systems reduce costs by using smaller transformers, lower-capacity medium-voltage transmission and distribution (T & D) lines and local lines. The system is designed for lower ADMD (after diversity maximum demand)[4] across a whole community. While more communities can be connected for the same budget, the weak grid will only meet some energy services and not all peak demand. Other fuels, such as LPG, will be needed for cooking and heating (ERC 2004a). This is what is meant by using a broader set of energy carriers for 'energisation' rather than only electrification.

Table 4.1 *Changes in mean household expenditure on fuels with poverty tariff*

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

Source: Prasad & Ranninger (2003)

The extent to which the poverty tariff alleviates poverty depends on the energy burden (the percentage of the total household budget spent on energy). As shown in Table 4.1, the energy burden of poor households in remote rural villages can be up to 18 per cent of the total household budget. The 50 kWh provided by the poverty tariff reduced the energy burden by one-third (6 percentage points). Monthly expenditure on electricity and other fuels was found to decline by 18 per cent and 16 per cent respectively, due to the poverty tariff.

A reduced energy burden means that the poverty tariff makes sense for the economics of households. At a national level, some consideration of an economic rationale for the poverty tariff will help to make clear what the economy-wide benefits could be.

THEORY OF POVERTY TARIFF

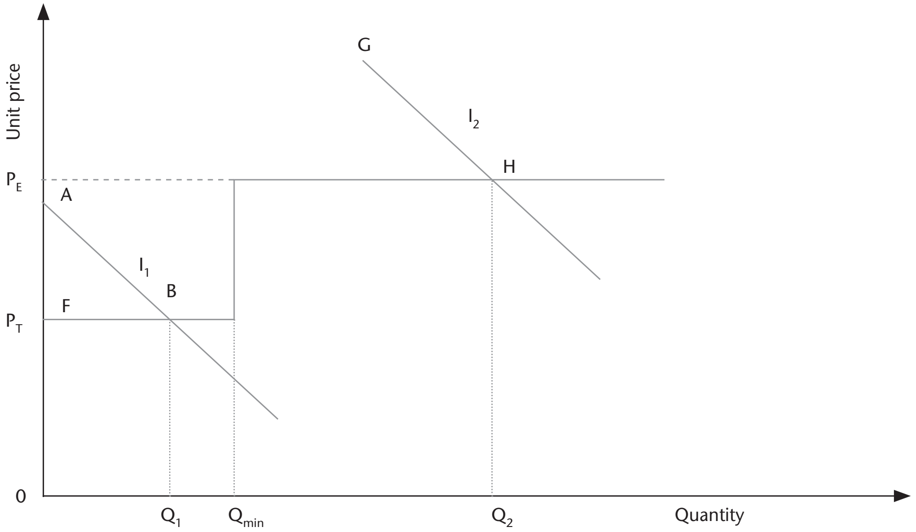
The social benefits of a poverty tariff are clear, but the level of such a tariff can be justified by using economic theory. Figure 4.1 shows two demand curves AB and GH, representative of lower-income (I_1) and higher-income (I_2) households; the poverty tariff P_T applies to the minimum consumption block from 0 to Q_{min}. If the economic tariff based on the long-run marginal cost (LRMC) is at P_E, the higher-income households will be consuming the optimal level Q_2, but the poorer households will not be able to afford the service (Munasinghe 1992).

Government attaches weight to social benefits to poor households, so the consumer surplus ABF is increased. Although A lies below P_E, the weighted distance 0A could be greater than the marginal cost of supply. Adopting the poverty tariff P_T for the first block, followed by P_E, allows the capture of the weighted consumer surplus. The richer households still consume close to optimum, apart from the slight change due to their reduced expenditure for the first block. A means of identifying the magnitude of Q_{min} should be based on criteria for identifying 'lower-income' groups and establishment of consumption levels. In developing countries, it is typically around 50 kWh per month (Munasinghe 1992). A simple welfare model suggests that

$$P_T = \text{LRMC} \times (\text{poor persons' income/critical income})$$

where critical income is a nationally established poverty line (Munasinghe 1992). In South Africa, Q_{min} has been set at 50 kWh but the tariff has been set at zero.

Figure 4.1 *Welfare economic basis for poverty tariff*



Source: Munasinghe (1992)

Funding continued electrification

Within the electricity sector, funding for both electrification and the use of electricity will remain a high priority. Direct government subsidies will have to increase as more remote areas are connected and as central government takes over funding. The National Electrification Coordinating Committee recommended that capital costs be covered within the DME budget, with income from Eskom taxes and dividends after corporatisation (NECC 2000). Operational shortfalls are to be borne by the EDI, which will initially not earn a return on electrification assets, but only provision for future refurbishment. The DME has funded the Integrated National Electrification Programme since 2001–02, with future expenditure for 2004–07 expected to be around R1.1 billion per year, and R600 million in the 2007/08 budget.[5] Transfers are made to Eskom and conditional grants will be allocated to municipalities, with responsibility for the latter shifted to the Department of Provincial and Local Government in 2006–07 (DME 2004b).

Historically, Eskom has played an important role in distribution and effectively funded the first phase of electrification (Borchers et al. 2001). With funding in future coming from National Treasury, Eskom will remain responsible for electrification in its supply areas and will receive a grant (National Treasury 2003a). However, the relationship between municipalities and Eskom was formalised in service-level agreements from 2003 onwards (National Treasury 2003a). These agreements give effect to municipalities' role as service authorities and regulate Eskom's activities within their areas.

As the price of electricity is expected to rise in future – with new capacity soon required and restructuring and/or privatisation imminent – the affordability of using electricity is likely to become an even greater issue. With the restructuring of the distribution industry, REDs will be required to undertake local integrated resource planning (IRP) – and if they supply small customers who cannot negotiate tariffs, they will also have to show increases in tariff over the next five years (NER 2002b).

Government has allocated R300 million for the poverty tariff nationally as part of the local government equitable share of nationally raised revenue (National Treasury 2003a: 233). The equitable share allocation contains an energy component (DME 2004c), but the funding is unconditional and is typically absorbed into the general municipal income pool (Fowles 2004). The largest transfer from national to local government is for a Consolidated Municipal Infrastructure Programme; electrification falls into the second-largest group, making up 41.9 per cent of the 'S grant' (R228 million out of an equitable share of R7 698 million for 2005–06) (National Treasury 2003a: 38–39). Funds will be allocated to municipalities, which allocate funds to deliver services to poor households (National Treasury 2003a). Where Eskom is the distributor, the municipality is invoiced at a rate of 34.5c per kWh (excluding VAT), a rate lower than the standard 'Homelight' tariff (Fowles 2004: 27). Eskom will provide 50 kWh only to customers using a 20 A supply and who consume less than 150 kWh per month (Fowles 2004: 27).

How poor households are identified varies across municipalities, with one proposal being self-targeting – consumers agreeing to use a reduced 10 A level of supply (UCT 2003) – the other requiring municipalities to identify indigent households (Fowles 2004). Government considered both approaches, as well as a broad-based approach where all households would receive the benefit (DME 2003e). The average cost of 50 kWh of free electricity is about R25 (National Treasury 2003a: 233), depending on tariffs.

Affordability is obviously shaped by electricity prices. Electricity prices (or tariffs) have been strongly regulated in the past. The further the sector goes along the path of privatisation, the more prices should be set by supply and demand. The extent to which markets should play a role in energy governance is a major policy issue in its own right – the debate around privatisation in the energy sector.

Energy governance – to privatise or not?

Reform of the electricity industry has been a major policy issue for the last decade globally. If carried through to its full extent, it would reshape the context in which all electricity policy takes place. Before considering the impacts of privatisation on environmental and social benefits (such as affordable tariffs), the chapter first outlines what privatisation is and why it is on the agenda.

Privatisation[6] of the electricity industry relates to generation (producing electricity at power stations), transmission (at high voltage over long distances) and distribution (at lower voltage over shorter distances) of electricity. The process aims to increase competition by changing industry structure to include both more generators (wholesale competition) and more distributors (retail competition).

The debates extend well beyond the electricity sector, with the restructuring of state-owned enterprises in transport, telecommunications and defence also being reconsidered (Erwin 2004; *Mail & Guardian* 14–20 May 2004[7]). Broader ideological debates on the role of markets and the state influence the debate on restructuring in the power sector (Bond 2000). The South African debate on reform of the electricity industry feeds into a broader international discussion on the advantages and disadvantages of power sector reform, particular its effect on the poor (Dubash 2002; Jannuzzi 2005; Johannson & Goldemberg 2002; Karekezi & Kimani 2002; TNI 2002; Wamukonya 2003a). The results of power sector reform in other parts of Africa have been mixed at best (Clark 2001a; Turkson 2000; Wamukonya 2003b).

While there are positive motivations for power sector reform, there is also substantial opposition to privatisation in South Africa. Municipal government has objected to restructuring, fearing loss of revenue and citing their constitutional rights to distribute electricity (NER 2001b). The unions have been arguing strongly that the state should retain a role in development, in particular in sectors delivering basic services (COSATU 2001). While the blueprints for privatisation make provision for continued electrification (PWC 2000), the fact that connections have not been financially viable in the past makes their future in a highly competitive environment uncertain. Electricity consumers have raised an important concern about rising electricity prices, with tariffs set to increase anyway as new capacity needs to be financed.

Policy on privatisation is not fixed. The liberalisation agenda so strongly promoted at the beginning of the Gear macroeconomic framework may not be realised, or only partially (Streak 2004). More recently, the emphasis has returned to the 'developmental state', including its role in the economy and in public service delivery (Fakir 2007; Swilling et al. 2008).

In practice, power sector reform has proceeded piecemeal. On the supply side, Eskom has been corporatised. The Eskom Conversion Act (No. 13 of 2001) gave effect to the commercialisation and corporatisation of Eskom. Eskom is to be run more like a business, subject to performance contracts. While still wholly owned by government, the corporation will now pay taxes and dividends. Transmission remains a 'natural monopoly, to be run by a separately owned state company. The electricity *distribution* industry is in need of reform, due to several problems' (Clark 2001a: 127–128). A key issue is the lack of financial viability, with many municipalities close to bankruptcy and not paying Eskom for bulk supplies (NER 2001b). As noted earlier, the first RED – RED One – was launched in Cape Town in mid-2005.

Policy on privatisation sets an important framework for future policy options in the residential and electricity sectors. If power sector reform is not to undermine sustainability, public benefits (both environmental and social public goods) need to be maintained or enhanced. Policy has been proposed to continue funding for electrification as a major social benefit in a liberalised electricity supply industry (Clark & Mavhungu 2000). In the context of the swing back to the notion of the developmental state (see Chapter 3), full retail competition in the electricity sector has been emphasised less, with AsgiSA focusing instead on a large-scale state-led infrastructure development programme (AsgiSA 2006; National Treasury 2005).

The impact on managing energy-related environmental effects is ambivalent (Winkler & Mavhungu 2001). On the one hand, privatisation opens up the market to IPPs, some of which may use renewable energy sources (for example, the Darling wind farm, DARLIPP). On the other hand, private investors are arguably less likely to invest in RETs due to their higher upfront costs. Policies to promote renewable IPPs include standard contracts for IPPs and non-discriminatory access to the grid (Dubash 2002).

Managing energy-related environmental impacts

The major environmental impacts associated with energy in general were outlined in Chapter 3. Electricity in particular is associated with impacts of outdoor air pollution in the local environment, and emissions of GHGs which contribute to global climate change (Van Horen 1996b). Other issues relate to water consumption in the coal cycle, as well as fiscal subsidies and other impacts of the nuclear cycle (Spalding-Fecher, Afrane-Okese et al. 2000). Significant *positive* externalities are improved health from reduced indoor air pollution, which adds to the socio-economic benefits of electrification (Spalding-Fecher & Matibe 2003). Table 4.2 classes the major impacts as Class One (serious and measurable), Class Two (potentially serious but not readily measurable) and Class Three (unlikely to be serious).

Table 4.2 *Externalities associated with electricity supply, by class*

	Class One	Class Two	Class Three
Coal cycle			
Air pollution and health	*		
Air pollution and acidification		*	
Air pollution and visibility		*	
Water quality impacts			*
Water consumption and pricing		*	
Nuclear cycle			
Fiscal subsidy			*
Other impacts (risk of accidents, waste)		*	
Electrification			
Health benefits	*		
Socio-economic benefits		*	

Source: Spalding-Fecher & Matibe (2003)

South Africa's GHG emissions are high by international comparison, both per person and in proportion to economic output (see Table 3.7). Similarly, energy intensity is relatively high. Both of these realities are recognised by government (DME 2003d; RSA 2003). Policy instruments need to be applied to minimise the environmental impacts of electricity generation.

Regulatory policies

Some policies to manage the impacts of electricity supply have been discussed in the sections above. Cleaner coal technologies can produce more electricity for the same amount of coal burned and therefore the same level of emissions. More efficient use of electricity (see later in this chapter) reduces demand and hence indirectly also emissions.

Standards can be set to directly address impacts of coal-fired electricity on outdoor air pollution. The initial development of regulations for national ambient air quality standards focused on sulphur dioxide (RSA 2001), which would necessitate the use of FGD. Technical standards are being developed for common local pollutants (sulphur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, ozone, lead, benzene and dust), volatile organic compounds and air toxics (Standards SA 2005a). The framework for regulation establishes *limit values* which are to be attained over a period of time; lower *target values* which should be attained through long-term planning to minimise impacts on environmental health; and higher *alert thresholds*, beyond which there is an immediate risk to human health from brief exposure (Standards SA 2005b). 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 GHGs. The Act includes mechanisms in domestic legislation that can be used to implement international obligations as well, by listing priority pollutants and activities, as well as requiring pollution prevention plans to be submitted and controlling the use of certain fuels.

Another end-of-pipe solution, carbon capture and storage, may become an option for policy-makers in the longer term (IPCC 2005). All these options reduce the levels of pollution *per unit of electricity*, but this might still lead to rising emissions depending on the rate of growth of total electricity demand.

Standards for GHG emissions – which are not included in the national ambient air quality standards – would be one policy approach, in which case direct caps on power stations and other point sources might be more cost-effective. Domestic emissions trading schemes could be set up as ‘cap and trade’, allowing polluters to either meet targets in their own facility or sell excess reductions or buy from others to meet shortfalls.

As with other technologies, a key policy question is who pays for incremental costs, given that many advanced technologies have higher upfront capital costs than conventional coal. While government requires utilities to make investments, costs will ultimately be passed on to consumers. As outlined in Chapter 3, low tariffs are a major energy policy priority, both for industrial competitiveness and to widen access to electricity. Dedicated funding mechanisms are needed, with one possibility being the recycling of revenue from environmental taxes on energy use.

Funding options

A source of funding receiving much attention is the CDM under the Kyoto Protocol. The CDM allows industrialised countries to invest in projects in developing countries, in return for the emissions reductions generated. Industrialised countries use these credits towards their quantified mitigation commitments under the Protocol, while the CDM project should contribute to sustainable development in developing countries. CDM investment is seen by the South African government as an important source for funding the implementation of the renewable energy target. The scale of funds allocated for CDM investment internationally had reached US$800 million by 2004 (Ellis et al. 2004), but the funds are to be spent over several years. What share of such investment will come to South Africa remains to be seen and depends in part on the promotion of the country as an investment destination.

Use of economic instruments such as emissions trading and taxation would generate more financial flows that are more directly linked to the scale of emissions in the country. Domestic emissions trading would result in trading of certificates between facilities included under the cap. An alternative policy option is tradable permits for electricity from low-emission sources, such as the Tradable Renewable Energy Certificates (see later in this chapter). In this case, it is the 'good' of clean electricity that is traded, rather than the 'bad' of emissions.

Pollution taxes

Taxes could be levied either on GHG emissions (a 'carbon tax' as implemented in some European countries) or on air pollutants. There has been some initial consideration of environmental taxes by National Treasury, including a focus on electricity. A carbon tax in principle internalises the externalities of GHG emissions; a pollution tax may be more politically acceptable. An air pollution tax could be associated with the regulatory framework established by the Air Quality Act (No. 39 of 2004). It would have the effect of making coal energy-intensive products more expensive, and thus send price signals through the economy that a shift to less pollution-intensive production and consumption is favoured (EDRC 2003a).

The risk of a tax on pollution, however, is that it could disadvantage the poor. In principle, South Africa might follow the Dutch example of using a consumption threshold to protect low-income groups from proportionally higher tax burdens (Nedergaard 2002). Given the policy objective of promoting *affordable* access to modern energy services, this is critical in South Africa. Another means of dealing with the tension in policy objectives would be to recycle revenue generated from pollution taxes, directing it toward reducing the general tax burden on the poor (for example, reducing VAT on basic foodstuffs) and promoting investment in cleaner technologies and services (Winkler 2005). Recent analysis suggests that a reduction in food prices may pay 'triple dividends' in mitigating the unwanted effects of environmental taxes (Van Heerden et al. 2006).

The tax should reflect the damage costs of power generation, and industrial, commercial and agricultural use of fuels. From an economic point of view, the tax should be set so as to adjust the private marginal cost to the social marginal cost. In practice, the tax may be adjusted based on negotiations between government and various stakeholders, and in response to the observed effectiveness of the tax.

A considerable amount of research has been devoted to estimating the social and environmental costs of energy supply and use in South Africa (Spalding-Fecher 2000b; Spalding-Fecher & Matibe 2003; Spalding-Fecher, Williams et al. 2000; Van Horen 1996a, 1996b). Such research faces serious difficulties – absence of local epidemiological studies establishing dose-response relationships; controversies about the 'value of a statistical life'; broad estimates for morbidity. Nonetheless, the most recent power sector study (Spalding-Fecher & Matibe 2003) summarises low, central and high estimates of local and global pollution (see Table 4.3).

Table 4.3 *Summary of external costs of Eskom coal-fired electricity generation per unit*

	Per unit of coal-fired power produced		
	Low	*Central*	*High*
Air pollution and health	0.5	0.7	0.9
Climate change	1.0	4.3	9.8
Total	1.5	5.0	10.7

Notes: Unit = 1999 c/kWh
This excludes the benefits of electrification from avoided use of dangerous household fuels.
Source: Spalding-Fecher & Matibe (2003)

Externality costs for energy consolidated as damage estimates per unit of pollutant were reported more fully by the Energy and Development Research Centre (EDRC 2003a), including damages from Eskom power stations, industrial and commercial energy use, household energy use and municipal power stations.[8] Cost estimates of negative externalities such as those described above can be used to set a reasonable level for a pollution tax.

Economic instruments such as taxes and subsidies are important tools for managing the environmental impacts of electricity supply. The next section further considers the use of such instruments, as well as the contribution that future electricity policy can make to economic development.

Economic development and instruments

Economic policy sets the overall context for electricity policy options. At the same time, policy-makers can make use of economic instruments to promote particular policy objectives. Changes to electricity prices – such as taxes or subsidised tariffs – are examples of market-based policy tools. Beyond individual policy interventions, however, lies the question of the energy structure of the economy and its intensive use of electricity in particular.

Changing the energy structure of the economy

Chapter 3 outlined the history of the South African economy, with the 'minerals-energy complex' at its centre. Driven in part by low-cost coal and electricity, energy-intensive industries make up a large portion of the economy – mining itself, but also the beneficiation of minerals.

Policy on industrial development has promoted electricity-intensive investments, such as the smelting of aluminium at Coega or steel at Saldanha. Low electricity tariffs for industry are seen as a competitive advantage in attracting aluminium smelters to South Africa rather than to other countries (Bond 2000). The marketing of investment opportunities highlights the availability of electricity at 'very favourable rates' as one of the attractions (CDC 2004). In the context of the electricity shortages of 2008, the sustainability of this policy is now being more widely questioned.

The risk of the current approach is that, while it may promote industrial development in the short run, it carries a high risk of 'locking in' the economy into energy-intensive industries, when environmental, economic and social pressures may push South Africa in the opposite direction (Spalding-Fecher 2001). The reason for the 'lock-in' effect is that, once a major investment like a smelter is made, there are very limited opportunities to improve the energy efficiency or the production process. Recent investments in steel and aluminium bear this out – while the processes may be optimised for that technology, the wholesale switch to a more efficient technology is very costly after construction (Visser et al. 1999).

Forward-looking economic and industrial policies could target less energy-intensive economic sectors. 'An active industrial policy is required to diversify the economy forward from South Africa's mineral-energy complex into capital and intermediate goods' (Michie & Padayachee 1998: 634). This would represent a major shift in industrial policy and would take decades to complete, given large investments in infrastructure. Such a change would have to be integrated into the Department of Trade and Industry's National Industrial Policy Framework and Action Plan (DTI 2007a, 2007b).

However, given the 'lock-in' effect, short-term decisions (the next power station, the next smelter or not) are critical in changing the trajectory of South Africa's energy development path. 'Bending the curve' requires a long-term perspective, but also involves policy changes in the immediate future (Raskin et al. 1998).

What interventions might shift the South African economy to less emissions-intensive sectors? Five possible strategies have been examined elsewhere (Winkler & Marquard 2007), but are summarised here. The first strategy would be to adjust state incentives (including industrial incentive programmes and special dispensations on low electricity prices) to avoid attracting further energy-intensive investments on terms which would severely restrict future mitigation options, and shift these incentives to lower carbon industries. Secondly, South Africa might focus its mitigation efforts on non-energy-intensive[9] sections of the economy, assuming that their international competitiveness would suffer less. Thirdly, however, the energy-intensive sectors themselves should not be ignored – they would be required to reduce their energy intensity while protecting employment. This third strategy would require a combination of reviewing existing policy promoting beneficiation, specific energy-intensity targets, international negotiations on best location for such industries, and diversification within these sectors (Winkler & Marquard 2007). The fourth strategy might be economic instruments, such as a carbon tax or domestic emissions trading, which would be expected to affect the energy-intensive sectors most strongly. Fifth, the focus of industrial policy and investment strategy could shift to less energy- and emissions-intensive sectors of the economy.

The aim of these strategies would be to protect South Africa's competitive advantage in the short and medium terms, while aiming to build other competitive advantages in the long term. The tariffs paid by energy-intensive users, particularly for electricity, are closely related to such efforts.

Policy on electricity prices, tariffs and taxes

Electricity tariffs in South Africa have been low by international standards, although not necessarily affordable to all customers. There are multiple reasons for low tariffs, as described in Chapter 3, including excess capacity, low debt and tariffs that do not reflect all costs, certainly not external costs. The short-term marginal cost of generating electricity has been low and large customers have paid tariffs of around 13 or 14c per kWh – industry 12.88c per kWh, mines 14.14c per kWh and redistributors (mainly municipalities) 14.09c per kWh (Eskom 2002b: 135). Residential tariffs are higher per unit, at an average of 33.43c per kWh in 2002 (Eskom 2002b: 135). Tariffs are likely to increase in future as new electricity-generation capacity is needed (Eberhard 2003).

However, higher tariffs are in tension with the established policy goal of keeping electricity prices low. In reiterating the policy position of universal access to electricity, the president qualified it with an acknowledgement that new power plants are needed and the concern that 'administered prices do not unnecessarily add to the general costs of production and inflationary pressures in our economy' (Mbeki 2004a). The energy minister also reflected the tension that while the 'progressive rise of energy prices cannot be avoided South Africa still intends to keep low electricity prices' (Mlambo-Ngcuka 2003). With the 2008 electricity crisis, Eskom applied initially for a 14 per cent increase in tariffs and then for an effective 60 per cent increase.

Different drivers of tariff policy work in opposite directions, some favouring price increases and others keeping them low. The National Electricity Regulator (NER), which regulates electricity tariffs, aims at multiple objectives in developing a pricing policy for the future. Such a policy 'must balance affordable electricity prices for households, low cost electricity for industrial consumers, efficient market signals by accurately reflecting cost of supply and generate a price level that ensures the financial sustainability of utilities' (NER 2003b: 5). The first two priorities aim to keep prices low, whereas the latter two could raise tariffs.

One of the key motivating factors to keep electricity prices low is affordability of residential tariffs for poor households. Continued electrification makes little sense if customers are not able to afford using their connections. Government is subsidising some limited use through the poverty tariff, effectively setting the price of the first 50 kWh to zero. The second main driver is industrial competitiveness and the policy of attracting energy-intensive industry.

In future, electricity prices are likely to be pushed upwards, as the building of new generation capacity will raise the cost of supply. A study considering the potential of renewable energy predicted a future average tariff of 24c to 40c per kWh by 2010 (DME 2000a: 18). While previously the NER had kept increases of electricity tariffs below inflation, Eskom has since 2001 applied for above-inflation increases (*Business Day* 10 May 2001[10]), although these have not always been approved.

While competition theoretically should reduce prices, international experience has generally been that privatisation has often led to higher prices (Dubash 2002). In the South African context, the corporatisation of Eskom already requires payment of taxes and dividends, costs that will eventually be passed on to customers. Without the financial cover that Eskom enjoyed as a parastatal, private investors are likely to have higher financing costs and to expect higher rates of return than typical in public sector investment.

If the privatisation process extends to retail competition, some customers (contestable customers) would be eligible to choose the company from which they purchase electricity (PWC 2000). Contestable customers are defined as those using more than 100 GWh per year.[11] Once competition between generators is established, these customers could be supplied by any distributors. Smaller customers are confined to the distributor into whose area they fall and are known as captive customers. They are unlikely to benefit from competitive supply and hence require regulatory protection through control over tariffs and quality of service (PWC 2000).

Policy options for future electricity tariffs will have to make choices in resolving the tension between maintaining low tariffs for energy-intensive users, and internalising some costs of supply and raising prices. A wholesale electricity pricing system (WEPS) has been developed for large customers such as municipalities and energy-intensive industries (Ellman 2001). The first phase of WEPS was implemented within Eskom by 2003 (Eskom 2003), with the second phase to be extended to other wholesale customers (including municipalities). WEPS-3 is to be introduced when Eskom is unbundled and REDs have been established (NER 2003c). Previous tariffs have not been cost-reflective and cross-subsidies have been implicit and not transparent.

The WEPS takes a cost-of-supply approach, unbundling the electricity bill of wholesale customers into direct costs (for example, energy, networks, transport, reliability) and more indirect costs (taxes, levies, billing, administrative costs) (NER 2003c). If wholesale customers were to buy at cost-reflective tariffs, their current contribution to cross-subsidies could stop (NER 2003c). Moderately subsidised tariffs are needed for poor households to benefit from electrification (NER 2003b).

A major objective of WEPS is to make cross-subsidies transparent. Cross-subsidisation of tariffs includes geographic considerations (higher costs for transmitting electricity), subsidies across different tariffs and within tariff classes (averaging), and electricity levies (NER 2003c). Large customers will continue to pay their electricity levies for electrification and electricity supply to rural areas (NER 2003c). Thus the WEPS falls within the overall NER pricing policy, which seeks to balance the long-term sustainability of suppliers, affordable prices for the poor and cost-of-supply pricing for industrial customers (NER 2003b). Establishing a tariff agreement forms part of government's programme of action (RSA 2005).

Policy instruments to internalise the social and environmental costs of electricity generation would be taxes or subsidies (Spalding-Fecher 2000a; Spalding-Fecher, Afrane-Okese et al. 2000; Van Horen 1996a, 1996b). Taxes could be levied either directly on air pollution or on energy to include the external costs of fossil fuel use in the fuel price. Carbon and pollution taxes have been extensively implemented in Europe, but have also been proposed for South Africa (EDRC 2003a). Taxes on local air pollutants may be more politically acceptable in developing countries than a carbon tax, since responsibility for climate change rests primarily with industrialised countries. Given the central role of energy in development, there may similarly be reluctance to tax energy for global environmental reasons. Taxes that relate more directly to local environmental damage, such as the health impacts of air pollution, address local concerns more directly (EDRC 2003a). In order not to place an increased burden on poor households, they could either be exempted from such taxes or the tax revenue could be recycled to reduce other taxes affecting the poor. Examples would be zero-rating of VAT on essential foodstuffs or financing the poverty tariff.

Initial work has been conducted for the National Treasury on environmental fiscal reform (Eunomia & UP 2004) and a discussion document was developed (National Treasury 2003b). An internal government policy paper was released for public comment in 2006 (National Treasury 2006). The initial documents suggest that the energy sector is likely to receive attention in future developments, particularly in relation to electricity generation and air pollution. An input tax on fossil fuels used for electricity generation may be considered, as might an electricity consumption tax. Such taxes would be likely to generate significant revenues, larger than the loss in sales revenue to Eskom. Net revenues could be used to compensate municipalities for their lost revenues under restructuring; to support transitions of affected sectors; or to promote specific projects with environmental benefits, such as end-use energy efficiency and renewable energy. Of particular interest are 'tax shifting' programmes that use revenues from environmental taxes to offset taxes on labour. Taxes would have to be levied at the bulk level and explicitly exclude poor households (EDRC 2003a; Nedergaard 2002).

Recent analysis using a computable general equilibrium (CGE) model to analyse environmental taxes on energy investigated the potential for recycling. Four taxes considered were on GHGs, fuel inputs, electricity use or energy. Revenue recycling could occur through one of three ways: i) a direct tax break on both labour and capital, ii) an indirect tax break to all households, or iii) a reduction in the price of food. The analysis concluded that with a 'food tax handback', all four taxes had the potential to reduce carbon dioxide emissions, grow GDP and reduce poverty (Van Heerden et al. 2006). However, in establishing an updated GHG inventory, the authors depart from the standard IPCC methodology and rely entirely on energy balances. Future work should combine the analysis in this book with the complementary work in the article by Van Heerden and colleagues, improving the rigour of GHG analysis while adding the benefit of indirect economic effects from CGE modelling.

In summary, tariff policy in future faces the choice of either continuing to promote low-cost electricity or making the services more reflective of costs – financial, social and environmental. A variety of other economic policy instruments are available, including subsidies for renewable energy (described later in this chapter) and policies promoting efficiency in electricity use.

Policies promoting the efficient use of electricity

In meeting the goal of the 1998 White Paper on Energy Policy of stimulating economic development, energy efficiency plays a particular role. Energy efficiency and economic concepts of the efficiency of the market are quite distinct (Jochem 2000). Yet clearly, producing higher levels of energy efficiency allows more economic production for the same amount of energy. By reducing the costs of a key input to many productive activities, efficiency contributes to economic development. Some of the policy options available to promote electricity efficiency are outlined in this section.

There is great potential for energy efficiency in South Africa across a range of sectors, from industry, commercial and transport to residential. Interventions for energy efficiency in the residential sector can contribute significantly to development for households – improved quality of life at reduced cost (Clark 1997; Simmonds 1997; Spalding-Fecher et al. 1999; Winkler, Spalding-Fecher, Tyani & Matibe 2000). The residential policies analysed in this book (see Chapters 6 to 9) will examine the potential for savings in the framework of a national energy model.

Significant savings are also possible in the industrial sector, both through end-use efficiency and load management (see Table 4.4). The NER included estimates of potential future savings in its Integrated Electricity Outlook (NER 2002c) and Integrated Resource Plan (NER 2004a). Savings from energy efficiency are expressed as equivalent cumulative electricity-generation capacity that would be avoided by efficiency programmes up to 2010 and 2020. Since the market penetration of energy efficiency is critical to the results, estimates reflecting different assumptions are summarised.

Table 4.4 *Potential future savings from energy efficiency and demand-side management*

	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

Note: Cumulative capacity equivalent in MW.
Source: NER (2002c)

Experience exists with innovative technologies and programmes for energy efficiency and demand-side management (DSM). Eskom's DSM programme has focused on three key areas: load management, typically carried out by the utility; industrial equipment; and efficient lighting. Energy efficiency improvements are typically made by end-users. More detailed technologies and policies for electrical efficiency are examined below.

ENERGY EFFICIENCY IN LOW-COST HOUSING

Many interventions can be introduced in low-cost housing to improve energy efficiency, save households money and improve the environment (Spalding-Fecher, Clark et al. 2002). A possible package of interventions in a standard 30m^2 RDP house could include a ceiling, roof insulation, wall insulation, window size, and partitions. All of these measures pay for themselves in short periods of time (Winkler, Spalding-Fecher, Tyani & Matibe 2000).

Several government departments have for some time been investigating a framework for regulation of environmentally sound building (DEAT et al. 1998). A recent decision to include an additional R1 024 for damp-proofing in the housing subsidy may have the effect of providing more efficient cavity walls, plastering and ceilings. The additional subsidy applies in the 'Southern Condensation Area', covering large parts of the Western and Southern Cape and some of the Eastern Cape. An extension of this policy is modelled in Chapter 5 and Chapter 8 picks up the policy implications of making standards mandatory.

BUILDING CODES FOR COMMERCIAL AND RESIDENTIAL BUILDINGS

Policy support for energy efficiency in buildings need not be limited to low-cost housing. Residential and commercial building codes can require higher efficiency standards in middle- and upper-income houses and commercial buildings. Since wealthier customers can afford to pay the upfront cost to benefit from the long-term savings, regulation can be used rather than outright subsidy. The government may still consider options for financing the initial costs through concessionary loans. Local governments could finance efficiency measures and recoup the outlay by structuring tariffs to include the saved energy costs as repayments.

Concessionary loans for efficient industrial equipment

Industry, like richer households and commercial buildings, should be able to invest in more efficient use of electricity. Measures often pay back within periods of months or a few years (for case studies, see ERI 2000a) and have significant potential for job creation (Jeftha 2003). Lack of awareness and information is a key barrier that could be overcome by programmes promoting energy efficiency. Technical interventions with large potential for energy-efficiency savings across many industries include variable speed drives, compressed air and HVAC (heating, ventilation and air conditioning) systems (ERI 2000b).

The overall potential for greater efficiency of electricity use in industry is large (Spalding-Fecher et al. 2004). A study using an input–output model of the South African economy has shown that a 5 per cent increase in electricity efficiency in 2010 would lead to a net increase of some 39 000 jobs and labour income of about R800 million (Laitner 2001). The primary reason is that spending is diverted away from sectors with lower wage and salary multipliers towards construction, finance and manufacturing, which have higher income multipliers. The study did not specify particular equipment to be replaced, but gave a sense of the benefits of across-the-board efficiency improvements.

Industrial equipment still bears a higher upfront cost, and while government may not need to pay for capital costs in full, concessionary finance can make investments more attractive. Concessionary loans would offer lower than commercial repayment rates, and be used to introduce more efficient technologies and production facilities. The focus of such a policy should be on the most electricity-intensive equipment and industrial process. Loans in the range of 10 to 20 per cent of the incremental capital would likely be enough in many cases to tip the balance in favour of energy-efficiency investments (EDRC 2003a).

Efficient appliances

A first step to promoting the use of more efficient electrical equipment is to provide information to users through labelling. Household appliances that might be labelled include lighting, refrigerators/freezers, air conditioners, water heaters (electric or gas), cooking equipment, washing machines and dishwashers, and electronic equipment like televisions, stereos and computers. Commercial equipment includes HVAC systems, water-heating systems and electronic office equipment like computers, printers and copiers.

Equipment labelling involves indicating a certain performance standard on the equipment, based on pre-testing appliances for their efficiency, and may include estimated operating costs. Appliance labelling can be a voluntary programme, where government develops the guidelines and testing procedures but companies choose whether they wish to use the label. Labelling could also be mandatory: all products would have the label, but with or without restrictions on their efficiency.

The most stringent approach would be mandatory labelling together with prescribed minimum performance standards for all new appliances. Regulations would specify performance for different kinds of appliances and equipment and restrict the use of any that fail to meet the prescribed standard.

Using financial incentives rather than regulation, government can offer tax credits or direct subsidies to taxpayers for installing efficient electrical appliances. Financing – either in the form of direct subsidies or small-scale, affordable loans – for equipment and technical upgrades could be provided (EDRC 2003a).

Smaller appliances – for example, compact fluorescent lights (CFLs) – have lower first-cost barriers to overcome than buildings. Nonetheless, prices need to be brought down. This has already happened to some extent under Eskom's Efficient Lighting Initiative, which installed 18 million CFLs by 2003, supported by a $15-million grant from the Global Environmental Facility (ELI 2005: 1). Municipal government can play a key role in promoting the continued dissemination of CFLs, which reduce the power used for the same lighting by 75 to 80 per cent.

Promoting solar water heaters

A solar water heater (SWH) delivers hot water from a renewable energy source, saves energy by displacing use of electricity and therefore avoids emissions. It combines energy efficiency and use of renewable energy. The potential for SWHs is large, as acknowledged in the White Paper on Renewable Energy, which assesses the savings as 18 per cent of urban residential consumption[12] or equivalent to a large coal-fired power station (900 MW) (DME 2003c).

However, SWH projects have not been widespread, with the only significant project being in Lwandle township near Somerset-West (Lukamba-Muhiya & Davidson 2003; Thorne et al. 2000; Ward 2002) despite support from the Global Environmental Facility being available for a national solar water heating programme (DME 2001a).

Models of delivery other than grant-funded development projects are possibly needed. Electricity service companies might instal SWHs in institutions (for example, hotels) in return for a fee for the hot water service. In middle- and upper-income markets, financing for the higher upfront cost could be facilitated through bonds. A barrier remains low public awareness of the technology or its economic benefits (DME 2003c). Policies are needed to create larger markets and economies of scale, which would help bring down the relatively high capital costs. A larger market for SWHs in turn could build a local manufacturing industry and increased employment opportunities (DME 2003c).

ENCOURAGING UTILITY DSM

DSM encompasses a set of measures by electric utilities that save energy and also reduce GHG emissions. Strategic growth of off-peak demand, load shifting, geyser ripple control, interruptible load agreements, time-of-use tariffs and other measures enable DSM in both the industrial and residential sectors. The utility benefits by reducing the peaks of consumption ('shaving the peak'), so reducing the need for installed capacity. DSM can benefit the national economy by delaying the need to invest in supply-side capacity, at a lower cost.

Eskom has a DSM programme, but further measures are needed to promote investment in these technologies and to ensure that they continue as the EDI is restructured (Clark 2000b, 2001b). The structure of tariffs is important in this regard.

Regulated tariffs often link energy sales (kWh) with utility revenues and profits, with little incentive for the utility to engage in DSM. Eskom is not an exception in this regard, with the DSM programme battling against the perception that it represents lost revenue. Tariffs can be structured differently, de-coupling revenue from sales and linking them to some other measures of service (EDRC 2003a).

If implementation of efficiency programmes was linked to revenue, this would directly encourage investment in DSM measures. In the United States, many state regulatory boards chose in the 1980s to base utility profits on a return on capital invested, including demand-side capital, rather than on a margin on each unit sold (Eto et al. 1998; Swisher et al. 1997). Utilities that can show efficiency improvements may be allowed to earn higher profits and/or a higher rate of return. In the design of this system, it is important that the DSM incentive is not offset by a rate formula that rewards increased sales. In other words, the incentive only works where revenues, not tariffs, are subject to regulated caps (EDRC 2003a).

Such regulatory policies may be needed to promote energy efficiency under power sector reforms, since privatised utilities have little incentive to invest in measures that reduce their sales revenue (Barberton 1999; Clark & Mavhungu 2000; Tyani 2000). Regulatory policy can make energy-efficiency investment a licensing requirement. The REDs, for example, could be required by the NER to implement DSM, which would be consistent with the Framework for Integrated Resource Planning (NER 2002d).

TURNING THE POTENTIAL OF EFFICIENCY INTO PRACTICE

While the more efficient use of electricity has great potential, achieving widespread implementation requires effort. Theoretical gains are not always realised in practice, for either technical or economic reasons. A 'rebound effect' is often observed, where increased efficiency makes the service cheaper – and hence firms or households demand more of the service (Greening et al. 2000; Herring 2006; Roy 2000; Schipper 2000). Total energy consumption decreases less than the technical potential. Removing key barriers – informational, institutional, social, financial and market, and technical – is critical to the full realisation of energy-efficiency measures

(EDRC 2003a). Important success factors to implement efficiency measures include government policy (standards, incentives, recovery of programme costs), electricity pricing mechanisms that do not penalise efficiency, and the effectiveness of DSM delivery agencies (NER 2002c).

To put the wide variety of energy-efficiency measures together in a policy framework, the DME recently published an Energy Efficiency Strategy. The strategy set a goal for an improvement in energy efficiency of 12 per cent by 2014 (DME 2005a: 2). While the DME document covers all energy, the NER has approved policy for efficiency in the electricity sector in particular, with an energy efficiency and DSM policy. However, the policy does not set specific numerical targets. Its focus is on captive customers (that is, small customers), under the assumption that large contestable customers will respond efficiently to price signals (NER 2004b).

Energy-efficiency measures such as those outlined in this section are critical near-term measures. Because they save energy costs and pay back on their investment in short periods, they can be adopted quickly. Changing the fuel mix that generates electricity is a long-term endeavour. Yet increasing diversity of supply not only gives greater energy security, it is central to long-term sustainability.

Securing electricity supply through diversity

Environmental concerns relate directly to another major energy policy objective, that of securing supply through diversity. As described in Chapter 3, the current fuel mix for electricity generation is heavily dominated by coal. Moving to a more diverse mix of electricity-generation sources can both increase energy security – since diverse systems are more resilient to external shocks – and at the same time reduce the environmental impacts of electricity supply and use.

Cleaner fuels have less environmental impact, for industrial use as well as for electricity generation. In 2003, the government adopted a new policy paper on renewable energy (DME 2003c), with earlier drafts indicating that a further policy position on other 'cleaner energy technologies' was to be developed. The government has made it clear that it intends using all energy sources and not choosing winners among technologies (Mlambo-Ngcuka 2003).Which technologies are used will shape the electricity sector for several decades, given the long lifetimes of energy technologies.

The excess capacity that the electricity sector experienced in the last three decades of the twentieth century is ending (see Chapter 3). Winter of 2006 saw an initial set of shortages in the Western Cape (AEJ 2006), but it was indeed 2008 that saw the arrival of the electricity crisis, prompting the DME to issue a national response (DME 2008a). Much of the short-term response needs to focus on using less energy and using that efficiently, as reflected in regulations published for comment on mandatory energy conservation and efficiency (DME 2008b). Such short-term responses need to be implemented in a manner that ensures that consumption does not bounce back to pre-crisis levels (IEA 2005).

In the long term, the need for additional supply options remains. Building new power stations after decades of using up excess capacity will undoubtedly raise the price of electricity, which in turn is a key signal to use the resource more efficiently. But the question remains as to who will supply new power stations and what energy sources they will use (ERC 2004a).

The former question will be shaped by the framework of privatisation (see earlier in this chapter). Eskom's market power will continue but to some degree will be supplemented by IPPs. Assuming that IPPs are profit-making firms, they will require higher rates of return on their investment (say 15 per cent) than typical of public utilities (ERC 2004a). This would force electricity tariffs up, making the use of electricity less affordable.

In light of the long lifetimes of energy infrastructure, choices made in the near term will shape the system for several decades, including the mix of fuels used to generate electricity. The current mix is dominated by coal for electricity (93 per cent), with three-quarters of total primary energy supply (all energy carriers, not just electricity) coming from comparatively cheap coal. Given the priority afforded to industrial competitiveness and access to reasonably priced electricity, achieving the White Paper on Energy Policy goal of diversity of supply requires substantial effort. Determined policy interventions will be required to initiate a transition to a cleaner fuel mix for the electricity supply industry.

Three major options of diversifying fuels for electricity generation domestically are examined – renewable energy sources, gas and nuclear. Major opportunities are already being set up within the southern African region for the import of hydroelectricity. Finally, since coal will continue to dominate the sector for several decades, policies promoting cleaner technologies using the 'old' fuel are considered.

RETs for electricity generation

The energy minister recently restated that 'renewable energy plays an important role in the energy mix and increases supply security through diversification' (Mlambo-Ngcuka 2002a). In practice, renewable electricity technologies[13] have remained in the research, development and demonstration phase. In 2003, the government adopted a target of 10 000 GWh renewable energy consumption by 2013 (DME 2003c). Although this is not limited to electricity but also includes solar water heating and biofuels, the policy document explicitly calculates that this would be 4 per cent of expected *electricity* demand in 2013. The key challenge is to implement this policy at scale, beyond pilot projects.

Renewable electricity sources are derived from natural *flows* of energy that are renewable – solar, wind, hydro, biomass, geothermal and ocean energy. A recent estimate of the long-term global technical potential of primary renewable energy by the IPCC was given as at least 2 800 EJ per year (IPCC 2001b: Chapter 3). While this number exceeds the upper bound of estimates for total energy demand, the realisable potential is lower, limited by the ability to capture dispersed energy, markets and costs. While wind and solar photovoltaic technologies have grown at rates of around 30 per cent over five years, they start from a low base (10 GW and 0.5 GW respectively [UNDP et al. 2000]; for comparison, South Africa's total capacity is roughly 40 GW).

Perhaps the key factor limiting the potential of RETs globally is cost. Table 4.5 shows international cost data for RETs, according to the World Energy Assessment. Investment costs for coal or gas plants are under US$1 000 per kW, while the energy cost in South Africa is below 2c per kWh (although likely to rise in future).

Table 4.5 *International cost data for RETs*

Technology for electricity generation	**Operating capacity, end 1998**	**Capacity factor**		**Turnkey investment costs**		**Current energy cost of new systems**		**Potential future energy cost**	
	GW_e	*%*		*(US$ per kW)*		*US c/kWh*		*US c/kWh*	
		Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
Biomass	40.0	25	80	900	3 000	5	15	4	10
Wind	10.0	20	30	1 100	1 700	5	13	3	10
Solar PV	0.5	8	20	5 000	10 000	25	125	5	25
Solar thermal	0.4	20	35	3 000	4 000	12	18	4	10
Small hydro	23.0	20	70	1 200	3 000	4	10	3	10
Geothermal	8.0	45	90	800	3 000	2	10	1	8
Tidal	0.3	20	30	1 700	2 500	8	15	8	15

Notes: GW_e = $\text{gigawatt}_{\text{electric}}$; PV = photovoltaic
Source: UNDP et al. (2000)

South Africa's potential for renewable energy lies overwhelmingly with solar energy, equivalent to about 280 000 GW (Eberhard & Williams 1988: 9). Technological and economic potentials would be lower than the theoretical potentials – by various estimates – shown in Table 4.6 overleaf. Other renewable energy sources – wind, bagasse, wood, hydro, and agricultural and wood waste – are much smaller than solar.

The most recent estimates of the potential of renewable energy are being compiled for the South African Renewable Energy Resource Database.[14] More detailed GIS (geographic information system) maps will be sold, with revenues used to update the data (pers. comm. Otto 2004[15]). In estimating economic potential, there is even less data. With little commercial use of renewable energy, there is not sufficient experience regarding local costs and markets to provide estimates of much accuracy.

Demonstration projects will in future need to be scaled up to meet the renewable energy target. The international literature suggests that a variety of policy tools could

Table 4.6 *Estimates of theoretical potential for renewable energy sources in South Africa*

Resource	DANCED/DME	Howells	RE White Paper
		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

Notes: DANCED = Danish Cooperation for Environment and Development; RE = renewable energy
Empty cells indicate that no estimates are reported for the renewable energy source from that publication.
Sources: DME (2000a, 2002d); Howells (1999)

be used by the South African government to promote renewable energy (Winkler 2005). Feed-in tariffs guarantee prices for developers, but lack certainty on the amount of renewable electricity such laws would deliver under local conditions. This shortcoming would be addressed by a renewable portfolio standard which sets a fixed share of renewable energy in the supply mix. The question for this instrument would focus on the incremental upfront costs compared to future health and environmental benefits. A renewables obligation, following the UK model, combines the setting of a target with a tendering process, but may be bureaucratic to administer (Winkler 2005).

Neither setting targets nor regulating prices alone, however, will be sufficient. More detailed policies are needed, including power purchase agreements, access to the grid and creating markets for green electricity. Given that RETs have to compete with relatively low electricity tariffs, funding will be needed. The extent to which these are utilised will determine the future mix of renewable energy in South Africa (Winkler 2005). An overview of possible policies for electricity from renewable energy sources is provided in Table 4.7.

Table 4.7 *Tools that governments can use to promote renewable electricity*

Tool	Advantages	Disadvantages
Power purchase agreements	Long-term, standard agreements help developers and facilitate investment	May require continuing unit subsidy to make the cost attractive
Investment incentives	Overcome high first-cost barriers	Encourage investment, not production
Production incentives	Encourage renewable electricity production	Do not address high first-cost barrier and require continuing subsidies over the long term

→

Tool	Advantages	Disadvantages
Renewable set-asides/mandated market shares	Competitive bidding encourages cost reductions	Can be bureaucratic
Externality adders	Allow for full-cost accounting in power planning	Implementation does not always follow planning
Environmental taxation	Correct energy prices, including costs of environmental impacts, provide a more level playing field for renewable energy	Taxes are often politically unfavourable
Research, development and demonstration	Builds long-term foundation for technological and industrial development	Difficult to pick a technological winner for R&D investment
Government-assisted business development	Builds market infrastructure	May become too bureaucratic
Green marketing	Allows choice in power purchases	May be undersubscribed

Note: R&D = research and development
Source: Oliver et al. (2001)

The new policy has effectively set aside a market share, moving beyond research, development and demonstration. In practical implementation, some initial progress has been made on green electricity. The approach taken to modelling renewable energy is described in more detail in Chapter 5.

Switching fuels from coal to gas

Energy security through diversity of supply is a well-established goal of energy policy. In the electricity sector, this goal is being pursued largely through developing the SAPP, planning increased imports of hydropower and developing gas markets. A transition away from coal to cleaner fuels will in the short to medium term most likely include natural gas imported by pipeline and/or LNG. One of the technologies that can further diversify the mix is gas-fired power, with environmental advantages for the country (Graeber & Spalding-Fecher 2000).

The initial use of gas from Mozambique will probably not focus on electricity generation. Energy plans by Eskom, DME and the NER, however, consider the use of natural gas in power plants (DME 2003d; NER 2004a). Gas-fired plants can have simple cycles, with efficiencies around 32 to 35 per cent, or combined cycles – producing both heat and power – with efficiencies ranging between 47 and 55 per cent. Beyond its greater efficiency, gas-fired power has further advantages in being commercially mature and having short installation times, relatively low capital costs (although gas prices influence variable costs) and low levels of local air pollutants (including nitrogen oxides). Natural gas is about 60 per cent cleaner than coal in terms of carbon dioxide emissions; however, fugitive emissions (leaks of gas from the pipeline) need to be minimised.

Developing new nuclear technologies

Uranium and gold are found together in mineral deposits and South Africa produces uranium as a by-product of gold mining, with an estimated 261 000 tons of uranium in 'reasonably assured resources' (205 000 tons) and 'estimated additional resources' (56 000 tons) (DME 1998b). In the apartheid era, South Africa manufactured finished fuel for the Koeberg nuclear power station near Cape Town. Currently, however, the finished fuel is imported because it is cheaper to do so (ERC 2004a).

National government has repeatedly stated its intention to develop all energy sources, including nuclear (Mlambo-Ngcuka 2002b, 2003, 2004). The country currently has one nuclear light-water reactor at Koeberg (1840 MW_e), but Eskom is developing the Pebble Bed Modular Reactor (PBMR), further developing an earlier German design (*Business Report* 23 June 2004[16]). The designers claim it is 'inherently safe', using helium as the coolant and graphite as the moderator (PBMR Ltd 2002). The fuel consists of pellets of uranium surrounded by multiple barriers and embedded in graphite balls ('pebbles'). 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 produce this technology not only for domestic use, but also for export.

One of the conditions of approval of the Environmental Impact Assessment for the first PBMR demonstration module – to be built at Koeberg – was that a Radioactive Waste Management Policy and Strategy be completed. This was published for comment during 2004 and was to lead to a Nuclear Waste Management Policy and Strategy (Mlambo-Ngcuka 2004). This would set the policy framework to deal with one of the key issues faced by nuclear technology – the long-term disposal of high-level waste.

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 southern Africa. Hydroelectricity is generated using the flow of water in a river or from a storage reservoir. South Africa itself has only small hydro resources (0.8 per cent of generation) (NER 2002a), and already imports electricity from the Cahora Bassa dam in Mozambique. Further developments could add to imports of hydroelectricity. A promising site is at Mepanda Uncua in Mozambique, about 60 kilometres downstream from the existing Cahora Bassa power station on the Zambezi River. The first stage of this project, which is being considered, is the installation of 1 300 MW_e capacity.

The scale of this is dwarfed by the potential at Inga Falls in the Democratic Republic of Congo, estimated to range between 40 000 MW for run-of-river to 100 000 MW for a storage reservoir (Games 2002; Mokgatle & Pabot 2002). Even the run-of-river capacity would equal South Africa's current total generation capacity.[17]

The SAPP facilitates the trading of electricity and was formally launched in Harare in 2003 (Mlambo-Ngcuka 2003). Southern African countries agreed that an integrated electricity market could provide economies of scale and benefits from shared resources. An operational control centre facilitates trading, and a short-term energy market (STEM) began in 2001. STEM is currently trading three types of futures contracts for electricity – namely, daily, weekly and monthly contracts – although most trade still occurs through fixed contracts (Spalding-Fecher 2002a). Contracts on a 'take-or-pay' basis lead to ongoing tensions relating to the price of imported electricity, which at an average of 2.15c per kWh is well below the cost of generating electricity in South Africa (NER 2001a).

Cleaner coal technologies

Advanced and cleaner coal technologies will not diversify the *fuel* mix for electricity generation, which is dominated by coal. However, even under the most progressive scenarios of shifting to renewable energy, coal continues to constitute the largest share.

A first step to cleaner coal technologies includes modifications to the existing pulverised fuel plants. Future plants are likely to be dry-cooled (reducing specific water use) and to instal FGD (removing sulphur dioxide). Both have cost implications, with dry cooling reducing efficiency by about one percentage point and desulphurisation adding some 30 per cent of the capital cost of stations (EDRC 2003a). Other options, such as super-critical and integrated gasification combined cycle plants, together with carbon capture and storage, are considered likely only in the medium- to long-term future.

The Integrated Resource Plan considers fluidised bed combustion (FBC) as the key cleaner coal technology. FBC plants mix coal with limestone and air is blown through it in a moving bed of particles. This 'fluidised bed' keeps the coal in the combustion zone longer and therefore poorer quality coal can be used. The process reduces local pollutants – sulphur emissions, as the sulphur combines with limestone and can be removed, and nitrous oxides due to lower temperatures. The major economic advantage lies in the ability to use discard coal, of which South Africa produces about 60 million tons per year (Howells 2000). The IRP base case envisages 466 MW of FBC by 2013 (NER 2001/02, 2004a).

The promotion of advanced technologies for coal-fired electricity can contribute to more diversity in technologies, albeit not fuels. Coal is the fuel with the highest GHG emissions per unit of energy, so that such changes will always remain marginal improvements. Policy support for cleaner coal technologies therefore needs to be part of a set of options that changes the fuel mix. But given the importance of coal in the South African energy economy, this partial approach can make an important contribution to managing the environmental impacts of electricity supply.

Summary of electricity supply options

The major options for ensuring security of electricity supply through diversity have been examined above. Scenarios to examine the options for future electricity-generating capacity are being examined for the next National Integrated Resource Plan (NIRP). A draft reference case for the NIRP has been prepared by Eskom, the Energy Research Institute and the NER (NER 2004a). Table 4.8 summarises energy and cost characteristics of the technologies being considered for this base case.

Table 4.8 *Options for new electricity supply*

	Type of station	No. of units	Total capacity	Unit size	Lifetime	Nominal capital costs	Capex/ installed capacity	PV of capex at 10% disc. rate	Lead time	Fixed O&M costs	Variable O&M costs	Fuel price	Efficiency (higher heat values)
			MW	*MW*	*Years*	*R millions*	*R/kW*	*R/kW*	*Years*	*R/kW/A*	*R/MWh*	*R/ton or GJ*	*%*
New coal-fired plants												R/ton	
CF 1 Dry excl. FGD	Baseload	6	3 942	657	30	35 338	8 964	11 274	4	121.93	5.70	60	35.52
CF 1 Dry + FGD	Baseload	6	3 850	642	30	37 723	9 799	12 324	4	125.28	7.51	60	34.59
Pumped storage													
Braamhoek	Peaking	4	1 330	333	40	4 200	3 158	5 179	7	90.00	9.00	n/a	76.00
Generic	Peaking	3	998	333	40	7 182	7 200	8 857	7	90.00	9.00	n/a	76.00
Gas turbines												R/GJ	
CCGT without trans. benefits pipe	Baseload	5	1 935	387	25	9 797	5 063	5 659	3	175.26	10.58	20	47.04
CCGT with trans. benefits pipe	Baseload	5	1 935	387	25	9 797	4 405	4 925	3	156.48	9.45	20	47.04
CCGT without trans. benefits LNG	Baseload	5	1 935	387	25	9 797	5 063	5 659	3	175.26	10.48	32	47.04
CCGT with trans. benefits LNG	Baseload	5	1 935	387	25	9 797	4 405	4 925	3	156.48	9.45	32	47.04
GT open cycle kerosene	Peaking	2	240	120	25	920	3 833	3 949	2	79.80	65.88	72	32.26
GT open cycle LNG	Peaking	2	240	120	25	920	3 833	3 949	2	79.80	65.88	32	32.26
GT open cycle Sasol gas	Peaking	2	240	120	25	920	3 833	3 949	2	79.80	65.88	28	32.26
GT open cycle LPG	Peaking	2	240	120	25	920	3 833	3 949	2	79.80	65.88	56	32.26
New coal (fluid. bed)												R/ton	
Greenfield FBC	Baseload	2	466	233	30	4 508	9 669	11 511	4	206.49	19.24	10	36.65

→

	Type of station	No. of units	Total capacity	Unit size	Lifetime	Nominal capital costs	Capex/ installed capacity	PV of capex at 10% disc. rate	Lead time	Fixed O&M costs	Variable O&M costs	Fuel price	Efficiency (higher heat values)
			MW	*MW*	*Years*	*R millions*	*R/kW*	*R/kW*	*Years*	*R/kW/A*	*R/MWh*	*R/ton or MWh*	%
Imports													
Imported hydro	Baseload	2	1 200	300	30	17 044	14 203	19 948	6.5	2 151.23	0	n/a	n/a
Renewables													
Solar thermal	Peaking	3	300	100	30	10 043	33 477	34 589	3	147.29	0.13	0	n/a
Wind	Peaking	20	20	1	20	154	7 714	7 768	2	167.02	0	0	n/a
Nuclear													
PBMR 1st MM incl. transmission benefits	Baseload	8	1 320	165	40	24 693	16 533	17 340	4	157.65	6.75	45	40.54
PBMR 1st MM excl. transmission benefits	Baseload	8	1 320	165	40	24 693	18 707	19 651	4	157.65	6.75	45	40.54
PBMR series MM excl. transmission benefits	Baseload	8	1 364	171	40	14 678	10 761	10 853	4	161.2	6.75	45	44.50
PWR incl. transmission benefits	Baseload	2	1 747	874	40	27 944	15 995	15 139	4	507.22	0	45	31.58
PWR excl. transmission benefits	Baseload	2	1 747	874	40	25 389	14 532	15 290	4	507.22	0	45	31.58

Notes: CCGT = combined cycle gas turbine; CF = conventional fuel (coal); GT = gas turbine; MM = multi-module; PV = photovoltaic; PWR = pressurised water reactor
Sources: NER (2004a, 2004c)

New coal-fired plants account for 29 per cent of new capacity in the NIRP's base case. Most of this is made up of conventional coal plants, some with FGD (adding about 10 per cent to capital costs) and some without. Only two units are envisaged with FBC. A shift to make coal technologies cleaner would require that more plants with FGD be constructed.

RETs are represented by wind and solar thermal electricity in the base case, but account for just over 1 per cent of total new capacity. The main reason is high upfront costs – solar thermal electricity capital cost is almost three times the present value of a new coal-fired plant with FGD. Wind is closer to competitive, being some 40 per cent more costly in capital costs but with no variable operation and maintenance (O&M) or fuel costs, and only slightly higher fixed O&M costs. Investment decisions that focus on initial capital costs will not favour renewable energy options, but if the longer-term variable costs are given more weight, they become economically more attractive, even before considering externalities.

Imported hydroelectricity in the base case accounts for only 4 per cent of new capacity, which would be built outside of the country. Capital costs are some 60 per cent higher than for coal plants in South Africa.

New nuclear options include the PBMR and the pressurised water reactor (PWR). A total of 26 per cent of new capacity is expected, made up of initial PBMR demonstration modules, PBMR developed at scale and PWR. Demonstration plants are some 60 per cent more expensive than a reference coal station, but this drops to around 40 per cent additional cost if the benefits of avoided transmission losses are taken into account. Assuming that costs reduce by learning in the commercialisation process, the PBMR would eventually have lower capex. The PBMR has O&M costs comparable to new coal, while the PWR has a fixed component but no variable O&M costs.

A significant proportion of new capacity uses gas-fired turbines, which represents a shift from coal to gas given that current generation capacity is about 90 per cent coal (NER 2003d). Together gas plants make up just over 30 per cent of total new capacity, mostly combined cycle (27 per cent) and some open cycle (3 per cent). Fuel costs depend strongly on international markets, but capital costs are significantly lower – half of coal plants for combined cycle, and under 40 per cent with the open cycle (although the latter has much higher variable O&M costs). Cost factors, together with shorter lead times in constructing new plants, make it attractive to address the immediate urgency of new capacity.

The options presented above are the NER's plan. The supply options of a cleaner fuel mix for electricity generation will be examined in the policy scenarios to be modelled in Chapter 6. Chapter 5 briefly outlines the modelling framework through which the quantitative analysis for the policy cases is conducted.

Conclusion

This chapter has argued that options exist for a transition from current constraints to a more sustainable future for the electricity and residential sectors. Chapter 3 outlined the development objectives as the starting point of the analysis. Rather than making development fit climate objectives, climate change mitigation is located in the context of sustainable energy development. Such an approach would implement the policy options suggested in this chapter as a basis for climate policy.

In identifying policy options for the future, this chapter has laid the basis for scenario modelling in the next section, which will combine different technological and policy options and examine their implications for meeting energy development objectives and implications for climate change.

Notes

1 Parts of this chapter relating to renewable energy have been published in Winkler (2005).

2 The national average rate of rural grid electrification was 54.0 per cent in 2003, but some provinces were lower, with rural KwaZulu-Natal only 44.5 per cent electrified and Eastern Cape 40.7 per cent.

3 The national policy indicates 50 kWh, although some municipal distributors are providing lower amounts, 20 to 50 kWh per household per month. Households in Eskom distribution areas receive 50 kWh.

4 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 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 underutilised at other times of day, or seasonally (ERC 2004a).

5 The medium-term expenditure estimates were R1 067 million for 2004/05, R1 126 million for 2005/06 and R920 million for 2006/07 (DME 2004b). National Treasury gives a total of R3.3 billion over the period 2004–07 (National Treasury 2003a: 234).

6 Also referred to as ‘restructuring’ or ‘power sector reform’. Privatisation implies a change from public to private ownership, whereas restructuring suggests a process of rationalisation that may be independent of ownership (Clark 2000a). The World Bank tends to promote power sector reform, with reform having the most positive association (Newbery 1995). All three terms are used in this chapter, depending on the context.

7 V Robinson, ‘Tough times need new policies’.

8 Municipal power stations, because they are older, in urban areas and have lower stack heights, will likely have much higher damages than Eskom power stations (Spalding-Fecher & Matibe 2003). For this reason, Eskom power station emissions are referred to as ‘high-level’ emissions in this study, while industrial and commercial emissions, as well as municipal power station emissions, are referred to as ‘low-level’ emissions.

9 Energy-intensive industries could be identified by the percentage of their costs spent on energy.

10 L Ensor, 'Eskom wins support for big tariff hikes'.

11 A middle-class household uses about 0.01 of a GWh per year, 10 000 times too little to qualify.

12 Assuming that some 30 per cent of total domestic electricity consumption is used for water heating and that 60 per cent of this electricity can be replaced by solar energy, using a hybrid solar-electric water-heating system, then the potential savings for urban residential households come to 5 900 GWh (Spalding-Fecher, Thorne et al. 2002; Thorne et al. 2000).

13 For convenience, renewable electricity technologies are abbreviated as RETs, as shorthand for technologies using renewable energy sources. However, it is not the electricity that is renewable, but the energy source. The abbreviation RETs is also often used for renewable *energy* technologies, not only those using electricity.

14 See www.csir.co.za/environmentek/sarerd/contact.html.

15 A Otto, Principal Energy Officer: Renewable Energy, Department of Minerals and Energy.

16 L Loxton, 'SA "needs a nuclear reactor" '.

17 While licensed capacity was 43 165 MW, the total operational capacity was 39 568 MW (NER 2001a), the difference mainly being accounted for by three mothballed coal stations.

5 Modelling energy policies

This chapter uses modelling as a tool to examine policy cases in South Africa's energy sector. A variety of policy cases are constructed, focusing on the residential demand and electricity supply sectors. In the methodology outlined in Chapter 2, modelling provides an important step in quantifying the implications of energy policies identified.

Models provide a systematic framework to examine such policy cases in quantitative terms. The results of the modelling are interpreted in Chapter 7 in economic, environmental and social terms, against criteria of sustainable development. The interpretation of model results informs the analysis of implementation of policies in Chapter 8. The modelling is therefore an important part of the methodology, but not the only aspect of it.

Various tools are available to develop policy cases quantitatively and to provide a consistent framework for their analysis. At least two broad types of energy models can be distinguished – simulation models and optimisation models. The Long-range Energy Alternatives Planning system and the Markal tools have both been used for energy analysis in South Africa, and represent these two types. Optimisation models use linear programming to optimise an objective function subject to specified constraints. Typically, the objective function is to minimise costs, subject to balancing energy supply and demand, as well as other constraints. Optimisation models are prescriptive rather than descriptive and tell the user how to make the best of a given situation in relation to a predefined goal (Alfstad 2004b). To perform this cost-effectiveness analysis, optimisation models include detailed technological information and costs. A typical research question would ask what the least-cost set of technologies is to provide energy supply and meet demands in the future.

Simulation models are based on cases determined by the user, meaning that assumptions for a set of potential futures are compiled. They also contain detailed data and sometimes costs, but rather than calculating 'optimal' (least-cost) solutions, cases are defined by the modeller. The simulation model is descriptive rather than prescriptive. This lends itself to 'what if' questions – what are the implications if a user-specified set of energy supply and demand technologies and policies is implemented?

Modelling of energy policies is an important component of the methodology for this book. The Markal modelling framework is used to develop systematic, quantified representations of energy policy cases. The aim in this book is not to develop new models, but as far as possible to use existing models to test new policy cases and their implications for sustainable development.

The Markal framework is used for a number of reasons. The database developed at the Energy Research Centre at the University of Cape Town has been used to directly inform planning in the NIRP and Integrated Energy Plan (see Chapter 6). The Long-range Energy Alternatives Planning system would have provided a simulation tool perhaps more closely aligned with a durability approach, but the tool does not provide detailed cost results. With the central aim of meeting development objectives, a detailed understanding of costs is required. The approach, then, is to use Markal as part of the methodology. The analysis in this book, however, does not end with modelling results. Rather, it uses these to inform a broader evaluation of indicators of sustainable development and an analysis of the implications for energy and climate policy.

An adequate understanding of these two sectors requires that their interactions with other sectors are described – liquid fuels on the supply side, and demand in industry, transport, commercial and agricultural sectors. These sectors are described much more briefly, based on existing work, to provide context for the more detailed analysis of electricity and residential energy. The industrial sector, for example, clearly makes a major contribution to economic development and offers potential for large energy savings. The broad contours of the potential benefits for sustainable development will be outlined in the base case for all sectors, but detailed policy cases are developed further for the focus areas.

The following section motivates the particular policy focus for this book, providing some details on policies in the residential and electricity supply sectors. Next, the key drivers for developments in the energy sector as a whole are described, and an overview of development in the base case for the broader energy sector is presented. This lays the basis for considering the base case, before considering several policy cases in the residential and electricity sectors. This chapter outlines how the policy cases were implemented in the modelling framework, while Chapter 6 presents the results.

Focus of policy modelling

The residential sector is critical for the assessment of the social dimension of sustainability. Its complex socio-economic patterns are reflected in a variety of energy-use patterns. Past analysis has tended to focus on case studies and surveys (Davis & Ward 1995; Mehlwana 1999b; Prasad & Ranninger 2003; Simmonds & Clark 1998; Thom 2000; Thom & Afrane-Okese 2001), but the diversity of the sector has not been adequately reflected in national energy modelling. The importance of this social dimension in South Africa is reflected in the first goal of energy policy – ‘increasing access to affordable energy services’ (DME 1998a). The goal of managing energy-related environmental impacts has an important dimension in the health impacts associated with indoor air pollution. The residential sector allows at least a minimum of disaggregation (by income, access to electricity and geographical location – see later in this chapter), enabling some analysis of the distributional impacts of policy, and hence social equity. This makes the residential energy sector important in achieving other development goals, beyond energy policy objectives.

The focus on the demand by households includes electricity, but other fuels cannot be ignored – particularly the use of LPG for cooking and its potential for productive use. Chapter 3 outlined the importance of electricity to development on the supply side. This chapter examines the major policy options for supplying electricity in the future. The major options – cleaner coal, imported hydro, renewable energy, PBMR nuclear and imported gas – have already been discussed in general in Chapter 4.

One means of assessing the impact of a range of policies on major policy goals is the Action Impact Matrix (AIM; see Table 5.1) (MIND 2005). The AIM tool is designed to understand the interactions between national development goals and policy goals. This method is useful to analyse how to make development more sustainable, and to motivate the scope of the detailed work of this book. A later part of the AIM methodology examines the impacts of climate change on both development and energy policy, but for the present purpose we only use the first four steps of the methodology, the others being more focused on climate change (MIND 2005).

The row headings of the matrix represent development objectives. The more detailed discussion of development objectives in Chapter 3 can be summarised, for the purposes of this book, in the major goals of Gear – growth, employment, redistribution – and those of the RDP – the delivery of services essential to meeting basic human needs. For the latter, we focus here on energy services.[1] Note that these criteria reflect a much broader understanding of development than simple economic growth (see the discussion in Chapter 2 on the tension between these concepts). In the AIM matrix, note that the criterion of economic growth is immediately followed by a concern about equitable income distribution.

The column headings are policy options. A broader set of energy policy interventions is taken from a study entitled South African Energy Policies for Sustainable Development (Winkler, Howells & Alfstad 2005). It considers, among other policies, the major options for electricity supply, and examines interventions in households that include CFLs, SWHs, geyser blankets (GBs) and more efficient building shells (mainly through ceilings). These policies are similar to the ones proposed for this book, but the set here also includes industrial energy-efficiency measures to meet a national goal of 12 per cent reduction in final demand (DME 2005a: 2). A similar goal could be achieved in commercial buildings with the introduction of building codes, efficient lighting and HVAC systems, and SWHs. Liquid fuels are important for transport, and the policies considered are importing petroleum products (rather than continuing with coal-to-liquids or gas-to-liquids at Sasol) and refining biofuels. A cross-cutting policy, a fuel tax on coal for electricity generation, is also included, with coal providing 93 per cent of electricity generated.

For the purpose of focusing this book, the question of interest is the impact of the policy interventions on development. A simple scoring system ranging from –3 to +3 is used, with –3 representing a high negative (undesirable) impact/effect and +3 a high positive; scores of 1 are low, 2 are medium and 0 have no impact/effect (MIND 2005). Typically, this exercise would be conducted with stakeholders but here the scores simply reflect the author's judgement.

Table 5.1 *Action Impact Matrix assessing the impact of policy interventions on development goals*

	Industrial EE	Commercial CFLs, SWHs, HVAC, building codes	Efficient houses, CFLs, SWHs, LPG	Elec: cleaner coal	Elec: imported hydro	Elec: renewables	Elec: imported LNG	Elec: PBMR nuclear	Imported petroleum products	Biofuels	Fuel tax, with recycled revenue
Development goals											
Job creation	+3	+3	+3	–2	–1	+3	–1	0	–3	+3	0
Economic growth	+3	+2	+1	+2	0	+2	0	+2	0	+2	0
More equitable distribution of income	0	0	+3	0	0	0	0	0	0	+2	+2
Delivery of energy services for basic needs	0	0	+3	+2	+1	+2	+1	+2	+2	+2	–1
Energy policy goals											
Improve access to affordable energy services	0	0	+3	+3	+1	+2	+1	+2	+2	+2	–1
Governance	0	0	0	0	0	0	0	0	0	0	+2
Stimulate economic development	+3	+2	+1	+2	0	+2	0	+2	0	+3	+1
Manage energy-related environmental impacts	+2	+2	+3	+1	0	+3	0	–2	0	+2	+3
Secure supply through diversity	+2	+1	+1	–3	–1	+3	+2	+3	–3	+2	0

Note: EE = energy efficiency
Source: Author's own analysis

The scores in Table 5.1 may be subjective but they provide a systematic, consistent motivation for the focus taken in this book. Highlighting the high positive and negative scores, the residential policy interventions (efficient housing shells, CFLs, SWHs and GBs) are expected to have several high positive impacts on development. Among the electricity supply options, the initial assessment suggests that there are positive and negative aspects for several options. The one high negative score reflects the well-known problem of South Africa's dependency on coal, in the energy sector in general and even more acutely in electricity (see Chapter 4). The need for greater diversity makes it worthwhile examining all alternative options in more detail through modelling.

Mobility is an important contributor to quality of life. The transport sector aims to 'move South Africa' (DoT 1999). From an energy-environment perspective, the sector accounts for most energy used in local areas (Winkler, Borchers et al. 2005) and is the fastest-growing contributor to GHG emissions (Naude et al. 2000; Prozzi & Sperling 2002). The growing of biofuels can be decentralised to small growers with potentially significant socio-economic benefits. However, significant data problems arise in analysing this sector, with collection of transport information typically not providing energy data, and general energy analysis not disaggregating transport sufficiently. Analysing transport energy infrastructure deserves detailed future analysis, but will require a sophisticated understanding of vehicle stocks, ages, turnover rates, infrastructure and its costs, and the possibilities for behavioural changes.

The policy option of importing refined petroleum products, instead of continuing with production of synfuel from coal, might raise problems related to the volatility in the oil price.

From Table 5.1 it can be seen that securing supply through diversity faces major barriers, with the current dependence on coal. The 1998 White Paper on Energy Policy clearly recognised this constraint (see the –3 for cleaner coal/diversity). Two major domestic energy resources – flows of renewable energy and large stocks of uranium – exist to potentially meet demand. From an environmental perspective, they are often considered polar opposites – yet from the point of view of GHG emissions, both radically reduce emission (zero for operation, but some in construction). These factors motivate the focus on the electricity supply.

The multiple high positive scores for efficiency and fuel-switching measures confirm the motivation for focusing on the residential sector. Energy policies in this sector can make a major contribution to South Africa's development objectives. The focus, then, is on residential policies on the demand side and options for electricity generation on the supply side.

Policy since 1994 has included the national electrification programme, raising the rate of grid access from about one-third to two-thirds over the 1990s. The issue of affordability is emerging as critical, with consumption levels of newly electrified households remaining low. The poverty tariff has sought to address this issue. The energy policy goal of increasing access to affordable energy services (DME 1998a) has been pursued vigorously, but more needs to be done. Residential energy policies can contribute to managing environmental health impacts, another major energy policy goal. The third relevant energy policy goal is governance, with power sector reform concentrating on the distribution side (see Chapter 4).

Having identified and prioritised development objectives and energy policies, the chapter now turns to representing these in a modelling framework. Important drivers – including economic development, population growth, technology, and fuel prices – shape both policy cases and the base case. The next section discusses the key drivers of future trends and the assumptions made about how these might change in the future.

Drivers of future trends and key assumptions

Future energy needs depend on the number of people in a country, as well as the rate of economic change. Two important drivers of future energy trends include economic growth and population projections. A third important factor is technology and the rate at which technological learning occurs. Fourth, future fuel prices are important, particularly for fuels that are internationally traded. Fifth, the discount rate makes an enormous difference to any modelling in an economic framework and warrants discussion in relation to the Markal model used here. Finally, the emission factors for local air pollutants and global GHGs are stated.

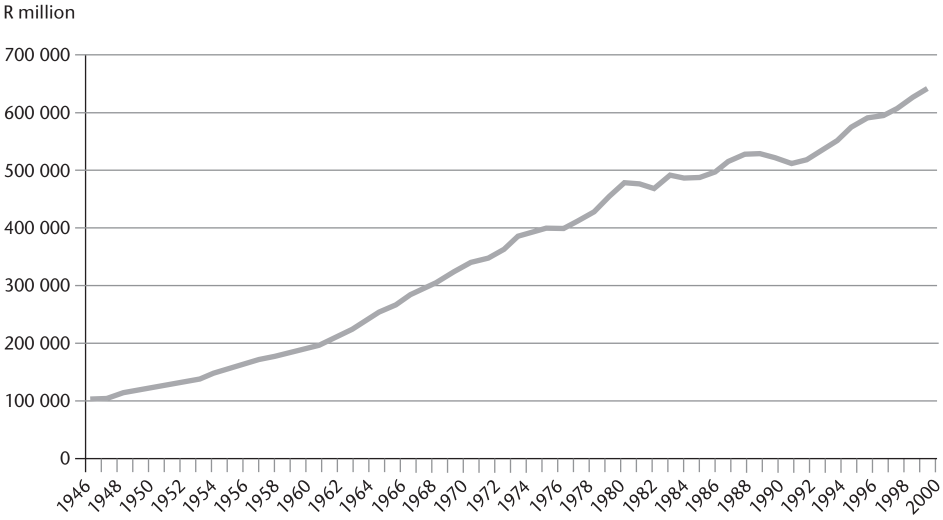
Economic growth increases energy demand

In the absence of interventions that de-couple energy demand from economic growth, projections of GDP are an important driver.

Figure 5.1 shows the historical trends in GDP, which are clearly upward in general but with significant downturns in the 1980s and 1990s. Economic growth over the next 25 years is hard to predict year-on-year, but the upward trend can be assumed to continue.

GDP itself is an imperfect measure of economic growth (see, inter alia, Blignaut & De Wit 1999; Daly & Cobb 1989; Munasinghe 2001; Norgaard 1994; Pearce et al. 1989). It accounts for all economic activity, even when that activity may have negative social or environmental consequences. For example, the clean-up of an oil spill or expenditure on replacing stolen goods would add positively to GDP. GDP also accounts for the sale of natural resources as positive income, thus assigning a zero value to implied depletion of scarce natural assets (Munasinghe et al. 1999). Other indicators, such as the Human Development Index, include a broader composite of social factors, including literacy, life expectancy and GDP per capita (Atkinson et al. 1997), with the index having declined in the context of AIDS.

Figure 5.1 *Trends in GDP, 1946–2000*



Note: GDP at market prices – constant 1995 prices.
Source: SARB (various)

Despite the critique of GDP, it is widely used in international comparison and for national planning. Most South African government projections therefore assume a smooth growth rate into the future. Annual GDP growth was assumed to be 2.8 per cent per year in the first Integrated Energy Plan (DME 2003d: 13), also used as the central value in the second National Integrated Resource Plan (NER 2004a: 4).

A central GDP growth figure of 2.8 per cent was used in the modelling for this study. While GDP growth in South Africa has fluctuated between 0.5 per cent and 5.0 per cent, targets for GDP growth rates have been set as part of AsgiSA (AsgiSA 2006; National Treasury 2005). While the target range was not achieved immediately, GDP growth has been above 3.0 per cent. But these considerations can be tempered again by considering the long-term implications of climate change. IPCC assessments have shown GDP rates settling over time (IPCC 2001b). Balancing these considerations, the earlier assumption for electricity and energy plans seems not to be too far off.

Population projections impact on energy consumption

The number of people in the country drives energy consumption, unless per capita consumption is reduced. For the residential sector, the *household* growth rate is important – this differs significantly from the population growth rate by *individuals*. Urban and rural households differ in many respects, including their energy-use patterns. The impact of AIDS on all population projections makes a marked difference. All these factors have implications for future residential energy demand (discussed later in the chapter).

URBAN–RURAL SHARES IN FUTURE

The analysis of the residential sector divides households into six types, distinguished along urban/rural, high-/low-income and electrified/non-electrified lines.

The first of these distinctions, the urban–rural, is relevant since energy-use patterns differ markedly. 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; for example, population growth from 1946 to 1970 was 3.45 per cent per year, and 3.09 per cent for 1970 to 1996 (SACN 2004). Overall, this gives a picture of a growing population, but 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).

This question is complicated by definitions of urban and rural, and the intermediate categories of peri-urban and dense rural settlements – the latter a legacy of apartheid, where large numbers of people were moved to rural 'homelands' and settlements were developed with high density but very little industrial or commercial base. Furthermore, the 2001 Census data no longer report by urban–rural division (Stats SA 2003a). For the analysis of energy demand, it seems reasonable to assume that peri-urban and dense rural settlements are more similar to urban areas than to 'deep rural' ones. This book assumes that virtually all the household growth – moderate as it is projected to be – will occur in this broadly defined urban category and that rural household numbers will remain stable. Under these assumptions, 64 per cent of the population will be urbanised by 2030.

This assumption has some support in the analysis of migration patterns between provinces, where Gauteng, the Western Cape and the North West had a positive net migration rate in 2004, the former two having large urban populations, while provinces with a higher percentage of rural populations, namely the Eastern Cape and Limpopo, had the highest outflow of people. The Development Bank of Southern Africa's (DBSA) approach of assuming stable numbers of rural households is adopted for this book (Stats SA 2004a).

HOUSEHOLDS AND HOUSEHOLD SIZE

Energy use in many respects relates more directly to households than to individuals. Electricity connections, for example, are made to each household. A notable trend across South African cities is that households have been growing faster than the population. Most of the population growth is expected to occur in urban areas in future. Across South Africa's nine largest cities, populations grew between 1996 and 2001 by 2.8 per cent per year, but households increased at 4.9 per cent per year (SACN 2004: 179). Possible reasons include people moving out of backyard shacks and establishing new households, migration from rural areas to the cities, and increased household formation.

The average number of people per urban household dropped from 3.98 in 1996 to 3.58 in 2001 (SACN 2004). In the national picture, it dropped from 4.48 to 4.0 over the same time (Stats SA 1996, 2003a), although these trends are probably partly the result of reconsideration of earlier Census data. Given demographic trends elsewhere in the world, it seems plausible to assume that household size will continue to decline further, reaching 3.8 people per household by 2030.

THE IMPACT OF HIV/AIDS

Studies considering the future – of energy development or other matters – have to consider the potential impact of HIV/AIDS. While the topic is strongly debated, some highly respected studies show a substantial levelling off in population during the study period. Major institutions have conducted investigations projecting trends in population, some distinguishing between scenarios with higher or lower impacts of HIV/AIDS. However, due to the HIV/AIDS pandemic in the country, population projections might be higher than actual population numbers. The DBSA's population projections differentiate between low and high HIV/AIDS impacts (Calitz 2000a, 2000b). The first Integrated Energy Plan also included projections of population growth (ERI 2001), which are shown together with other estimates in Table 5.2. Not all studies covered all years.

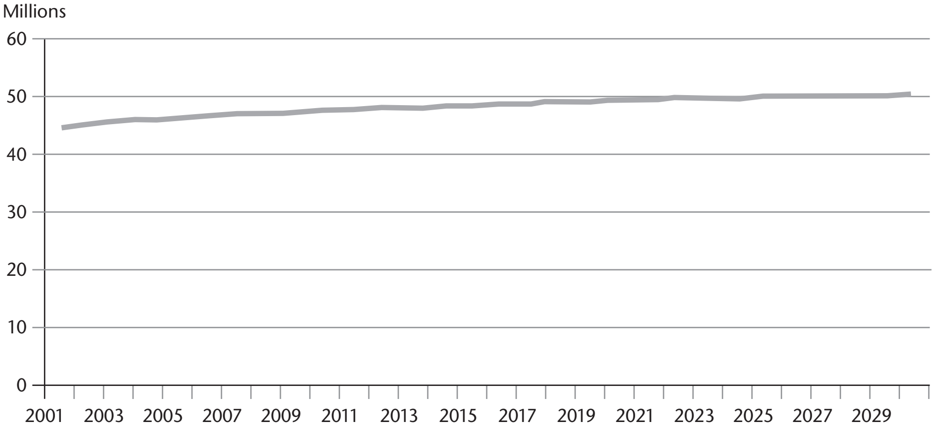
Table 5.2 *South African population projections from various sources (millions)*

Year	DBSA low AIDS impact	DBSA high AIDS impact	ASSA (base run)	Integrated Energy Plan 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

Notes: *The 2001 Census reported 44 819 778 people in South Africa (Stats SA 2003b) and this number is used instead of ASSA's projection.
ASSA = Actuarial Society of South Africa
Sources: ASSA (2002); Calitz (2000a, 2000b); ERI (2001); UN Population Division (2000)

Academically, studies by Professor Dorrington of the University of Cape Town's Commerce Faculty for ASSA are well respected (ASSA 2002). The ASSA projections seem reasonable, still indicating population growth over the period but at lower rates, growing 12.0 per cent over the 30-year study period, with annual growth rates between 0.1 and 1.0 per cent (see Figure 5.2). For this book the assumption is that the past pattern of household/population growth will continue but, based on other studies, will assume lower growth rates due to the impact of HIV/AIDS.

Figure 5.2 *Population projections based on the ASSA model*



Source: Based on ASSA (2002)

THE FUTURE OF POVERTY

Perhaps one of the most difficult assumptions is about the future of poverty. The approach taken here is a middle path between assuming that no inroads are made into the shares of poorer households, and dramatic decreases in poverty. At least in absolute terms, we assume that overall income levels increase so that 70 per cent of urban households are non-poor up to the end of the modelling period (drawing on Van Ryneveld et al. 2003), compared to 61 per cent in 2001 (Stats SA 2002). Shares of low-income households decline to 60 per cent in the base case by 2030, down from 69 per cent in 2001. This overall effect does not claim to address issues of relative poverty, where these households may still consider themselves poor as high-income households grow wealthier.

FUTURE HOUSEHOLD NUMBERS

In summary, population projections used for the base case in this study assume that the overall population projections from the base run of the ASSA model are reasonable, and comparable with the range in the literature. Population grows at moderate rates, reaching 50 million by 2030. Household numbers grow slightly more slowly as household size declines, increasing – with growth in urban areas – from 11.2 million in 2001 to 12.9 million in 2030. Rural household numbers stay constant. Electrification is almost complete in urban areas by the end of the period, while 10 per cent of rural households do not have electricity services – but all high-income rural households are assumed to be electrified.

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 5.3.

Table 5.3 *Number and share of households*

	2001		2030	
	No. of households	Share of households (%)	No. of households	Share of households (%)
UHE	4 074 438	36	5 709 438	44
ULE	1 255 728	11	2 290 812	18
ULN	1 349 240	12	304 155	2
RHE	1 181 279	11	1 702 030	13
RLE	1 095 449	10	2 061 822	16
RLN	2 249 571	20	762 447	6
Total	11 205 705		12 830 705	

Notes: Number/share of households estimated for 2001 and projected for 2030.
See the list of acronyms for explanations of the abbreviations in column 1.
Source: See text for underlying data and assumptions.

Population projections, as described in this section, are complex. They have been simplified for the purposes of analytical tractability in the modelling to six household types – still an improvement on the usual modelling approach of treating all households as homogeneous. Another complex driver of energy futures is technology and the dynamics of its costs.

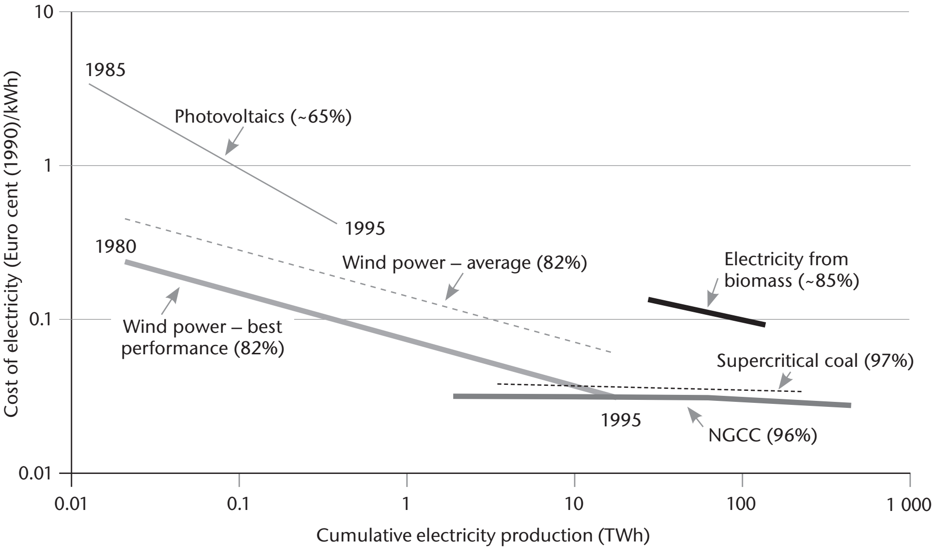
Technological learning can reduce costs

Technology is an important driver of energy development and technology costs change over time. One of the most important factors shaping the results of energy models is the assumptions they make about technology learning (Energy Innovations 1997; Fisher & Grubb 1997; IEA & OECD 2000; Repetto & Austin 1997) – the extent to which technologies get cheaper per unit over time. New technologies tend to benefit from learning-by-doing and economies of scale.

The first prototype is typically much more expensive than later models, which are produced in smarter, more cost-effective ways and often in larger production runs. Learning by experience reduces costs (Arrow 1962) and this general finding has been found 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 IEA has published estimates of learning or 'experience curves', which show the decline in costs (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 cost savings decades or centuries earlier. According to the IEA, photovoltaics declined by 35 per cent in price for doublings between 1985 and 1996, wind by 18 per cent, electricity from biomass by 15 per cent, while supercritical coal declined by only 3 per cent and natural gas combined cycle by 4 per cent (IEA & OECD 2000) (see Figure 5.3).

Figure 5.3 *Learning curves for new and mature energy technologies*



Source: IEA & OECD (2000)

Technology costs for new energy technologies change over the period. Technology learning rates are included in some of the policy cases on both the demand and supply sides. Such analysis should 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 components where the learning effect is likely to be less pronounced.
- The applicability of international learning rates to South Africa remains to be examined.

Future fuel prices

Prices of domestic fuels are important for the residential sector. Of particular concern, though, is price volatility in imported and exported fuels. The oil price exceeded US$100 per barrel in 2008, affecting South Africa's imports and impacting on the local petrol and diesel prices. The prices for exports of South African coal have been volatile (DME 2004d). Predicting these prices into the future is uncertain. The prices for the base year (2001) are stated in Table 5.4, as are the assumptions for the middle (2013) and end (2025) of the period.

Table 5.4 *Fuel prices by fuel and for selected years*

Price for fuel	Units	2001	2013	2025	Data source
Crude oil price	Real crude oil price local production (R/GJ)	24.8	18.0	21.4	IEA 2004b
	Real crude oil price imports (R/GJ)	27.6	20.0	23.8	IEA 2004b
Petrol price	IBLC (R/GJ)	50.3	51.4	60.9	DME 2001b
Diesel price	IBLC (R/GJ)	44.9	45.9	54.4	DME 2001b
Paraffin price	Bulk (R/GJ)	58.0	59.3	70.3	DME 2001b
	Drum (R/GJ)	80.5	82.3	97.6	DME 2001b
HFO price	Bulk (R/GJ)	35.7	36.4	43.2	DME 2001b
LPG price	Bulk (R/GJ)	112.1	114.6	135.8	DME 2001b
	Drum (R/GJ)	124.4	127.2	150.8	DME 2001b
Coal price	Electricity generation (R/GJ)	3.02	3.02	3.02	Prevost in DME 2002b
	Sasol (R/GJ)	2.54	2.54	2.54	Prevost in DME 2002b
	Domestic/commercial (R/GJ)	3.45	3.45	3.45	Prevost in DME 2002b
	Industry (R/GJ)	3.18	3.18	3.18	Prevost in DME 2002b
Biomass price	Wood (R/GJ)	30.0	30.0	30.0	ERC 2004a, drawing on several studies
	Bagasse (R/GJ)	0.0	0.0	0.0	waste, assume no cost
Natural gas price	LNG (R/GJ)	21.5	21.5	21.5	NER 2004c
	PetroSA (R/GJ)	20.0	20.0	20.0	DME 2003d
	Sasol pipeline (R/GJ)	22.1	22.1	22.1	Sasol 2004
Electricity price	Import (R/GJ)	5.5	Endogenous	Endogenous	NER 2001a
	Export (R/GJ)	16.3	Endogenous	Endogenous	NER 2001a
Electricity price including distribution costs	Agriculture (R/GJ)	41.4	Endogenous	Endogenous	NER 2001a
	Commercial (R/GJ)	41.0	Endogenous	Endogenous	NER 2001a
	General (R/GJ)	57.4	Endogenous	Endogenous	NER 2001a
	Manufacturing (R/GJ)	10.5	Endogenous	Endogenous	NER 2001a
	Mining (R/GJ)	9.8	Endogenous	Endogenous	NER 2001a
	Residential (R/GJ)	44.6	Endogenous	Endogenous	NER 2001a
	Transport (R/GJ)	21.8	Endogenous	Endogenous	NER 2001a
Uranium price	Import (R/GJ)	3.2	3.2	3.2	NER 2004c

Note: HFO = heavy fuel oil
Sources: Winkler, Howells & Alfstad (2005); detailed sources listed in the last column

The projections of future oil price appear flat from the perspective of 2008. As Table 5.4 makes clear, these were based on the IEA's forecasts in 2004. Since then, the oil price has risen sharply, the debate about peak oil (or at least the end of cheap oil) has broadened, and the IEA itself has revised its projections. The focus of this book is on electricity supply and the residential sector, where the impact of higher future oil prices is less direct. However, the impact is likely to be substantial in the transport and liquid fuels sectors and should be considered in future mitigation scenarios.

Discounting costs favours the present over the future

Discount rates reflect the time preference for money. Since the modelling undertaken for this analysis operates in a least-cost optimising energy-economy-environment model, the discount rate is an important factor. A higher discount rate implies that policy interventions that have high upfront capital costs and good returns in the future (for example SWHs) are favoured less than if a lower rate is used. The current costs are counted fully but future benefits are discounted. Conversely, the higher discount rate favours technologies and policies with low initial costs but higher costs in the future (for example gas-fired power stations).

The Stern Review (2006) on the economics of climate change generated significant debate on appropriate discount rates. Some analysts suggested they had been very low (Nordhaus 2007) and had mainly been influenced by ethical considerations. Stern responded in clarifying that the discount rate is defined by the 'standard social welfare discounting formula $r = \eta\gamma + \rho$, where r is the consumption discount rate, η is the elasticity of the social benefits attained (also called the social marginal utility), γ is per-capita consumption growth rate, and ρ is the time discount rate (also called the pure rate of time preference)' (Stern & Taylor 2007: 203). He points out the ethical implications of using 2 per cent pure time discounting rate ($\rho = 2$), which halves the ethical weight given to someone born in 2008 relative to someone born in 1973. The discount rates in this book are composites, not pure time preference. The discount rate chosen is related to various ones chosen in public investments, private lending and planning studies.

In South Africa, discount rates vary between social discount rates, reflecting public investment at 8 per cent (Borchers et al. 2001; Davis & Horvei 1995), and private lending rates between 15 per cent and 20 per cent (SARB 2001). The first Integrated Energy Plan used a rate of 11 per cent (DME 2003d), although this may be revised for the second plan.

The general discount rate used in the study is 10 per cent, in real terms. However, we assume that poorer households have a higher discount rate than high-income households, but for poorer households we assume their time preference for money is 30 per cent (Banks 1999; Spalding-Fecher, Clark et al. 2002). In other words, poorer households strongly prefer money now to money later. The implication is that they will be less likely than other sectors to invest in technologies that will lead to energy savings in the future, even though they would reduce monthly energy bills.

Table 5.5 *Cost deflators based on Gross Value Added*

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

Sources: SARB (2005); Stats SA (2004b)

Costs are reported in 2000 rands. Where there is a need to adjust cost data from other years, a deflator based on Gross Value Added is used, as shown in Table 5.5.

Emission factors

Emission factors are needed to convert energy consumption (in energy units, for example PJ or GJ) to emissions. The IPCC default emission factors (in t C/TJ or t CO_2/TJ) are used for emissions of carbon dioxide, methane, nitrous oxide, nitrogen oxides, carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (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 are made.

For carbon dioxide from other bituminous coal, an emission factor of 26.25 t C/TJ is used instead of the IPCC default of 25.8 t C/TJ. The adjustment is based on direct measurements at South African coal-fired power stations (Lloyd & Trikam 2004). The higher emissions are consistent with the lower calorific value of South Africa's sub-bituminous coal at 19.59 MJ per kilogram, whereas the IPCC default value is 25.09 MJ per kilogram of 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 (sulphur dioxide, nitrogen oxides, carbon monoxide, NMVOC), but not particulate matter. Emission factors for particulates are highly technology-specific, and no similar set of default factors as for other pollutants was readily found. An important area for future research would be to examine the applicability of the international literature to South Africa (IIASA 2005; US EPA 2000). Future research should review previous work in South Africa (Howells 2004; NER 2004a) and establish a list of emission factors (kg TSP/TJ) for the particular technologies.

Conclusions on drivers of future trends

The discussion of economic growth, population, technology learning, fuel prices, discount rates and emission factors shows that the base case implemented in the model is driven by a set of complex factors. The critical assumptions made about these factors and how they might change in the future have been outlined. The drivers are important for policy cases, but in particular in shaping the base case.

The base case (sometimes also called the 'reference scenario') represents the continuation of current development trends, including some existing policies. The base case provides a benchmark against which policy cases can be measured. The next section presents key elements of the base case.

The base case

The base case presents a path of South Africa's energy development that can also be called 'current development trends'. The base case for this analysis is similar to that of government plans, the first Integrated Energy Plan (DME 2003d) and, for electricity, the second NIRP (NER 2004c). The technologies chosen for the NIRP were described in Chapter 4. Table 4.8 summarised the key characteristics of the technologies for electricity generation. The reference case for the NIRP was conducted in collaboration with Eskom, the NER with the Energy Research Centre's modelling group (NER 2004a), and the assumptions for the base case here are very similar.

An important difference relates to population projections. The assumptions made for this book were clearly stated earlier in this chapter. The population projections used in the Integrated Energy Plan were for 50 million (here: 47.4 million) and 57 million (49.1 million). While the Plan's projections are reduced from previous estimates, they are still higher. Another difference relates to confidential data used in previous studies, which were not available for this book.

The time frame for the base and policy cases is from 2001, the base year, until 2025. The modelling approach was to extend the model run to 2030 to avoid sudden changes in the end year. References to the 'end of the period' are for 2025. Costs are reported in year 2000 rands.

The major changes reported here are those for future demand in the energy sector as a whole. The broader analysis provides the context for the policies in the residential sector. The fuel mix for electricity generation is reported on the supply side. More detailed results of the base case will be elaborated, as the base case is used as a benchmark for new policy cases.

Fuel mix on the supply side

Given the focus of the analysis, the overall energy supply is reviewed briefly, before considering electricity supply in the base case in a little more detail. The overall mix of fuels in the base case is illustrated in Table 5.6. Clearly, coal dominates TPES, with most of it being used for electricity generation. Consumption at Sasol for coal-to-liquids provides a major share, with ‘other’ coal supply feeding industry and other domestic uses. Coal exports are deducted from indigenous production to reach the figure in ‘other’ coal production. Discard coal, as the name suggests, is not mined separately but would have been discarded. It will be used after 2010 for FBC.

Table 5.6 *TPES by fuel group in the base case*

	2001	**2005**	**2010**	**2015**	**2020**	**2025**
Coal for electricity	1 718	1 966	2 286	2 650	2 872	3 205
Coal other	624	647	648	646	648	490
Coal Sasol	859	859	859	859	859	859
Biomass	76	41	37	33	29	25
Crude oil	966	966	1 376	1 469	1 542	1 542
Discard coal	–	–	–	962	1 080	1 169
Hydro	7	7	7	7	7	7
Gas	98	98	98	98	98	98
Total PJ	4 347	4 583	5 311	6 723	7 134	7 395

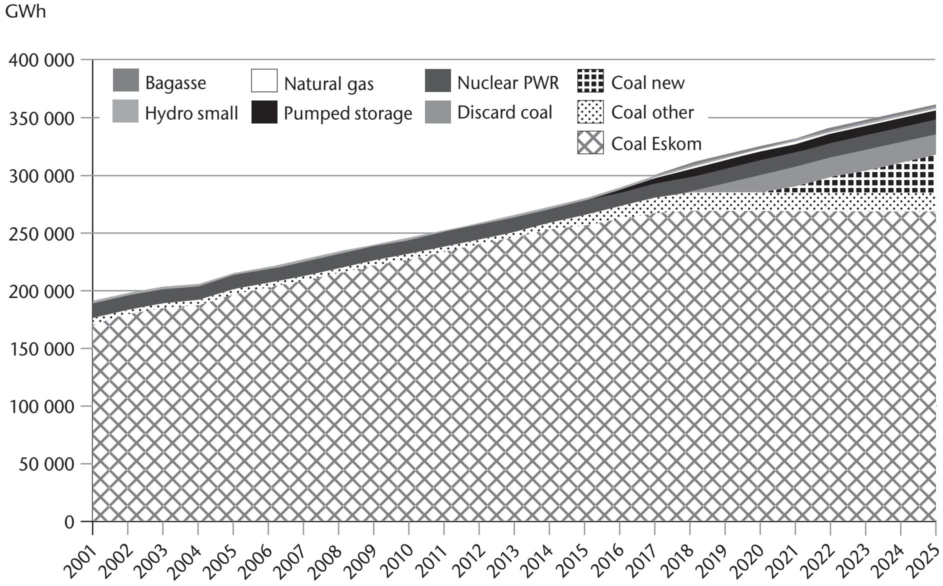
Source: Author’s own analysis, modelling data

As the table shows, the contribution of fossil fuels to primary energy supply increases, notably coal and discard coal, although gas remains constant. The contribution of hydroelectricity remains constant, with few large new sites available, while biomass declines as other fuels are preferred. TPES in 2001 is within half a percentage point of the 4 370 PJ reported in the National Energy Balance for that year (DME 2003a).

The fuel mix for electricity generation is illustrated in two ways. Figure 5.4 shows the power plants by the output of electricity generated. The plants are grouped by fuel to make the graph more readable. The most striking feature is the continued dominance of coal-fired power plants. Most of these are Eskom plants, but as generation from these levels off in the latter half of the 2020s, new coal (pulverised fuel) and FBC plants using discard coal come in (see later in this chapter). Nuclear power from Koeberg adds some more baseload from its PWR. Several types of plants provide peaking power: pumped storage, natural gas combined cycle, small hydro and the only renewable – bagasse co-generation.

Coal plants using pulverised fuel dominate the base case, warranting a brief summary of their key characteristics (see also Table 5.14). The stations have an investment cost just under R10 000 per installed kW. Variable O&M costs are low reflecting the relatively low cost of coal at R3.02 per GJ. Costs are unlikely to decrease very significantly over time and economies of scale have already been factored in. Since this is a mature technology, efficiencies of such plants have been improved in the past already and are assumed to remain at similar levels, 35 per cent (NER 2004c). Efficiencies assume that new stations are dry-cooled and use FGD. For South African coal characteristics, about 65 per cent of sulphur must be removed (NER 2004a) so that the dry FGD method at 70 per cent efficiency can be used.

Figure 5.4 *Electricity generation (GWh) in the base case, grouped by fuel*

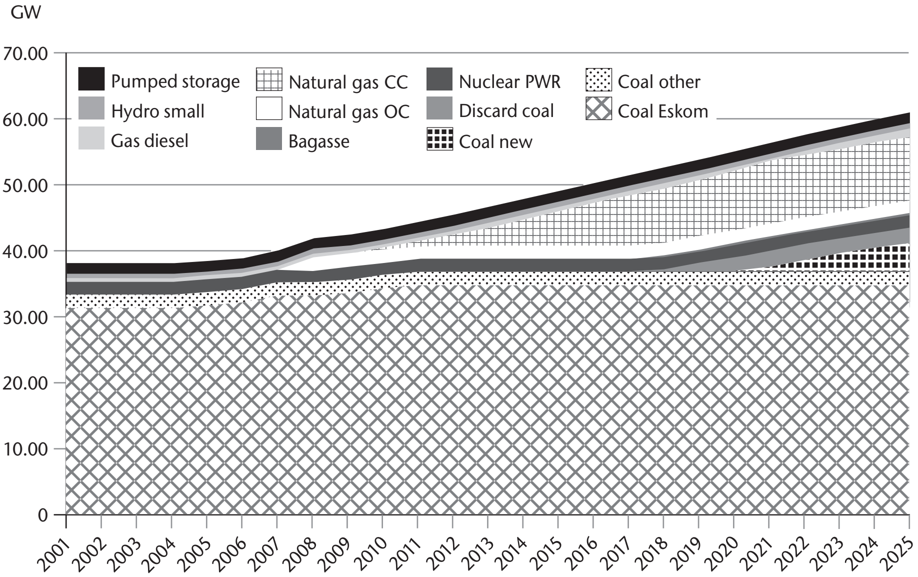


Source: Author's own analysis, modelling data

Figure 5.5 shows a similar picture, but by capacity (GW). The difference is striking – while coal is still clearly dominant, other technologies take up a much larger share than by generation (GWh). The difference reflects different load factors, that is, the extent to which plants are used – these would be high for baseload plants and low for peaking plants. Several plant types have capacity that does not generate electricity, notably open cycle gas and diesel turbines. Such plants might be built to maintain the reserve margin and for emergency and peaking power. Since the modelling framework chooses least-cost options, relatively expensive options would not be chosen to generate electricity.

The supply options exist to meet energy demand. The base case projections for energy demand from all sectors is presented first, before homing in on residential demand more specifically.

Figure 5.5 *Electricity capacity (GW) in the base case*



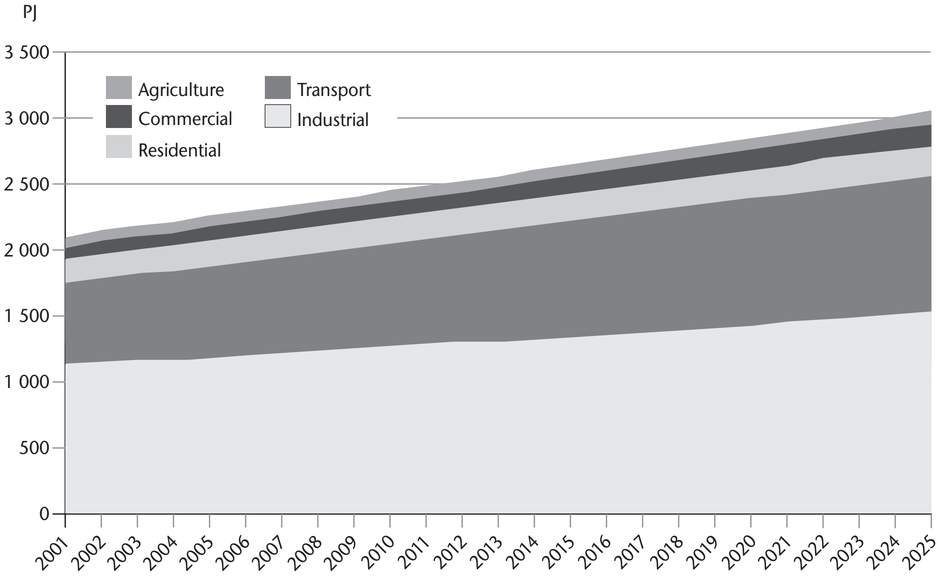
Source: Author's own analysis, modelling data

Demand projections

While the focus of analysis is the residential sector, the base case provides the context of the broader energy system. Figure 5.6 shows that the demand for future energy services comes predominantly from other sectors, the largest being industry and transport.

Fuel consumption in the base year for the reference case is dominated by industry at 54 per cent, with transport being the next highest at 29 per cent. The other sectors make up smaller shares, with residential (9 per cent), commerce (4 per cent) and agriculture (3 per cent). The transport and agriculture shares are similar to those reported in the National Energy Balance (DME 2003a). Industry is somewhat higher and commercial fuel consumption lower. Of particular note is that the residential sector here has a share that is lower than the 16 per cent of final energy consumption that can be calculated from the energy balance. Examining the latter data more closely shows that almost half (49 per cent) of the residential consumption derives from 'renewables and waste', the category which includes biomass (calculated from DME 2003a). Biomass data vary significantly from year to year and are highly uncertain; on their own, they constitute 8 per cent of final demand in the energy balance, that is, a greater amount than the difference between the share in this book and the energy balance. The approach taken here is to work with the detailed estimation of energy demand derived through bottom-up analysis. Results comparing policies *within* the residential sector would be relative and unaffected; care should be taken if comparing policies *across* demand sectors.

Figure 5.6 *Projected energy demand by sector in the base case*



Source: Author's own analysis, modelling data

Projections of residential energy demand

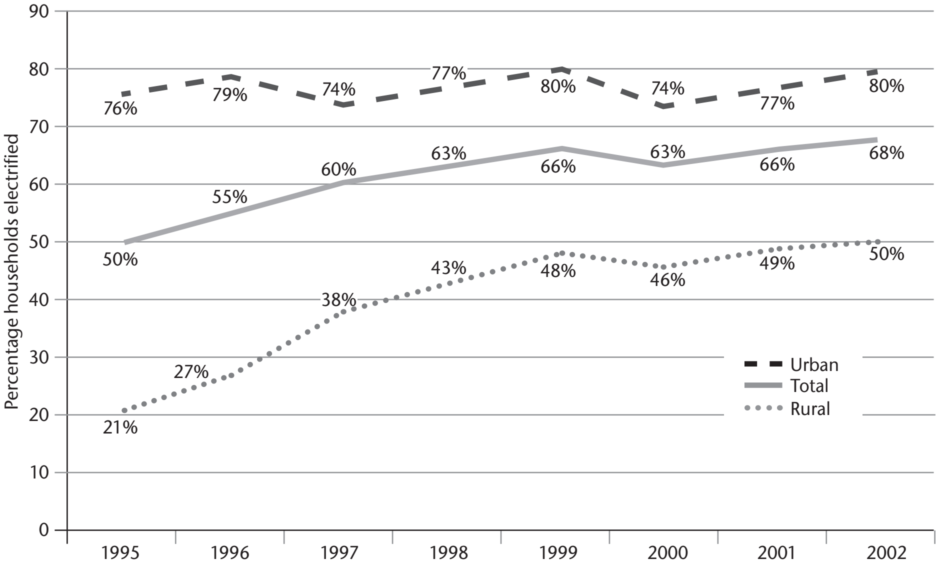
Given that the residential sector is a major focus of the modelling for this book, a more detailed description of future trends is warranted. The trends in the base case, that is, without policy intervention, are described here, followed by a section detailing the future policies.

One of the key changes since 1990 has been the electrification programme, which has gradually moved energy-use patterns to a greater reliance on electricity – although, as noted, affordability of using electricity remains an issue in low-income households. Many other fuels, such as kerosene, coal, fuel-wood and LPG, are used as well.

Figure 5.7 shows how electrification rates have increased since 1995, with urban centres reaching 80 per cent by 2002 despite their populations growing. While half of rural areas remained non-electrified by 2002, this was a significant increase from only 21 per cent electrified in 1995.

Universal access to affordable electricity will remain a cornerstone of policy for the sector and will be treated as a 'given' in considering policy choices. The government's commitment to achieving universal access has been reiterated in many policy speeches (Mbeki 2004a; Mlambo-Ngcuka 2002a, 2003, 2004).

Figure 5.7 *Trends in electrification of households in South Africa, 1995–2002*



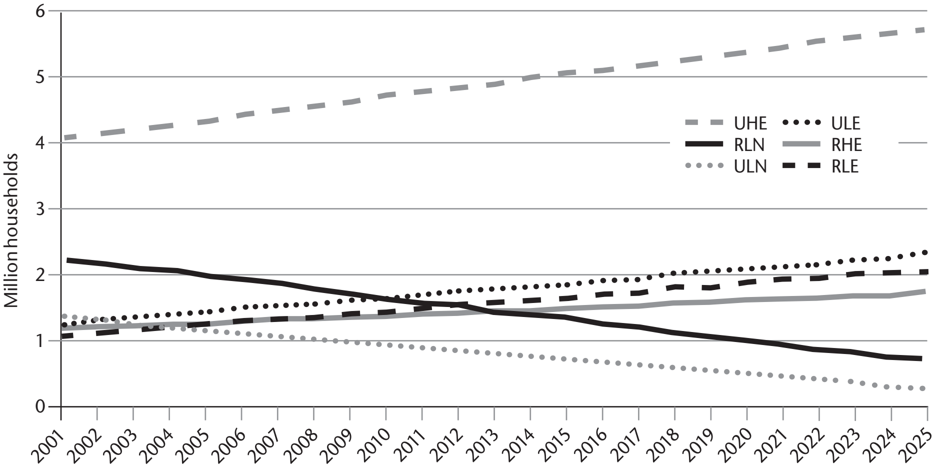
Note: The drop in urban electrification rates from 1999 to 2000 is explained by changes in the numbers of households reported in the 1996 Census. As a result, the number of households for statistical purposes increased markedly from 1999 to 2000 (NER 2001c).
Sources: NER (2001c, 2002a)

The base case assumes that the current development trend of electrification will continue. Having moved from roughly one-third to two-thirds with access to electricity in the 1990s, the trends continue. However, as the 'easier' connections were made first, the last third of households will be more marginal – both geographically and economically. Some rural households might remain distant from the grid, and their marginalisation in terms of poverty might mean that off-grid options do not reach them either. By 2030, it is assumed that almost all urban households and 90 per cent of rural households will have access to electricity.

Continuing electrification has implications for the household types as defined here. The two categories of non-electrified households (urban, ULN and rural, RLN) will decline, as can be seen in Figure 5.8. The growth of numbers in other household types is the result of three trends – increasing electrification, higher urbanisation and a moderate growth in total number of households. The growth in UHE households – where all three factors are positive – is the highest.

Projected future energy demand in the residential sector, in the first instance, would depend on the changing number of households in each group, as well as on the changes in energy services consumed by each household. Future household numbers, in turn, are likely to depend on population growth rates, the impact of HIV/AIDS, and migration patterns. Changes in useful energy intensity would depend on changing fuel use (notably electrification) and income levels. We assume that this pattern of household/population growth will continue, but that population growth rates will be lower due to the impact of HIV/AIDS. Since this important assumption is a driver of future energy patterns beyond just the residential sector, it was discussed together with other key assumptions about the future earlier in this chapter.

Figure 5.8 *Projected changes of household numbers in the base case, 2001–2025*



Note: See the list of acronyms for explanations of the abbreviations in the key.
Source: Author's own analysis, modelling data

The base case and all the policy cases assume increased access to electricity. Disaggregated by household type, household numbers shift from non-electrified households (ULN, RLN) to electrified household types. Assuming that urban electrification rates reach 99 per cent and rural 90 per cent by 2025, there are some 3 million fewer poor households unelectrified by the end of the period. Much of this is made up by 2.4 million more low-income electrified households (ULE, RLE), plus a smaller shift into the higher-income category. All this occurs against a backdrop of household growth occurring mainly in urban areas, with this group growing by almost 2 million households over the period.

Changes in population have a relatively small direct impact on energy demand, since the residential sector accounted for only 16 per cent of final energy consumption in 2001 (DME 2003a). However, demographic changes have significant indirect consequences. The impact of reduced population growth would be felt more strongly through reduced labour, consumption of goods and other factors reflected in GDP. Understanding potential changes in future residential energy demand is also particularly important in social development and improving the quality of life of ordinary South Africans.

Energy demands for different end uses by each household type are shown in Table 5.7. Estimates of demands used in the modelling for the base year (2001) are shown together with projections for the end year (2025) and an intermediate year (2014), for which the energy-efficiency target is set.

Table 5.7 *Energy demand (PJ) by household type and end use, selected years*

		RHE	RLE	RLN	UHE	ULE	ULN
Cooking	2001	1.79	0.59	4.37	15.84	1.43	1.89
	2014	2.22	0.87	2.8	19.29	2.06	1.1
	2025	2.58	1.11	1.48	22.2	2.6	0.43
Lighting	2001	3.7	1.31	0.04	7.64	2.05	0.02
	2014	4.58	1.93	0.02	9.3	2.96	0.01
	2025	5.33	2.46	0.01	10.7	3.74	0
Other electrical	2001	3.28	0.08	–	12.57	0.11	–
	2014	4.34	0.12	–	16.33	0.17	–
	2025	5.33	0.16	–	19.86	0.22	–
Space heating	2001	1.68	0.53	4.8	16.31	2.42	1.83
	2014	2.09	0.78	3.08	19.85	3.5	1.06
	2025	2.43	1.0	1.63	22.85	4.41	0.41
Water heating	2001	2.85	0.67	2.75	23.22	4.35	0.87
	2014	3.53	0.99	1.76	28.27	6.29	0.5
	2025	4.11	1.26	0.93	32.54	7.93	0.2

Note: See the list of acronyms for explanations of the abbreviations in the column headings.
Source: Author's own analysis, modelling data

The demands are total demands for the household type, so that declines in the RLN and ULN categories should be understood against the decline in numbers of these households. Overall, energy demands are increasing over the period. Most of the increase derives from increasing incomes – more households move from the poorer to richer classification, where more energy is used per household.

Having outlined how energy patterns unfold in the base case, an overview of the policy cases is presented in the following sections – first a brief overview, before the residential energy policies and electricity supply options are each outlined in more detail.

Overview of policy cases

Sketching a policy case of sustainable development should not suggest that this is easy to achieve. The challenge of building new power stations presents a major opportunity to choose cleaner technologies, but significant resources and effort are required to make such major changes. Some models that focus on sustainability too easily assume a shift away from fossil fuels for coal-dependent countries (Berk et al. 2001). Such a transition involves major changes in infrastructure and the requirements should be carefully examined in policy analysis. A sustainable development policy that has low impact on the local environment, promotes access and favours an equitable allocation of wealth and resources represents a major challenge.

A short overview of the policies in the residential demand and the electricity supply sectors is provided in Table 5.8. The policies, described in more detail in the following two sections, are grouped under electricity and residential sectors. The electricity policies focus on supply from renewable energy, PBMR nuclear and importing hydro or gas, and also consider the impacts of cleaner coal in the base case. On the residential demand side, efficiency in lighting, water heating and space heating (houses) is complemented by a fuel switch to LPG.

Table 5.8 *Summary of policy cases in residential demand and electricity supply sectors*

Short name	Key features	Markal name
	Households	
SWH/GB	Cleaner and more efficient water heating is provided through increased use of SWHs and GBs. The costs of SWHs decline over time, as new technology diffuses more widely in the South African market.	RESWHGB
CFLs	More efficient lighting, CFL use, spreads to more households, with a slight further reduction in costs beyond that achieved already.	RESCFL
Efficient houses	The shell of the house is improved by insulation, prioritising ceilings. Since the technology has zero fuel costs, bounds are placed to ensure that no more houses are built than households exist.	RESHOUSE
LPG switch	Households switch from electric and other cooking devices to LPG stoves and rings.	RESLPG
Combined elec.	The combined effect of all the above policies.	RESCMB
	Electricity	
Renewable energy	The share of renewable electricity increases to meet the target of 10 000 GWh by 2013. Shares of solar thermal, wind, bagasse and small hydro increase beyond the base case. New technology costs decline as global production increases.	ELCRET
PBMR	Production of PBMR modules for domestic use increases capacity of nuclear up to 4 480 MW by 2020. Costs decline with national production and initial investments are written off.	ELCPBMR
Hydro	Share of hydroelectricity imported from SADC region increases up to 15 GWh by 2010, from 9.2 GWh in 2001. As more hydro capacity is built in southern Africa, the share increases.	ELCHYDRO
Gas	Sufficient gas is imported to provide 1 950 MW of combined cycle gas turbines, in units of 387 MW.	ELCGAS
Base w/out FBC	FBC using discarded coal, a low-cost resource, is part of the base case already. The implications of what would have happened without this resource are explored.	EBASEFBC

Source: Author's own analysis, modelling data

The energy policies are elaborated in the following two sections. The data input for these policies and its implementation in the modelling framework is described.

Residential energy policies

Having examined the broader energy sector, the chapter now turns to the first focus area, energy policies in the residential sector.[2] The analysis disaggregates the residential sector in a way that has not been done in previous national energy modelling in South Africa. Detailed surveys and analyses have been conducted in understanding household energy use (Cowan 2003; Eberhard & Van Horen 1995; Mapako & Prasad 2005; Mehlwana 1999b; Mehlwana & Qase 1998, 1999; Prasad & Ranninger 2003; Simmonds & Clark 1998; Spalding-Fecher et al. 1999; Winkler, Spalding-Fecher, Tyani & Matibe 2000), but these have generally focused at a local level and have not linked into modelling. Rural villages' energy systems in South Africa have been modelled (Howells et al. 2005), but again not linked into national projections.

Defining six household types

The key unit in the residential sector is the household. Energy is mostly related to households rather than to individuals – for example, electricity grid connections are made to households and monthly expenditure is better known per household than per person.

Six household types are defined here, differentiated along urban/rural, high-/low-income and electrified/non-electrified dimensions. The energy-use patterns of richer and poorer households differ quite markedly, as do those of rural and urban households. Given the policy drive since the 1990s to universal electrification, 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 – 11 205 705 according to the 2001 Census (Stats SA 2003b). Definitions of urban and rural are technically difficult in South Africa, exemplified by the existence of 'dense rural settlements' like Bushbuckridge and Winterveld, and the Census no longer reports this distinction. Other statistical publications continue to report different patterns of urban and 'non-urban' (e.g. Stats SA 2000, 2002). For the purposes of evaluating electrification, the NER distinguishes between urban and rural connections (NER 2001a, 2002a), so for the purposes of this study we can assume a 60:40 split of urban to rural households.[3]

There is no single source breaking down these household types by income group. However, the income statistics are reported for urban and non-urban households in Table 5.9, dividing each group into quintiles.

Table 5.9 *Income in urban and non-urban areas in 2000 market values*

	Income (%)	
Quintile (1995)	*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

Source: Stats SA (2002)

It seems reasonable to define energy poverty for the purposes of this analysis by treating the bottom two quintiles as 'poor', that is, the poor are those with an annual per capita income less than R4 033 and expenditure less than R3 703 (Stats SA 2002: Figure 4.9).[4] Consequently, 61 per cent of urban households could be considered 'not poor' or 'rich' (medium to high income), while in rural areas only 31 per cent would fall into this category. In other words, almost 7 out of 10 rural households are 'poor' by these assumptions.

The average expenditure per household of the groups is reported by Statistics South Africa (2002). The average income of 'poor' households can be taken as R7 547 (break point between bottom two quintiles) and R41 041 (upper point of quintile 2). For analysis of the household types defined here, deductions about relative urban/rural incomes are possible; rural household incomes were about 41 per cent of urban incomes in 2000 (Stats SA 2002: Figure 4.9). No breakdown of incomes between electrified and non-electrified households was found at national aggregate level.

The proportion of poorer and richer households varies across urban and rural areas, with the former 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 5.10.

Table 5.10 *Numbers and % of rural and urban households, electrified and not*

	Electrified	**Unelectrified**	**Rich**	**Poor**
Urban – households	5 330 166	1 349 240	4 074 438	2 604 968
Share of total (%)	79.8	20.2	61	39
Rural – households	2 276 729	2 249 571	1 403 153	3 123 146
Share of total (%)	50.3	49.7	31	69

Sources: Author's own calculations, based on NER (2002a) and Stats SA (2002)

Taking three categories – richer/poorer, urban/rural, electrified/non-electrified – would yield eight household types. However, richer urban households are all electrified, as are most rural richer households. Again, there is no comprehensive statistical survey available and it is furthermore clear that access to electricity still differs by population group. Almost all African (99 per cent) and coloured (>99 per cent) 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 per cent of African and 93 per cent of coloured households) (Stats SA 2000: 70). These percentages refer only to the highest-income group and, weighted by population groups, would give as electrified some 84 per cent of richer rural households. Further calculations reveal that 33 per cent of the rural poor are electrified, while not quite half (48 per cent) of the urban low-income households have access to electricity. With this information, it is possible to derive the number of households in each of six household types shown in Table 5.11.

Table 5.11 *Household types, with total numbers in 2000, shares and assumptions*

Household (HH)	Acronym used in this book	No. of households	Share of all households (%)	Notes
Urban richer electrified	UHE	4 074 438	36.4	Virtually 100% of richer urban HH are electrified
Urban poorer electrified	ULE	1 255 728	11.2	Remainder of urban electrified must be poorer
Urban poorer electrified	ULN	1 349 240	12.0	Rest of urban HH must be non-electrified
Rural richer electrified	RHE	1 181 279	10.5	Assume 84% of richer rural HH are electrified
Rural poorer electrified	RLE	1 095 449	9.8	Remainder of rural electrified must be poorer
Rural poorer unelectrified	RLN	2 249 571	20.1	Rest of rural HH must be non-electrified; number of HH includes the few richer rural not electrified

Source: Author's own calculations, based on assumptions and data in the text

Of course, reducing all households in the country to six types still abstracts enormously from the rich diversity of different energy patterns. However, for purposes of national-level policy, cases provide some distinction of the major residential energy-use patterns. Perhaps the biggest omission is the lack of geographical disaggregation – poorer urban unelectrified households in Cape Town, for example, would use paraffin extensively for cooking, heating and lighting (Mehlwana & Qase 1999), while households in the same category in Gauteng are more likely to use locally available coal (White et al. 1998). Apart from responding to different fuel availability, there are also climatic differences.

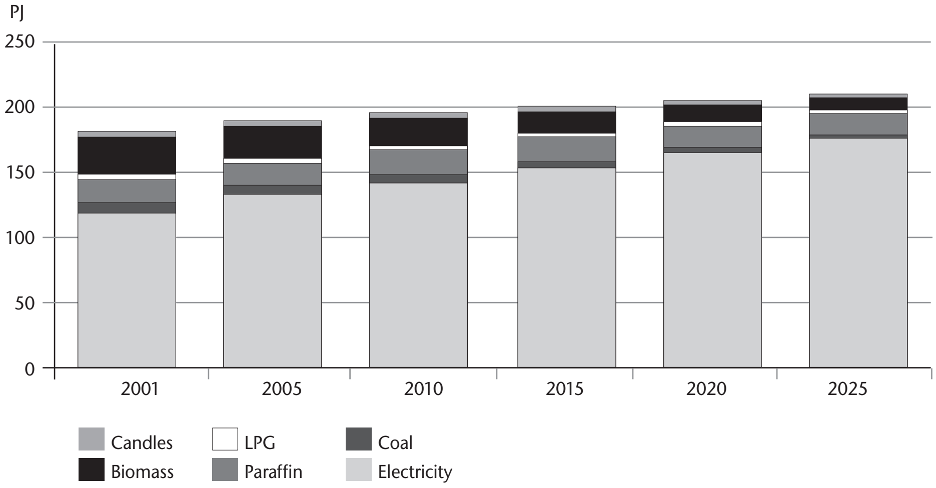
Since each additional household type requires additional data in the modelling, the number of household types needs to be limited. Further disaggregation could be achieved in future work, but is constrained by our limited knowledge of distinctive energy-use patterns. For example, there is relatively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

Energy-use patterns in the household types

Energy-use patterns in the residential sector show the continued use of multiple fuels. Five major end uses are 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 5.9). This reflects both in the increased use of energy, but also in the relatively high efficiencies of electrical appliances. The bar for electricity in 2001 represents 34.6 TWh or 124.5 PJ of final energy (NER 2001a).

Figure 5.9 *Trends in fuel shares in the residential sector in the base case*



Source: Author's own analysis, modelling data

Over time, electricity increases its share in overall residential demand, growing faster than other energy carriers. As noted, patterns of household energy demand differ significantly in richer and poorer, urban and rural households (Mehlwana 1999b; Mehlwana & Qase 1998; Simmonds & Mammon 1996). Electricity contributes a larger share of household energy use in urban areas than in rural, while the inverse is true for fuel-wood.

Consumption of other fuels is very difficult to attribute to individual end uses. Survey results (where they ask about energy consumption by household type at all) typically report monthly consumption of fuel. For example, household members may be able to give an indication of the litres of paraffin used per month, but not know how much is used to heat the house, boil water, cook or produce light.

Energy is needed to provide key services – for lighting, electrical appliances, cooking, and heating water and space. Five end uses are considered in the modelling framework. The appliances (residential end-use technologies) described in the following section convert energy into services. The mix of technologies differs by household type.

Table 5.12 *Energy demand (GJ) by household type for each end use*

	UHE	ULE	ULN	RHE	RLE	RLN
Cooking	3.9	1.1	1.4	1.5	0.5	1.9
Water heating	5.7	3.5	0.6	2.4	0.6	1.2
Space heating	4.0	1.9	1.4	1.4	0.5	2.1
Lighting (in PJ)	1.9	1.6	0.01	3.1	1.2	0.02
Other electricity	3.1	0.1	–	2.8	0.1	–

Notes: GJ per household per year, 2001.
See Table 5.11 for explanations of the abbreviations in the column headings.
Source: Author's own analysis, modelling data

Household energy-use patterns vary across the six household types. Table 5.12 shows the consumption for each end use for the base year 2001 (see Table 5.7 for aggregated demand, projected 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 5.13.

Characteristics of energy technologies

Markal is a technology-rich modelling framework. Demand for useful energy services is met by a range of technologies. The previous section indicated how these technologies provide energy services for cooking, heating, lighting and other end uses. The key characteristics of technologies included for the residential sector are shown in Table 5.13. Of course, there are many more technologies that are used, but some of the major energy-consuming ones have been included here. The information is organised by the services that households require – the end uses of cooking, water heating, space heating, lighting and electrical appliances.

The nominal appliance costs were collected by the author for a study in early 2005 (Winkler, Howells & Alfstad 2005). They were deflated from the end of 2004 to provide costs in year 2000 rands.

Table 5.13 *Key characteristics of energy technologies in the residential sector*

Fuel consumed	Device	Efficiency	Capital cost –nominal	Adjusted cost	Residual capacity*	Lifetime
		%	*2005 rand*	*2000 rand*	*PJ*	*years*
Cooking						
Electricity	Hotplate	65.00	229	178	0.6559	5
	Oven	65.00	2 349	1 823	16.2011	9
	Microwave	60.00	874	678	0.1004	5
Paraffin	Wick	40.00	107	83	0.1657	3
	Primus	42.00	37	29	2.4558	6
LPG	Ring	53.00	249	193	0.7088	5
	Stove	57.00	4 995	3 877	1.1136	9
Wood	Stove	25.00	848	687	4.1593	9
Coal	Stove	13.00	5 231	4 060	–	11
	Brazier	8.00	0	0	–	1
Water heating						
Electricity	Geyser dummy	100.00	2 172	1 686	29.1709	22
	Geyser, no blanket	70.00	–	–	–	22
	GB	79.55	150	116	–	22
Paraffin	Wick/kero/pot	35.00	37	29	1.8019	3
LPG	Geyser	84.00	4 298	3 479	0.2936	22
Solar	SWH (integral)	100.00	6 500	5 045	0.1922	17
Coal/wood/wastes	Stove (jacket/pot)	25.00	0	0	2.5709	1
Space heating						
Electricity	Radiant heater	100.00	100	78	11.8984	6
	Rib/fin/radiator	100.00	968	751	7.3770	9
Paraffin	Heater	73.00	59	46	3.4390	9
LPG	Heater	75.00	993	771	0.3012	5
Wood	Open fire/stove	40.00	0	0	–	–
Coal	Stove	59.00	5 231	4 060	–	11
	Brazier	8.00	0	0	–	1
Lighting						
Electricity	Incandescent	100.00	3	2	14.2820	1
	Fluorescent	290.29	13	10	–	4
	CFLs	400.00	17	14	0.0989	10
Paraffin	Wick	1.71	5	4	3.8536	4
	Pressure	7.43	192	155	–	4
LPG	Pressure	5.71	250	194	–	4
Candles		0.05	1	1	–	0.01
Other electrical appliances						
Electricity	Appliances	80.00	Various	Various	16.0407	5

Notes: *Residual capacity refers to the capacity available in the base year, without any further investment.
This is not assumed for all cases, hence empty cells; other empty cells are because absence of a geyser blanket incurs no cost.
Sources: De Villiers & Matibe (2000); DME (2003d); Winkler, Howells & Alfstad (2005); pers. comm. Cowan 2005 and Lloyd 2005

Lifetimes and efficiencies are taken from previous studies (De Villiers & Matibe 2000; DME 2003d), updated in some cases by expert input (pers. comm. Cowan 2005[5]; pers. comm. Lloyd 2005[6]). 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.

Penetration rates for different technologies were derived from existing technology shares of useful energy demand for the base case. In the modelling framework, upper and lower bounds were set, by defining user constraints in Markal. In the base case, these remained at the same level, the existing contribution of the technology to the end use. In policy cases, as described below, different values can be set for upper and lower bounds. A lower bound will require a certain amount of investment in the technology, but the model can seek the most cost-effective solution between the lower and upper bounds. Upper bounds are useful to prevent investment beyond known limits (for example, the number of households in South Africa).

Policy interventions in the residential sector

Having described the base case overall and provided more background on current trends and future projections for the residential sector, the chapter now turns to the policy interventions. In keeping with the methodology, the policy interventions in the residential sector modelled in this book should contribute further to development objectives, beyond what has already been achieved (see Chapter 3 and 'Overview of policy cases' in this chapter). People do not want energy for its own sake, but for the services that it provides. The policies considered focus on improving access, using cleaner and more efficient fuels, to provide energy services – energy to heat water, to cook food, and to light houses and keep them warm.

CLEANER AND MORE EFFICIENT WATER HEATING

Water heating uses up to 30 per cent of household total energy (DME 2004a) and so an energy-saving policy examines the installation of SWHs in middle- and upper-income households. Establishing local production of new SWH technology would assist in bringing upfront costs down. For electrified poorer households (ULE, RLE), GBs are promoted. The policy case is referred to in shorthand as 'efficient water heating' or 'SWH/GB'.

The development objectives of improving water heating by SWH/GB are:

- to make water heating more affordable due to reduced fuel (or electricity input);
- to enhance environmental health by avoiding the use of energy carriers other than solar energy and electricity to heat water, so reducing the health impacts of indoor use of fuels such as coal and paraffin;
- to use electricity more efficiently, where regular geysers are used; and
- to reduce household energy expenditure for water heating, with savings available to be spent on other life-improving activities, or using more hot water (itself a benefit).

The broad characteristics of SWHs and GBs are described in Table 5.13. A policy promoting these technologies is implemented in the modelling framework by allowing wider ranges for the penetration rates of SWHs and GBs for electrified households. In the base case, energy for water heating continued in the proportions of the base year, although total energy use could increase. However, one should consider the maximum penetration rates achieved elsewhere, which previous studies found to be from 20 per cent (De Villiers & Matibe 2000) to 33 per cent (DME 2004a). Based on calculations from the White Paper on Renewable Energy, a more optimistic approach for the policy case could increase up to 60 per cent (DME 2003c). A higher level is assumed only for urban medium- to high-income households and that only after 25 years (UHE: 50 per cent for SWHs, 20 per cent for GBs). For urban low-income and richer rural households, the analysis stays within the range (ULE and RHE, 30 per cent SWHs and 20 per cent GBs), while 20 per cent of rural households use SWHs and GBs. A brief sensitivity analysis on widening the ranges fully showed that the model would only invest in SWHs to the same extent as in the base case, providing no heuristic value. The modelled case with the ranges stated above still allows the model room to choose between the most cost-effective means for water heating, but requires a minimum level beyond electric geysers of 10 to 20 per cent. The results are then compared to the base case (Chapter 6).

The initial cost of SWHs is significantly greater than for electric geysers (see Table 5.13); however, over time, savings on electricity bills make up for the initial cost. The literature reports a 60 per cent saving of electricity for SWHs (Karekezi & Ranja 1997; Spalding-Fecher, Thorne et al. 2002). Geyser blankets, with lower upfront costs (~R150 [pers. comm. Borchers 2005[7]]), are available to all households, including poorer ones. According to the DME (2004a), 'virtually no SWH are encountered in low-cost housing areas' in 2004. Existing homes can also insulate electric geysers, since only 1 to 3 per cent currently do so (pers. comm. Borchers 2005), with the literature reporting a 12 per cent saving (EDRC 2003a; Mathews et al. 1998).

The policy case assumes that SWH costs decline over time, as new vacuum tube technology brings costs to a range of R4 000 to R6 000 per system (pers. comm. Borchers 2005). The technology already exists in South Africa, but is not yet widely dispersed (pers. comm. Morris 2005[8]). Since this cost reduction relies on economies of imported components (the vacuum tube), it is likely to be a step-change and not to be continued. The modelling assumes that investment costs decrease from R6 500 to R5 000. For the policy case, we assume that this cost reduction occurs by 2010, providing a 5 to 7 per cent reduction per year. Some further learning-by-doing and economies of scale in local manufacturing are possible later, but it is assumed that this has a more moderate rate of 2 to 3 per cent per year.

Efficient lighting

The policy case for efficient lighting examines increased penetration rates of CFLs. Development objectives include providing more affordable lighting, saving on energy bills for lighting, or using savings for increased lighting services. More lighting can contribute to education – through studying at home – and safety. Lighting is one of the smaller end uses compared to water heating, cooking and space heating, but often is used extensively in newly electrified households.

From the utility's perspective, lighting demand has a high degree of coincidence with peak demand, especially in winter when daylight fades early and the peak occurs in the evening. CFLs can therefore reduce expensive peak demand. 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.

Efficient lighting for UHE, ULE, RHE and RLE households occurs in the base case. The Efficient Lighting Initiative pursued a strategy of buying down the price of CFLs through a subsidy programme with participation from major manufacturers, in the expectation that prices would stabilise at new lower levels (ELI 2005). This would lead to higher sales and market penetration. One can assume that most of the price decline in CFLs happened by 2005, but a further drop to R10 in real terms by 2010 is included (pers. comm. Bredenkamp 2005[9]).

It is assumed in the base case, as in the second NIRP (NER 2004c), that the share of CFLs for electric lighting could increase up to 20 per cent. Even in the policy case, it is unlikely that 100 per cent of households will use CFLs, based on studies in the Netherlands, Germany and Denmark where penetration is high. In these countries, about half the households have CFLs installed (Netherlands 56 per cent, Germany 50 per cent and Denmark 46 per cent) (Kofod 1996). These high penetration rates are probably not matched anywhere else in the world and are the upper bound for our reference case, at 40 per cent for poorer households and 50 per cent for richer ones. The model still chooses the least-cost option; it is not required to meet an upper bound.

EFFICIENT HOUSES

The DME (2001c) suggested in its Strategy on Renewable Energy that housing could be made more sustainable if 50 per cent of all new houses built (including RDP houses) incorporated climate-conscious solar passive design principles in their construction, thereby eliminating the need for space heating and cooling. Housing developments in coastal areas already qualify for an incremental subsidy of R1 003 for 'weatherisation'.

More efficient houses may make economic sense, but are they affordable? The issue of affordability is prominent in this regard. While cost-benefit analysis of efficient houses indicates that they make financial sense (Winkler, Spalding-Fecher, Tyani & Matibe 2002), the upfront costs are typically beyond the reach of poorer households. The higher discount rate (30 per cent against the general rate for the modelling of 10 per cent) reflects the strong preference of these households for money in the present. A relatively small additional investment in housing for poorer communities creates more comfort, reduces household energy costs and cuts emissions from the residential sector (Winkler, Spalding-Fecher, Tyani & Matibe 2002). Financing mechanisms are an important policy consideration, as are building codes to make efficiency measures in housing mandatory.

The development objectives of efficiency in housing have much in common with more efficient water heating and lighting. Again there are energy savings for households, with reduced fuel expenditure for space heating. Less indoor space heating with other fuels contributes to better environmental health. Efficient houses are more comfortable, being cooler in summer and warmer in winter, therefore improving quality of life. Background research for low-cost efficient houses in Khayelitsha confirms this (SSN 2004).

Implementing the policy case in the model, one should first note that a constraint is needed in the base case. Without a limit, the model would implement excessively in efficient houses, since they have no fuel cost at all. Indeed, in an optimised base case, some 14 million efficient houses would be built in the urban-richer category (UHE) alone – the projection is that there might be about 3 million households in this category by 2025. A cap is placed on households in the base case, increasing from a higher estimate of 5.0 per cent of households to 50.0 per cent by the end of the period. In the base case, only 0.5 per cent of households were assumed to have SWHs. The policy case allows a more generous upper limit, drawing on the DME estimate.

Cooking more efficiently with LPG

The policy cases examined thus far in the residential sector all have efficiency gains. For cooking, it is not likely that appliances using a particular fuel, for example electric stoves, would get very much more efficient. However, switching to other fuels can have benefits. LPG is the policy option examined here. It has the advantage that it is possible to switch from electricity to LPG but, particularly for households not using electricity for cooking, it is an attractive option. The other fuels – paraffin, coal and wood – all have significant health impacts when used indoors for cooking. LPG can offer a cleaner, safer fuel which is also more efficient.

As with other policy cases on the demand side, the modelling approach is to increase the range for LPG for cooking. An increased lower bound means that some LPG must be used and the implications are examined in the results. Lower limits were established at 20 per cent, except where the base case already indicated that LPG as a least-cost option achieved a higher rate (ULN 21 per cent, RHE 33 per cent). Upper bounds between 40 per cent and 60 per cent were set, depending on the level already achieved in the base case. Up to this limit, the model chooses the most cost-effective mix.

Cost-effectiveness is similarly appropriate for electricity supply options. Electricity supply needs to meet growing demand and the cost of competing options is one key criterion. The following section examines the major options and their characteristics.

Electricity supply options

The excess capacity that South Africa developed in the 1970s and 1980s and that lasted into the 1990s has come to an end (see Chapter 4). Over the next two to three decades, some 17 000 MW will need to be built at approximately 1 000 MW per year. After 2020, many large stations will near the end of their life, and although options for refurbishment will then be considered, a significant portion of existing capacity will need to be replaced.

The options for electricity supply were reviewed in Chapter 4. The options included all available energy resources and conversion technologies – coal, nuclear, imported gas and hydro, and renewable energy. The options considered for the NIRP were reported in Table 4.8. The major options include:

- baseload coal stations, with FGD;
- cleaner coal technologies, in particular the FBC technology;
- nuclear technology in the form of the PBMR;
- imported hydroelectricity from Mozambique, Zambia or the Democratic Republic of Congo;
- imported gas; and
- RETs (wind, solar thermal, biomass, small hydro).

Characteristics of electricity supply technologies

Key characteristics of the electricity supply options are summarised in Table 5.14. The data served as input to the modelling and are broadly consistent with the second NIRP. Presenting the data in a consolidated table allows comparison across the various options.

Table 5.14 *Characteristics of electricity supply technologies in policy cases*

Type	Units of capacity	Investment cost	Lifetime	Lead time	Efficiency	Availability factor
	MW	*R/kW*	*Years*	*Years*	%	%
Imported gas						
Combined cycle gas turbine	387	4 583	25	3	50	85
Open cycle gas turbine (diesel)	120	3 206	25	2	32	85
Imported hydro						
Imported hydro	9 200 GWh p.a.	–	40	6.5	–	–
Renewable energy						
Parabolic trough	100	18 421	30	2	100	24
Power tower	100	19 838	30	2	100	60
Wind turbine	1	6 325	20	2	100	25, 30, 35
Small hydro	2	10 938	25	1	100	30

→

Type	Units of capacity	Investment cost	Lifetime	Lead time	Efficiency	Availability factor
	MW	*R/kW*	*Years*	*Years*	*%*	*%*
Landfill gas (medium)	3	4 287	25	2	n/a	89
Biomass co-gen. (bagasse)	8	6 064	20	2	34	57
Nuclear						
PBMR initial modules	165	17 136	40	4	41	82
PBMR multi-modules	171	10 761	40	4	41	82
Coal						
New pulverised fuel plant	642	9 980	30	4	35	72
FBC (with FGD)	233	9 321	30	4	37	88
Storage						
Pumped storage	333	6 064	40	7	Storage	95

Note: For imports, only the cost paid for electricity is of interest to the national energy model, not investment, efficiency or availability.
Sources: Markal database for this model (see Winkler, Howells & Alfstad 2005); NIRP database (NER 2004a); DME (2003d)

The background to the energy technology characteristics and more details on their implementation in the model are presented in the following sections.

The green option: RETs

MEETING THE TARGET

The energy minister restated in 2002 that ‘renewable energy plays an important role in the energy mix and increases supply security through diversification’ (Mlambo-Ngcuka 2002a). RETs[10] can contribute not only to diversity of supply, but also to another major energy policy objective – managing the energy-related environmental impacts. Whether these aims can be achieved at a large scale, while also meeting the socio-economic needs of the country, is a key question.

In 2005, the Renewable Energy Finance and Subsidy Office was established. The Office 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, procedural requirements, etc.). A once-off capital grant was made available for project developers in the 2005/06 and 2007/08 financial years. The subsidies for 2005/06 were R250 per kW capacity for electricity, R273 per kl capacity per year for biodiesel and R167 per kl capacity per year for bio-ethanol or equivalents for other RETs. The subsidy cannot exceed 20 per cent of the total capital cost and minimum project size is 1 MW (for electricity), implying a subsidy amount of R250 000.[11]

RETs (other than hydro) in South Africa have been largely confined to the realm of research, development and demonstration (see Chapter 4). In 2003, the government adopted a target of 10 000 GWh renewable energy consumption (DME 2003c). Although this is not limited to electricity but also includes solar water heating and biofuels, the policy document explicitly calculates that this would be 4 per cent of expected *electricity* demand in 2013. The approach taken here is to examine the durability of reaching 10 000 GWh of electricity from renewable energy sources by 2013. A number of technologies could contribute to the goal, including solar thermal electricity (both the parabolic trough and 'power tower' options), wind turbines, small hydro facilities and biomass co-generation (already done in the pulp and paper and sugar industries).

Approach to modelling RETs

To implement the policy case with various RETs in Markal, a lower bound was set to meet the target, moving incrementally up to 10 000 GWh from renewable resources by 2013. After 2013, a lower limit of 10 000 GWh is maintained; that is, the model can choose to generate more as long as it does not exceed the capacity. Global capacities for renewable energy were reviewed in Chapter 4; more specific factors developed for South Africa are shown in Table 5.15.

Table 5.15 *Technically feasible potential for renewable energy technologies*

RET	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
Solar water heating: commercial	2 026	2.0
Solar water heating: residential	4 914	6.0
Wind	64 102	74.0
Total	86 843	100.0

Source: DME (2004a)

The capacity for wind is higher than the range suggested in previous studies – the highest estimate of *theoretical* potential in Table 4.6 was 50 PJ (13 889 GWh). One would expect technical potential to be less than theoretical. However, since both this number and the estimate above well exceed the renewable energy target, the 50 PJ limit for wind is used.

A more aggressive approach would have been to keep increasing the target linearly. The approach taken here has the advantage of meeting the target, but allowing the model to choose how to meet it with the various options.

- Solar thermal plants use various arrangements to collect sunlight on a central receiver, generating steam to drive a turbine. The 'power tower' uses mirrors to focus on a central receiver, with molten salt providing some temporary storage of energy. The parabolic trough concentrates sunlight on long tubes containing suitable liquid. Areas of the Northern Cape have insolation of 6 000 W/m^2 (DME et al. 2001).

- Installed wind capacity in South Africa is limited to two projects in the Western Cape, Eskom's turbines at Klipheuwel and the Darling wind farm (DARLIPP). Eskom installed a 660 kW wind facility in August 2002. Eskom currently charges the Swartberg–Malmesbury municipality approximately 20c per kWh, while Cape Town pays 11 to 12c per kWh for bulk electricity. Several areas in South Africa, especially along the coast, have good wind sites, with estimated mean annual wind speeds of between 4 and 8 metres per second at a height of 10 metres above the ground (DME et al. 2001). However, wind is a site-specific resource, so an upper bound of 50 PJ is used (Howells 1999). Availability is an important factor with the intermittency of wind. The turbine availability is considered high, even though Eskom is experiencing lower availabilities at Klipheuwel with its three turbines reporting 73 per cent, 90 per cent and 75 per cent (Smith et al. 2003). To accommodate uncertainty about the availability of the wind resource itself, wind technologies at a range of availability factors between 25 per cent and 35 per cent are included. The load factor given for the Darling wind farm is 34.5 per cent (pers. comm. Oelsner 2001[12]) and that at Klipheuwel is expected to be 20 to 30 per cent (Smith et al. 2003). The life of each wind turbine is expected to be 20 years (IEA 2003).
- Small hydro stations are based on existing Eskom and private stations. The potential for hydro within South Africa is limited, especially when compared to the scale of imported hydroelectricity from the SADC (a separate policy case). Hydroelectric capacity constitutes six facilities owned by Eskom, three by municipalities and one by a private generator, accounting for approximately 0.8 per cent of electricity generation in South Africa (NER 2001a).
- Bagasse co-generation stations are already used in the sugar and the paper and pulp industries but new stations may also be installed.
- Landfill gas derives from the organic content of municipal solid waste and hence the energy source is renewable. There is a debate as to how CDM projects should relate to sustainable waste management practices (Lumby 1996; Omar & Mncwango 2003; TNI 2003). The local benefits are contested, but the benefits of avoiding global GHG reductions through CDM projects are clear. Landfill gas projects are included in the modelling in various size options, with limits on the total capacity related to the waste sites.

The characteristics of the renewable options are summarised for comparison in Table 5.14. Investment costs vary considerably, with solar thermal being the most expensive at present, while landfill gas and bagasse are competitive when compared to alternatives. For many RETs, O&M costs are only fixed ones, with no fuel costs. Efficiencies are typically assumed to be 100 per cent, 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).

LEARNING CURVE FOR RETs

The initial capital costs of RETs are relatively high. Costs of new electricity technologies can be expected to decline as cumulative production increases. To understand the market and economic potential of renewable energy sources for electricity generation, it is important to consider international trends in costs. Chapter 4 reviewed some international cost data on RETs, as well as the theoretical potential of the resources.

Table 5.16 *Current capacity, increases and progress ratios for RETs*

Technology for electricity generation	Operating capacity, end 1998 (GW_e)	Increase in installed capacity in past five years (%/year)	Number of years for doubling at historical rate*	Progress ratio** (%)
Biomass	40	~ 3	23	85
Wind	10	~ 30	3	82
Solar photovoltaic	0.5	~ 30	3	71
Solar thermal – parabolic trough	0.4	~ 5	14	83
Solar thermal – 'power tower'	0.4	~ 5	14	88
Small hydro	23	~ 3	23	–
Geothermal	8	~ 4	17	–
Tidal	0.3	0	–	–

Notes: *Years of doubling own calculation, ln (2)/historical increase (%/yr), and rounding up for small numbers of years.
**Progress ratios from Laitner (2002), except parabolic trough (NREL 1999).
Data not available for all technologies on all parameters.
Sources: Laitner (2002); NREL (1999); UNDP et al. (2000); World Bank (1999)

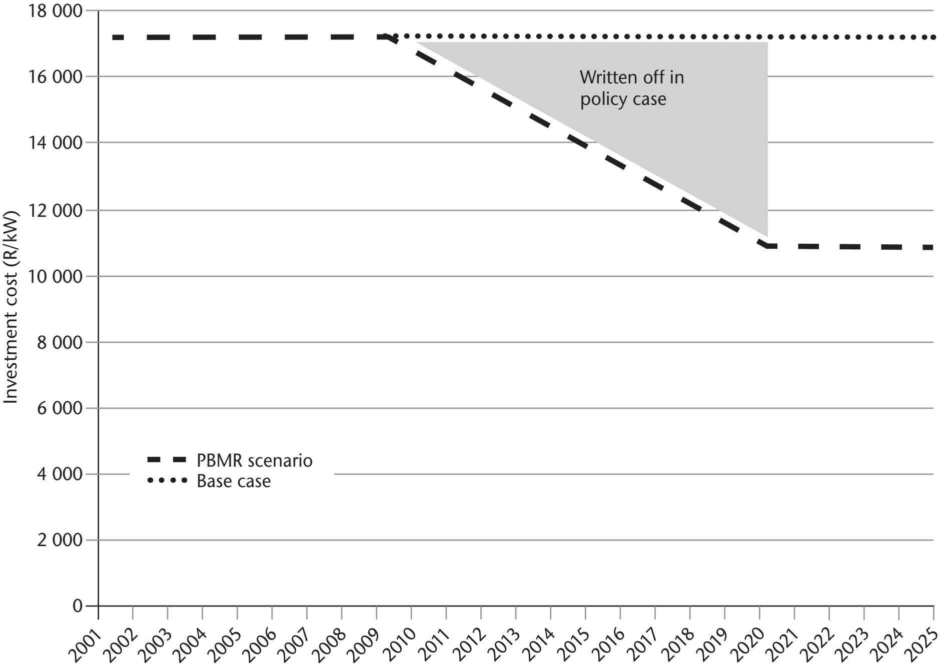
Table 5.16 shows estimates, again from the World Energy Assessment, of how capacity increased from 1995 to 2000. Using the percentage growth, an estimate can be made of the time it will take for capacity to double – assuming that current trends continue. In some cases, cumulative capacity might double faster (or slower). The approach taken here is to use the estimates based on current trends, together with the progress ratios from the literature. Progress ratios are the changes in costs after doubling of cumulative capacity, as percentage of initial cost. Based on these assumptions, the investment costs of RETs are assumed to decline in future.

The PBMR option: Nuclear

The PBMR was initially intended primarily for export but plans have shifted to include it for domestic electricity use. The policy case assumes that the PBMR will be built domestically and that the Environmental Impact Assessment will be approved.[13] The PBMR was to be developed first with a demonstration module in about 2008, after which modules of eight units of 140 MW each would be developed. The model is required to build a fixed amount per year, an average of 373 MW. In practice, this would be in increments of 140 MW units, that is, 280 MW or 420 MW, etc. The capital costs exclude benefits from avoided transmission losses, if these stations are built at the coast.

The capital costs of the first modules will be significantly higher than for later units. In this case, there is no global learning curve, although China began development of a design also based on the original German High Temperature Reactor (AEJ 2005). Economies of scale and learning-by-doing would operate at the national level, and by the time the assumed limit of 4 480 MW – based on 32 units – has been reached around 2020, costs are assumed to have declined by more than a third (37 per cent) from those of the first units. The approach is to include technology learning in the policy case, not the base case, similar to the approach taken for the other new technologies based on renewable energy (see Figure 5.10).

Figure 5.10 *Schematic description of assumed PBMR costs in reference and policy cases*



Source: Author's own analysis, modelling assumptions

The PBMR policy case implemented in the modelling for this book examines the implications of four such multi-modules being built. PBMR nuclear capacity is increased gradually, reaching 4 480 MW by 2020, taking into account lead times for about four years.

Decommissioning costs of a PBMR 'eight pack', which have been assessed at between R1.7 billion and R2.0 billion (at 2003 prices), are included in the investment cost. They would actually be incurred at the time of decommissioning, which could be at any time from the end of plant operating life (40 years) to the point at which the spent fuel is transferred to the final disposal.

At the time of modelling for this study, the PBMR was the nuclear technology under consideration. The second NIRP (NER 2004c) only mentioned this option, and then not in the preferred plan. Since then, PWRs ('conventional' nuclear plants such as the one at Koeberg) have re-emerged as an electricity supply option. The DME (2007) released a nuclear energy policy for comment and industry magazines reported investment in up to 20 000 MW of PWR nuclear (Engineering News 2006). By the end of 2007, the third electricity plan (NIRP3) had not yet been published, but was rumoured to contain a significant amount of nuclear power.

The southern Africa option: Importing hydro

One of the major options for diversifying the fuel mix for electricity is to meet growing demand by importing hydroelectricity from southern Africa. Importing electricity from another country, rather than generating it domestically, impacts on the balance of payments. Only if the imported electricity is cheap enough will it be attractive to incur the extra expenditure and the loss of local capacity and associated jobs. The potential to augment South Africa's small hydro resources (0.8 per cent of generation) (NER 2002a) and imports from Cahora Bassa with further imports was reviewed in Chapter 4.

Given the uncertainty associated with the political situation in the Congo, the case for importing hydroelectricity is based on firm power from Mepanda Uncua as for the NIRP (NER 2004c), but assumes that additional hydroelectricity can be imported from Inga Falls (Inga 3). In total, the additional imported hydroelectricity would be 15 TWh by 2010, approximately equally derived from Mepanda Uncua and Inga 3. Imports of 9.2 TWh (NER 2001a) are set as an upper bound in the reference case. The increase in the hydro policy case represents about two-thirds of this amount, increasing linearly thereafter.

The average cost of existing electricity imports was 2.15c per kWh, well below the cost of South African generation in 2001 (NER 2001a). The import costs are part of a long-term agreement with Mozambique for Cahora Bassa. The historical value (equivalent to R6/GJ) is assumed for imported electricity in the future.

The gas option: Importing natural gas

Running a gas-fired turbine requires importing gas, since South Africa's domestic resources are small. Gas is attractive because of its relatively low capital costs and the contribution it can make to meeting peak demand, a particular concern as reserve margins in South Africa are reduced.

As noted, gas has been imported by pipeline from Mozambique since 2004, but its preferred use has been for feedstock at Sasol's chemical and synfuel plants. The alternative is shipping of LNG, potentially landed at Saldanha in the Western Cape, Coega in the Eastern Cape or Richards Bay in KwaZulu-Natal. Construction of an LNG terminal would add two years to the lead time of a project. Gas turbines have relatively short start-up times and play an important role in meeting peak power. Chapter 4 provided some background on switching from coal to gas.

Gas-fired turbines can be run with an open cycle or a combined cycle, where the exhaust heat is used in a second loop. Efficiencies of a combined cycle gas turbine are about 50 per cent, significantly higher than for the open cycle gas turbine at 32 per cent. The capital costs of combined cycle gas turbines are, however, some 43 per cent higher (see Table 5.14).

The policy case modelled for imported gas assumes that 1 950 MW of electricity is generated from combined cycle gas turbines by 2020. Five units of 390 MW each are constructed with lead times of three years spreading them over the period.

Part of this supply could also be met by importing electricity from a gas-fired power station in Namibia. The differences in this option are not quantified here explicitly. While gas-fired electricity generation still has some emissions, these are significantly lower per GWh than for coal-fired plants.

A fuel cost of R21.5 per GJ is used for LNG and R45 per GJ for diesel run in an open cycle gas turbine, based on current wholesale fuel costs (see Table 5.4).

Cleaner coal technology in the base case

A potentially cleaner coal technology, namely FBC plants, is also taken up in the base case. The major economic advantage lies in the ability to use discard coal, of which South Africa produces about 60 million tons per year (Howells 2000). The technologies are part of existing policy, with their inclusion in the NIRP (NER 2004c) indicating a good likelihood of them being built. No separate 'cleaner coal' policy case is constructed, but the benefits of FBC plants being built, compared to new pulverised fuel or the continued operation of existing coal plants, are examined.

The capital cost is similar to pulverised fuel plants, just under R10 000 per kW (see Table 5.14). While technical construction time is assumed to be about four years, lead times of eight and nine years, depending on political and technical considerations, are reported in the international literature (pers. comm. Van der Riet 2003[14]). O&M

costs are still included due to the need to transport the discard coal to the power plant. Efficiencies are slightly higher than for other coal plants, although these are expected to degrade over time.

Other technologies, notably integrated gasification combined cycle power plants, are not likely to be introduced in the medium term. Since FBC enters the base case, one could assume that it requires no particular policy intervention. However, since there are no plants in operation yet, it is worth briefly examining the impacts against a case without any FBC (that is, only pulverised fuel plants for coal). The IRP base case envisages 466 MW of FBC by 2013 (NER 2001/02, 2004a). The modelling approach is to examine a version of the base case that explicitly excludes electricity generation from FBC, to examine the contribution made by the technology.

Other options

NEW PUMPED STORAGE

Pumped storage schemes are a net user of electricity and therefore results are not reported as one of the supply options. Nonetheless, they have an important role in meeting peak demand.

The demand for electricity is not uniform throughout the day or the year but has peaks in the morning and evening and in mid-winter. By storing energy to meet these peak demands, one can save on the capital expenditure for extra generation capacity. Electricity itself cannot be stored except in limited quantities but energy can be stored in forms that can readily be converted into electricity. This can be done in batteries, by compressed air and by pumped storage. In pumped storage schemes, water is pumped from a lower dam to a higher dam in off-peak times and then allowed to flow through a turbo-generator to the lower dam in peak times to produce electricity. South Africa already has pumped storage schemes at Drakensberg (1 000 MW_e) and Steenbras (180 MW_e), and further stations are considered in the second NIRP (NER 2004c).

OFF-GRID ELECTRICITY

Off-grid electricity deserves a mention due to its importance in rural electrification (Cowan 2003; NER 2001d). The literature indicates significant operational and institutional barriers to large-scale off-grid concession programmes (Afrane-Okese 2003; ERC 2004b; Thom & Afrane-Okese 2001), and some of the perspectives of local communities were discussed in Chapter 3. The overall contribution to electricity supply – even if 350 000 households were supplied – would amount to some 0.2 per cent of residential electricity demand.[15] This option is not modelled, but some of the existing initiatives are highlighted below.

Currently, most use of renewable energy is for off-grid electricity systems using photovoltaics, as well as solar cooking and water heating. Photovoltaic systems are used as stand-alone sources of electricity in areas remote from the grid, but are expensive compared to grid-connected electricity in South Africa. A number of projects have been implemented:

- The Schools and Clinics Electrification Programme provided off-grid energy services with SHSs to community facilities. By 2000, 1 852 schools had been connected and an unspecified number of clinics (DME 2001d: 97).
- A Shell/Eskom joint venture for SHS electrification built 6 000 systems for residential use by 2000 (DME 2001a; Spalding-Fecher 2002c); in 2002, indications were that 4 700 of these systems were operational (Afrane-Okese 2003). Based on recent reports (EC et al. 2000; pers. comm. Stassen 2001[16]), the size of the SHS market, outside of the major government programmes, has been estimated at R28 million in 2000 (Spalding-Fecher 2002c).
- Rollout of the off-grid electrification programme began in 2002. The programme is targeting 350 000 homes for SHSs but has been slowed down by negotiations among the government, Eskom and the concessionaires. In 2002, the DME agreed to the subsidy level (Kotze 2001) and Eskom's role in the programme was clarified. Concessionaires have signed interim contracts, with NuonRAPS, EdF and Solar Vision each installing some 200 systems.

For residential customers who wish to use renewable energy with a grid connection, two-way metering would be a benefit. Households can sell excess electricity during times when their resource is high (for example, the sun shines) but demand low. They obtain credit and buy electricity from the grid when conditions are reversed – low supply but high demand.

Conclusion

This chapter has motivated a focus on energy policies modelled for this book – the residential demand and electricity supply sectors. Key drivers for changes in the base case were identified as economic growth, population and technological change. Each of these factors is complex in its own right, as the discussion of population growth made clear. The projections made about future urban/rural dynamics, levels of poverty, household size and the impact of HIV/AIDS make an important difference, and impact on the projections of residential energy demand. An important change from previous analysis is the disaggregation of households into household types, allowing at least a basic differentiation of energy-use patterns in a national model.

The base case projections for residential demand were placed in the context of other demands, with residential demand being one of the smaller sectors. Supply was considered in the broader mix of primary energy supply, and more specifically the fuel mix for electricity supply. In the base case, South Africa will clearly remain dependent on coal for electricity generation up to 2025, particularly if analysed by generation rather than by capacity.

The heart of this chapter outlined energy policies and how they were modelled. On the supply side, the implications of increasing shares of four major options – renewable energy, PBMR nuclear, importing hydro or natural gas – formed the heart of the policy cases. The impacts of cleaner coal, which is already represented through FBC in the base case, were considered as well.

Residential energy policies have a large component of efficiency, be it more efficient houses or specific appliances such as CFLs. SWHs use a cleaner energy source and improve the efficiency of providing energy for heating water. The option of GBs was included, as they are more affordable. The importance of energy for cooking meant that a switch from electricity, paraffin, coal or wood to LPG was modelled.

While the focus in this chapter is on modelling, the overall development objectives that the policies are intended to meet were not forgotten. The policies add up to a substantial contribution to energy for sustainable development. In the next chapters, the results will be analysed policy by policy (Chapter 6) and against indicators of sustainable development (Chapter 7).

Notes

1 The focus is not on the contribution of energy policies to other services – for example, energy-efficiency measures providing better comfort in low-cost housing.

2 This section builds on and extends work done by the author in Winkler, Howells & Alfstad (2005).

3 The percentages used in the modelling are 59.61 per cent urban households, 40.39 per cent rural, but reporting them with two decimals would give a false sense of accuracy.

4 At exchange rates of R6/$1, this works out to less than $2 per person per day.

5 B Cowan, Senior researcher, Energy Research Centre.

6 PJD Lloyd, Honorary research fellow, Energy Research Centre.

7 M Borchers, Sustainable Energy Africa.

8 G Morris, Director, AGAMA Energy.

9 B Bredenkamp, Efficient Lighting Initiative, Eskom manager.

10 'Renewable electricity technologies' is used as shorthand for technologies using renewable energy sources. However, as noted, it is not the electricity that is renewable, but the energy source.

11 See http://www.dme.gov.za/dme/energy/refso.htm.

12 H Oelsner, Darling wind farm IPP.

13 The Environmental Impact Assessment for the PBMR was initially approved by the DEAT in 2004. However, the NGO Earthlife Africa brought a court case with the assistance of the Legal Resources Centre. The high court required a reconsideration of the decision, taking account of the objections by Earthlife.

14 M Van der Riet, Technology Services International, Eskom.

15 Own calculation of 0.06 TWh from SHSs, as share of 34.6 TWh (NER 2002a).

16 D Stassen, Manager, Energy Policy Programme, Development Bank of Southern Africa.

6 Assessing the implications of policies

The policy cases specified in Chapter 5 are examined in this chapter case by case. First, the results for policy cases in the residential demand sector are reported, followed by electricity supply options. The base case serves as a benchmark for each of the policy cases. An evaluation against indicators of sustainable development in Chapter 7 will allow comparison across both demand- and supply-side policies. Table 7.21 provides a consolidated table of quantitative results. The discussion here focuses on results of particular importance to the policy in question, starting with residential energy policies.

Residential energy policies

The results from the modelling of residential energy policies for social, environmental and economic dimensions are summarised in Table 6.1. The table is combined in Chapter 7 with a similar one for electricity supply. The results for each policy are discussed in the following sections.

Promoting efficient houses

The policy case for efficient houses introduced greater efficiency in insulating the shell of the building, in particular avoiding losses through the ceiling. Comparing the policy intervention to the base case, the first result that stands out is energy savings.

Total fuel use in the residential sector declines by 2.9 per cent by 2014 and by 5.3 per cent by 2025; the latter difference amounting to 11.2 PJ in absolute terms (see Table 6.1 for the data here and in the text that follows). The energy used for space heating per household varies considerably across households (from 0.49 GJ per household per month for RLE as the lowest to 4.0 for UHE), but does not differ significantly between the base and policy cases.

The reduction in overall fuel use is accompanied by a shift in consumption between groups of energy carriers. Consumption is reduced by 2 to 4 per cent in electricity and 20 to 40 per cent in liquid fuel, but there is a four- to fivefold increase in renewable energy use. Energy savings are achieved while keeping the demand for space heating constant, making efficient houses more comfortable without heating space by burning fuel.

Table 6.1 *Overview of results for residential energy policies*

Indicator		Unit	Base case	Efficient houses	CFLs	Water heating – SWH/GB	LPG for cooking	Residential policies combined
Social								
Fuel consumption in residential sector								
Electricity	2014	PJ	98.9	93.1	98.9	95.9	96.4	98.3
	2025		116.8	104.9	116.8	110.3	112.6	115.5
Liquid fuels	2014		51.9	43.0	51.9	51.9	41.3	51.9
	2025		58.9	39.3	58.9	58.9	36.1	58.9
Renewable energy	2014		1.7	7.9	1.7	1.7	9.5	1.7
	2025		3.5	16.7	3.5	3.5	20.1	3.5
Total fuel use	2014		201.1	195.3	201.1	201.5	195.2	200.5
	2025		213.5	202.3	213.5	214.4	202.1	212.3
Cost of energy services to households		c/kWh	37.8	34.2	34.8	34.8	34.8	34.2
Electricity in common units		R/GJ	105.1	95.1	96.7	96.7	96.7	95.1
Cost of energy services to households: Shadow price of non-electric fuels, residential								
Coal for households		R/GJ	3.5	3.5	3.5	3.5	3.5	3.5
Biomass			30.0	30.0	30.0	30.0	30.0	30.0
LPG			149.4	149.4	149.4	149.4	149.4	149.4
Paraffin			96.9	96.9	96.9	96.9	96.9	96.9
Candle wax			70.3	70.3	70.3	70.3	70.3	70.3
Monthly expenditure on electricity								
RHE		R/HH/month	87	78	80	80	80	78
RLE			16	15	15	15	15	15
UHE			164	148	151	151	151	148
ULE			62	56	57	57	57	56

→

→ Indicator	Unit	Base case	Efficient houses	CFLs	Water heating – SWH/GB	LPG for cooking	Residential policies combined
Environmental							
Local air pollutants (in 2025)							
Sulphur dioxide	kt SO_2	3 571	3 524	3 568	3 531	3 559	3 517
Non-methane volatile organic compounds	t NMVOC	888 450	888 038	888 432	888 139	888 387	888 011
Nitrogen oxides	t NO_x	2 156 438	2 132 925	2 155 275	2 137 627	2 151 339	2 129 828
Carbon monoxide	t CO	4 923 479	4 921 832	4 923 416	4 922 246	4 923 237	4 921 730
Global GHGs (in 2025)							
Carbon dioxide, total	kt CO_2	630 053	622 540	629 686	624 117	628 685	621 827
Methane	t CH_4	50 325	50 234	50 323	50 261	50 380	50 301
Nitrous oxide	t N_2O	8 171	8 065	8 165	8 082	8 149	8 052
Economic							
Total cost of energy system, cumulative over the period	R billions	6 120	6 119	6 119	6 115	6 121	6 115
Annualised investment in all residential technologies in 2025	R billions	29.78	30.23	29.58	29.71	30.65	29.75

Notes: HH = household; kt = kilotons (thousand tons); t = tons; see the list of acronyms for explanations of the abbreviations RHE, RLE, UHE and ULE.
Source: Author's own analysis, modelling data.[1]

Figure 6.1 *Implications of efficient houses on demand for space heating in UHE households*

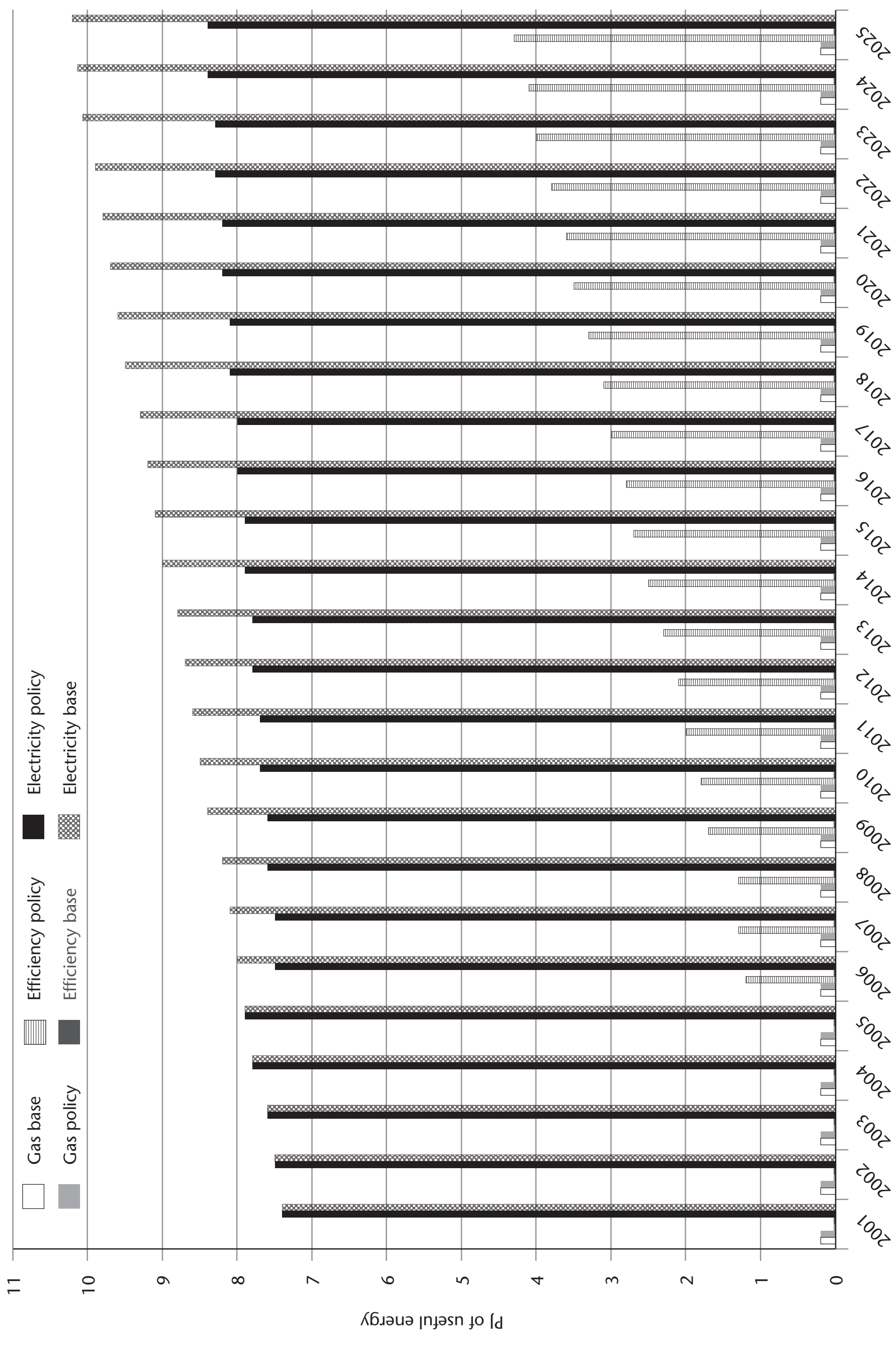


Figure 6.1 illustrates the implications of making houses in the richer urban areas (UHE) more efficient. The energy consumption for active space heating, using electricity or gas, is compared to the effective contribution of passively keeping the house warm. The efficient house is passive in the sense that no fuel is burned for space heating. The consumption of electricity for space heat in the base case (spotted grey bars) is clearly reduced in the policy case (black). The contribution of greater efficiency is seen clearly as the striped bars are built from 2007 onwards.

The savings in energy translate into reduced energy bills. Fuel costs across household types are 9.5 per cent lower than in the base case, with the shadow price of electricity in particular being reduced by 3.6c per kWh. In other words, with greater efficiency of using electricity in efficient houses, the opportunity cost of generating an additional unit of electricity is reduced. These abstract economics translate into real reductions in household expenditure. The data in Table 6.2 show that UHE households save R16 per household each month, with R9 for RHE and R6 for ULE. The absolute reduction for RLE is low due to low electricity consumption.

Table 6.2 *Reduction in monthly expenditure on electricity with efficient houses, by household type*

Household type	Base case (R/HH/month)	Efficient houses (R/HH/month)
RHE	87	78
RLE	16	15
UHE	164	148
ULE	62	56

Notes: HH = household
See the list of acronyms for explanations of the abbreviations in column one.

The energy system as a whole shows a 0.02 per cent reduction in total system costs. The fraction is small since the policy deals only with a small part of the overall system. The saving is worth R0.9 billion over the entire period. Total system costs account for all interactions in the energy system, including savings. Considering the investment required each year, these are R0.45 billion, or 1.5 per cent higher than in the base case in 2025.

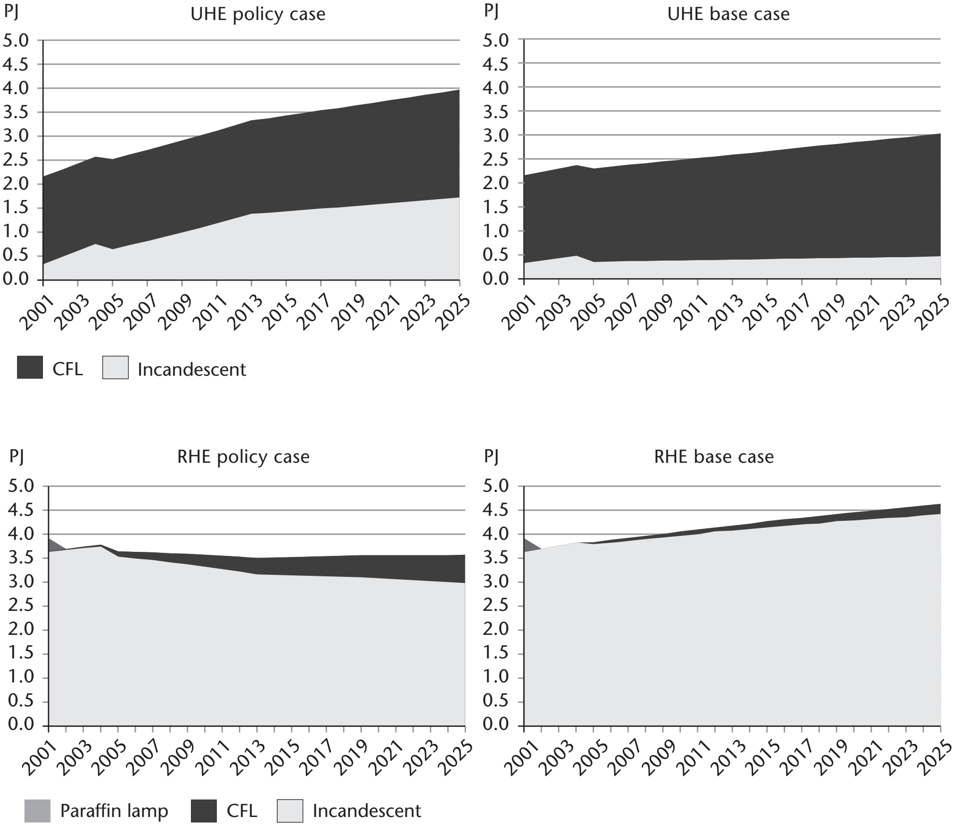
Efficient houses reduce local and global air pollutants, as shown in the environmental section of Table 6.1. Local air pollutants are reduced between 1 and 2 per cent against the base case, amounting to 46 000 tons of sulphur dioxide and 23 000 tons of nitrogen oxides reduced. Reduction in GHG emissions of 7.5 Mt CO_2-equivalent is achieved by the policy in 2025, which derives mostly (97 per cent) from carbon dioxide from electricity generation. A simple estimate of abatement cost divides the total emissions reductions (policy – base case) by the incremental costs of investments in technologies.

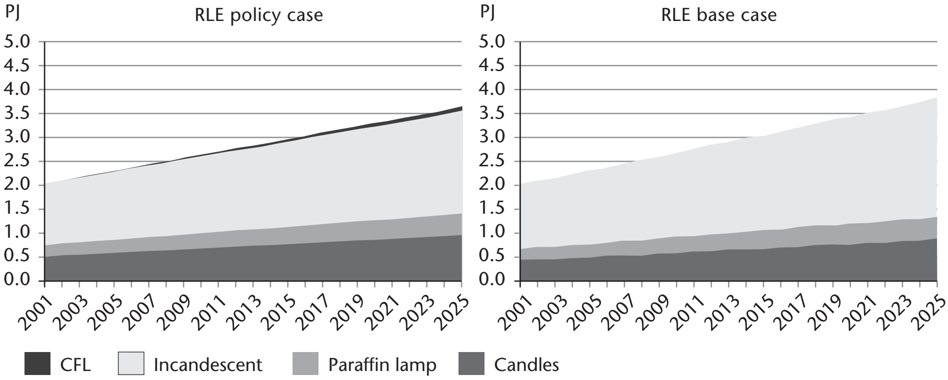
The results of the policy case demonstrate higher investment in efficient technologies, reduced local and global pollution, energy savings and reduced energy bills for households, as well as a benefit for the total energy system. A key policy question (see Chapter 8) is whether efficient houses are affordable, even if they make economic sense at national and household levels.

Efficient lighting for improved services

The lighting policy case considered the further spread of CFLs and a continued, albeit slight, reduction in costs. The changes seen in three household types illustrate the effects of the policy intervention (see Figure 6.2). A striking result is that the share of CFLs for richer urban electrified households (UHE) looks bigger in the base case. This is indeed the case, although one should note that total demand for lighting services is higher in the policy case (4 PJ versus 3 in the base case).

Figure 6.2 *Changes in lighting technologies in the CFL policy and base cases*





The explanation for the finding, then, is partly that CFLs are indeed an intervention that should work well in the market. In particular, more affluent households should be able to purchase CFLs as a least-cost strategy, given the price reductions that have already occurred (see Chapter 5). The second factor is that some of the energy savings are 'taken back' by UHE households consuming more energy.

For RHE households, the pattern is more as expected, with CFLs displacing incandescent lights. Population growth is projected to occur mainly in urban areas so, unlike the urban counterpart, growth in household numbers in rural areas is not a major factor. For poor rural households, consumption levels are low and CFLs show up only as a small band at the top. ULE households (not shown) have a greater share of CFLs displacing paraffin and candles.

What implications do the changes in CFL penetration rates have for the overall system (see Table 6.1)? Overall system costs are affected less than 0.1 per cent, with lighting being a smaller end use than space heating in the case of efficient houses. The annualised investment cost in residential technologies actually *declines*, by 0.7 per cent, by 2025. The reasons are that the longer life of the CFLs, together with their declining costs, makes them more competitive.

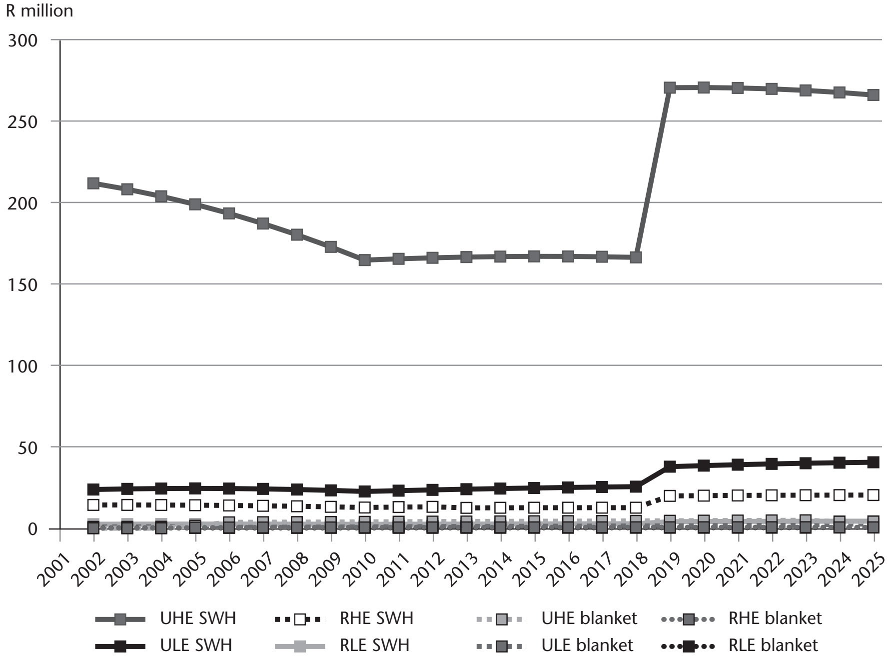
Households certainly can make energy savings, with total fuel use in the form of electricity declining by 1.23 PJ against the base case (or 342 GWh in electricity units). The more efficient use of electricity reduces the opportunity cost of electricity and the shadow price drops by 3c per kWh. Reductions in household expenditure are highest for UHE, at R13 per household per month. Consumption of lighting services in this group is highest, hence the largest savings can be made. Arguably as significant is the almost R5 that each poor urban electrified household can save from more efficient lighting alone.

The implications for local air pollution are not large compared to other residential policy cases. Reductions in local pollutants are small – CFLs mainly avoid incandescent electric lighting, with no local emissions. Even the limited use of other fuels is contained, unlike for cooking. The absolute value of reduction of GHG emissions is moderate at 336 kt CO_2 avoided through CFLs in 2025.

Solar hot water and insulation

The SWH/GB policy case increased the range of cleaner and more efficient water heating. Investments in SWHs and GBs total R339 million in 2025 in the policy case. All but R7.6 million (2 per cent) is invested in SWHs. Figure 6.3 shows that the required investments for the policy case are mostly spent in UHE households.

Figure 6.3 *Investment costs for SWHs and GBs, by household type*



Note: See the list of acronyms for explanations of the abbreviations in the key.

The aggregate figure tells only part of the story, however, as Table 6.3 shows.

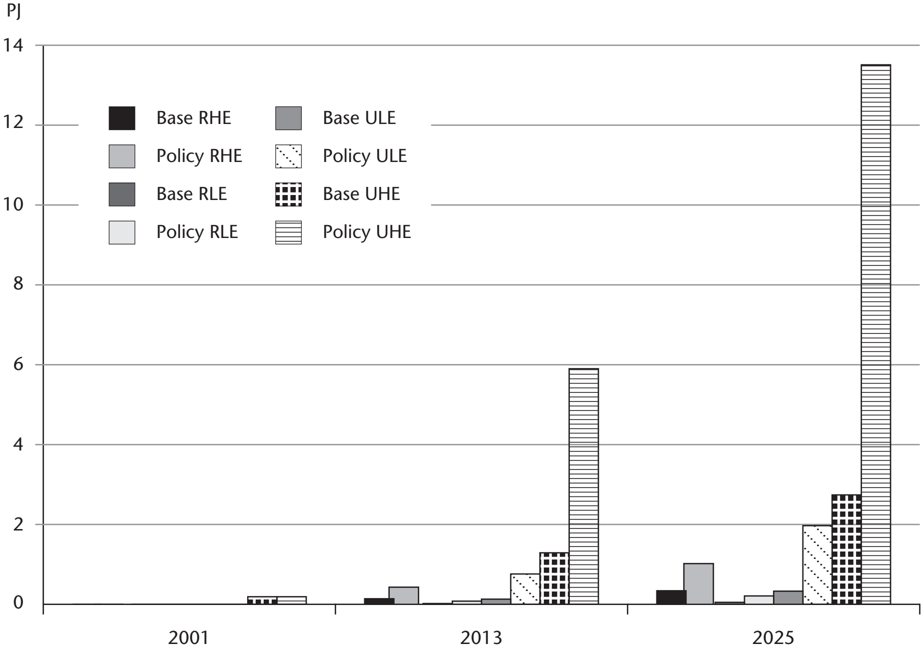
Table 6.3 *Energy saved and costs for cleaner water heating*

	Saved energy (policy – base case)	Total investment in policy case	Cost of saved energy	
	PJ	*R million*	*R/GJ*	*c/kWh*
GB	4.9	7.6	1.5	0.6
SWH	13.3	331	25.0	9.0

The much lower investment cost of GBs means that total investment is smaller. However, the energy savings are relatively large, and the cost per unit of energy saved is significantly lower for GBs. The lower cost – both upfront and per unit of energy saved – suggests that GBs are appropriate policy interventions in poor electrified households.

The policy results in a threefold increase in the use of solar energy in the residential sector, while the use of other fuels – notably liquid fuels like paraffin – for water heating declines. Total fuel use is 3 per cent lower with SWHs and GBs than in the base case. Figure 6.4 shows the savings by representing the equivalent of fossil fuel use that would have been consumed in the place of solar energy. The Markal model assigns a 'fossil equivalent' to renewable energy consumption, taking into account the relative efficiencies.[2]

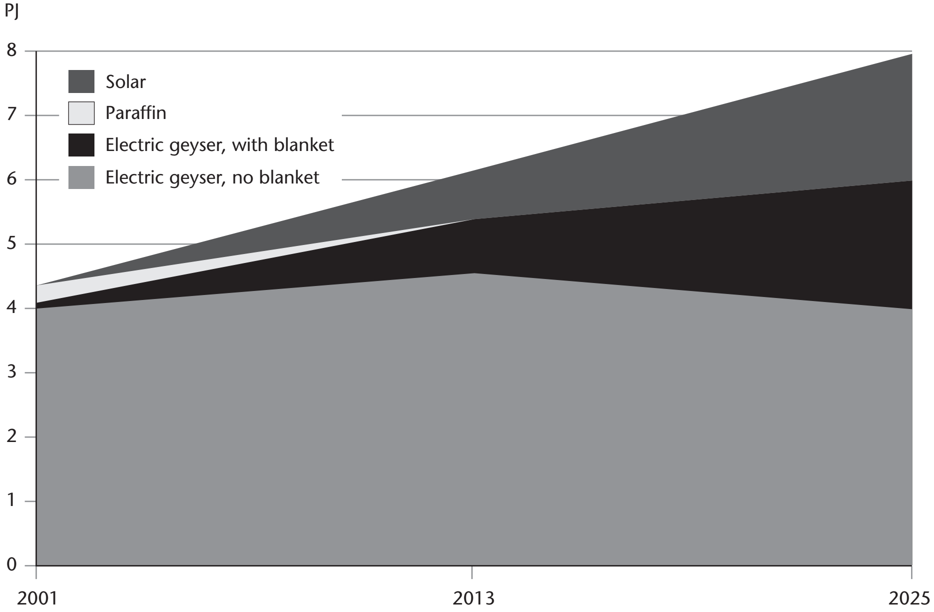
Figure 6.4 *Equivalent of fossil fuel use for solar water heating, by household type (PJ)*



Note: See the list of acronyms for explanations of the abbreviations.

For all household types, the energy savings increase over time – three years are selected here. Clearly, the greatest savings are made in the UHE household type, and the policy case shows clear gains over the base case for the respective household. To illustrate how the fuels used for water heating change over time, the example of ULE households is shown in Figure 6.5.

Figure 6.5 *Energy used for water heating by urban low-income electrified households*



The figure shows how SWHs increase their share over the period, completely displacing paraffin use at the end. The reduction of paraffin use is important from the social perspective, given the problems associated with its use in South Africa's poor communities (Lloyd 2002; Mehlwana 1999a). Electric geysers provide most of the water-heating services, but an increasing number are insulated with blankets.

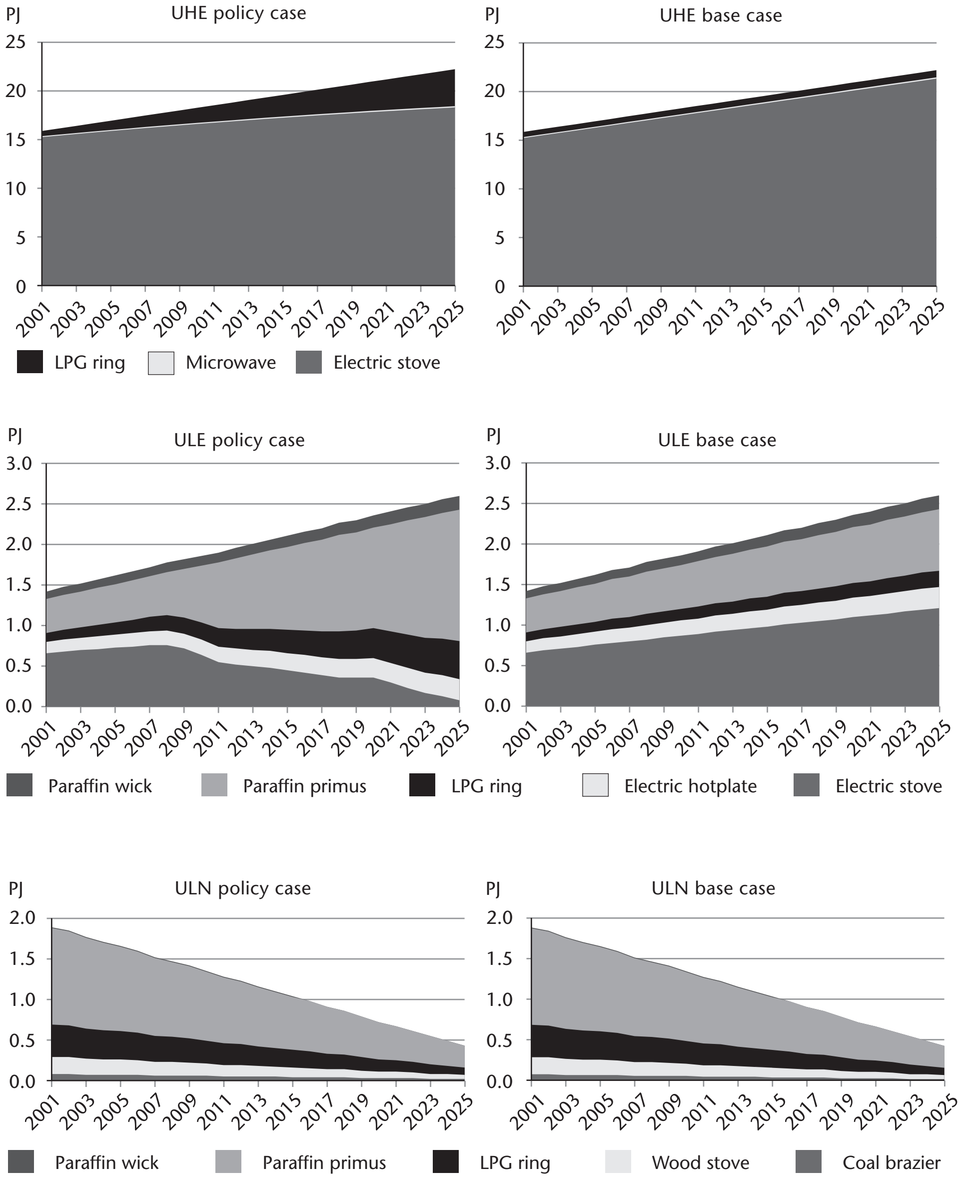
The saving on energy bills for households is about 8 per cent on the water-heating bill. Continuing with the ULE household example, this translates into R5 less spent on water heating per household per month.

In terms of reducing local air pollution, reductions of 18 800 tons of nitrogen oxides are notable and sulphur dioxide emissions are 40 000 tons less than in the base case. From a climate change perspective, a reduction of 5.9 Mt CO_2 can be achieved in 2025 at a cost of R21 per Mt CO_2-equivalent.

Switching to LPG for cooking

Cooking is one of the most important social uses of energy. The LPG policy case requires households to switch from electric and other cooking devices to LPG stoves and rings. Other cooking fuels commonly used by poor households for cooking, such as paraffin, coal and wood, have health impacts when used indoors. Figure 6.6 shows the changes resulting from wider ranges for LPG for three household types. For UHE households, the wider range that the model is allowed has the expected effect – LPG stoves replace electric stoves for cooking needs. For the poorer urban electrified households (ULE), however, the fuel switch to LPG does take place but another switch happens at the same time – the use of paraffin primus stoves increases even more dramatically than for LPG.

Figure 6.6 *Fuel switch to LPG for three household types*



Note: See the list of acronyms for explanations of the abbreviations.

The changes are the result of the model choosing least-cost options. The switches in fuels change the relative prices of fuel costs. Electric stoves have become too expensive and are partly replaced by hotplates as well. In addition, the investment costs of LPG cookers are slightly higher (R250) than for hotplates (R230), about double those for paraffin wick (R107) and much higher than for primus stoves (R37) (see Table 5.13 for the full range).

For non-electrified urban households (ULN), the effect of the policy case is negligible. The declining overall use due to electrification far outweighs the impact of the fuel switch.

Considering all household types, the LPG policy case has a relatively small impact on total energy system costs (see Table 6.1). The investments required in LPG cooking appliances are relatively modest – R176 million in 2025, the lowest for all the residential policies.

Despite this modest investment, 11 000 tons of sulphur dioxide can be avoided as well as 5 000 tons of nitrogen oxides. While substantial in absolute amounts of local air pollutants avoided, these reductions are below 1 per cent compared to the cooking fuel mix in the base case. In addition, some 1.4 Mt CO_2 can be avoided through cooking with LPG, at a cost of only R7.7 per ton of carbon dioxide.

Total fuel use (in energy units) *increases* by 0.9 PJ over the base case in 2025, but this amounts to only 0.4 per cent of total fuel use. Looking more closely at the fuels used, electricity consumption is reduced by 6.5 PJ. For RHE households, associated expenditure on electricity for cooking is reduced from R87 per household per month in the base case to R80. However, given the patterns shown in Figure 6.6, some subsidy for LPG may be required if higher penetration rates of a cleaner fuel are desired (beyond UHE households). Such a 'subsidy' need not be directed at the fuel cost but at making the fuel more readily accessible.

Conclusions on residential policies

Each of the residential policy cases modelled in Markal has been discussed separately above, with Table 6.1 providing an overview of results. In conclusion, the effects of combined policies are considered. Given the importance of the analysis of residential energy by household type, some concluding comments draw together the results from individual policies in this respect.

A policy case combining all four individual residential policies was included in the Markal model. The combined policy case includes SWHs, GBs, efficient houses and CFLs and allows fuel switching to LPG. The results are reported in the last column of Table 6.1.

Fuel consumption in the combined case decreases against the base case. The rows showing total fuel use in Table 6.4 indicate that the highest reduction comes from the efficient house case. The effect is particularly due to the reduction in liquid fuels, mostly paraffin. Note also the declining trend in paraffin for water heating, from the mid-term year 2014 to the end year 2025. The reduction makes the SWH/GB policy case the second-lowest in total fuel use of the individual policies.

Table 6.4 *Fuel consumption (PJ) in the residential sector across policy cases, 2014 and 2025*

		Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
Electricity	2014	98.9	98.3	96.4	95.9	98.9	93.1
	2025	116.8	115.5	112.6	110.3	116.8	104.9
Liquid fuels	2014	51.9	51.9	41.3	51.9	43.0	43.0
	2025	58.9	58.9	36.1	58.9	39.3	39.3
Renewable energy	2014	1.7	1.7	9.5	1.7	7.9	7.9
	2025	3.5	3.5	20.1	3.5	16.7	16.7
Total fuel use	2014	201.1	200.5	195.2	201.5	197.8	195.3
	2025	213.5	212.3	202.1	214.4	206.8	202.3

An important dimension of this book is the analysis of the residential sector across household types. In the discussion of the results of individual policy cases, several examples of the differential impact across household types were noted.

A consistent finding was that the greatest energy savings from efficiency were to be made in UHE households. The reduction in fuel use for this household type was greater in absolute terms. Beyond that, the expenditure on energy *per household* also decreased the most. Energy savings translate directly into expenditure when measured in terms of rands spent monthly on energy per household. The case of efficient housing showed reductions in monthly energy expenditure, with the greatest savings in rands per month for UHE, but similar in the percentage saved.

Given the higher consumption, the higher savings for UHE households are trivial in one respect – the same percentage saving applied to higher consumption (more kWh or GJ) would automatically yield a greater saving. The policy question that arises, however, is how much the savings affect affordability – what difference do the monetised savings make to household income? Put another way, further analysis is needed to indicate to what extent the saving might relieve the energy burden of the household.

A starting point is to consider energy consumption across housing types. Cutting across the policies, Table 6.5 shows the variation of energy consumption for different household types by 2025. Policy cases are associated with particular end uses – CFLs with efficient lighting, SWH/GB providing cleaner and more efficient water heating, better insulated housing shells reducing the energy needed to heat space, and LPG use focusing on cooking.

Table 6.5 *Energy consumption by end use for household types, 2025*

	RHE	RLE	RLN	UHE	ULE	ULN
Cooking	126	45	162	324	95	118
Lighting	261	99	1	156	136	–
Other electric	261	6	–	290	8	–
Space heating	119	40	178	334	160	112
Water heating	201	51	102	475	288	55

Notes: Consumption measured in MJ/household/month.
See the list of acronyms for explanations of the abbreviations in the top row.
No results are reported for electric appliances in unelectrified households, and lighting in ULN households is close to zero.

Table 6.5 illustrates the significant variation across household types in monthly energy consumption. Taking the highest consumption type, UHE, as 100 per cent, ULN only consume in aggregate 18 per cent as much energy per month, and RLE 15 per cent. The shares for RLN households are increased beyond expected levels, since relatively large portions of their energy requirements are met from wood or coal in inefficient appliances. As noted in individual policies, however, the numbers of households in the RLN and ULN categories are small by 2025. The comparison here is per household and the implications for household income will be explored further in the following chapters.

Not all measures achieved energy savings greater than the base case for all households. The LPG case showed the expected fuel switch only in some households, for example ULE. However, other changes took place at the same time, with more paraffin being consumed, reflecting different investment costs of the appliances as well as relative price changes. UHE households had already shifted to LPG in the base case as an optimal strategy, while for ULN the shift hardly showed up, since household numbers in this group declined with electrification.

Put differently, some policy interventions are already ‘optimal’ in a least-cost framework. Efficient lighting was found to be a policy intervention that should work in markets for higher-income households. Penetration rates in the least-cost framework were high. In a case such as CFLs for richer households, market mechanisms are clearly appropriate as policy instruments.

Other policy cases may need more intervention for benefits other than economic ones. Water heating, for example, was shown to change the fuels used for water heating in ULE households. The social benefits from savings for poorer households and improved indoor air quality would motivate this policy rather than least-cost optimality.

Having examined the results of residential policy interventions, the next section provides insight into the implications of different electricity supply options.

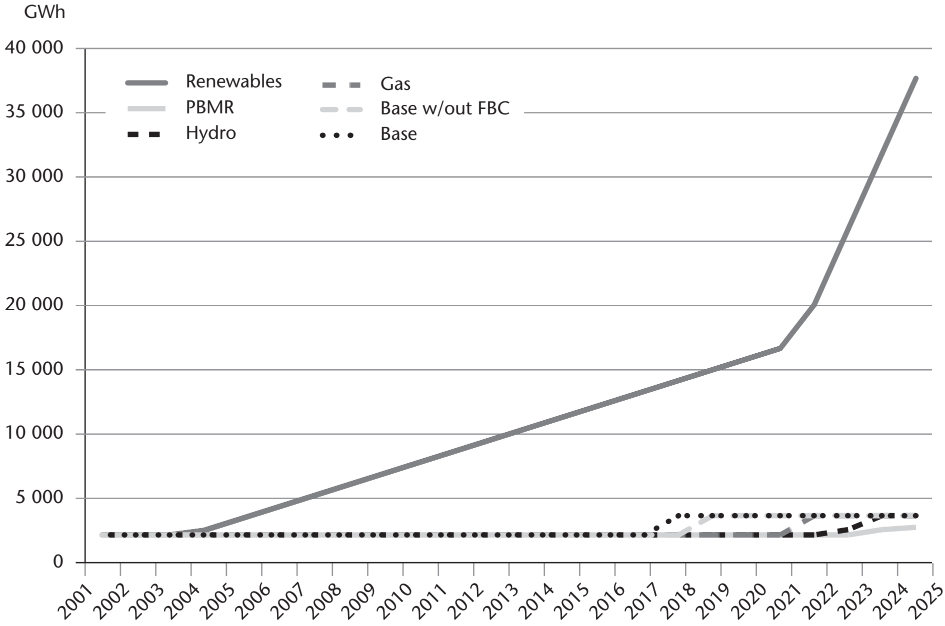
Electricity supply options

The various options for electricity supply are best compared across the major dimensions of sustainable development – economic, social and environmental. Since the focus of Chapter 7 is such an evaluation, most of the comparison is reported in that chapter. Note also that Chapter 5 already reported important *input* parameters (see Table 5.14). In this chapter, key results for each option are highlighted briefly, reporting policy by policy.

Renewable energy

The renewable energy policy case was designed to meet the target of 10 000 GWh by 2013 with a combination of technologies – biomass (bagasse and pulp and paper co-generation), wind, solar thermal (trough and 'power tower'), small hydro and landfill gas. Costs of RETs were assumed to decrease as global markets grow. The increase in electricity generation from renewable resources is clearly apparent in Figure 6.7, which shows the renewables case increasing well above all other policy cases and the base case. Note that the increase occurs gradually up to 2013 (the year the target is set) and beyond. The sharp turn-up after about 2020 reflects the fact that renewables have become competitive with other technologies.

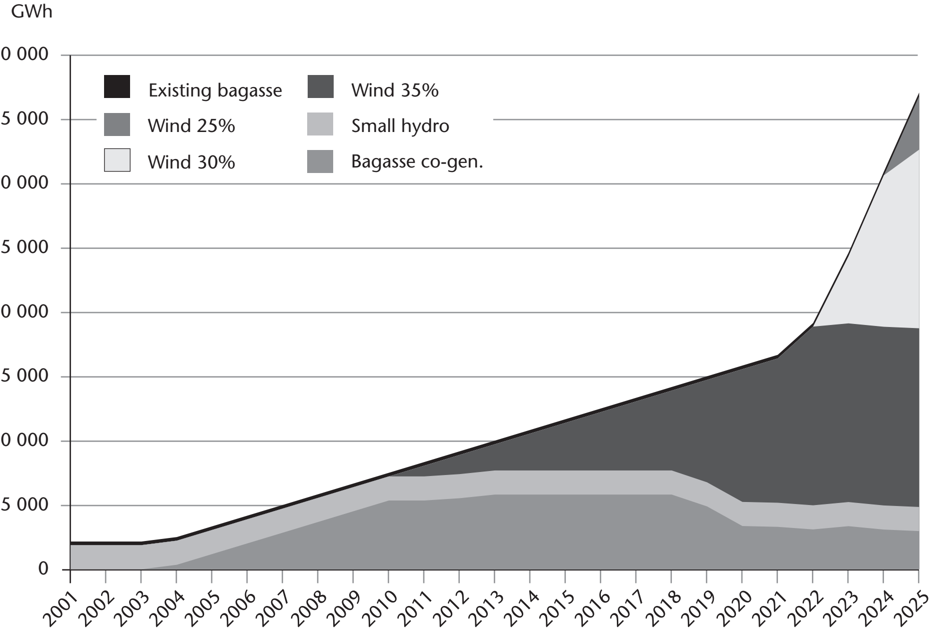
Figure 6.7 *Renewable energy for electricity generation, by policy case*



Consequently, diversity in the fuel mix is increased. By 2025, the share of electricity generated from renewable sources increases to 11 per cent, while generation from coal decreases from 88 per cent to 78 per cent. Even in this policy case, however, three-quarters of electricity still comes from coal over a 25-year period.

The RETs chosen in the policy case include existing bagasse and small hydro facilities (see Figure 6.8). New bagasse co-generation and wind are the two new technologies that are chosen by the model. For wind, the technology assuming the highest availability factor (35 per cent) is chosen first, until it reaches the available capacity. Some wind at the lower capacities is added in later years. The solar thermal and landfill gas technologies are not chosen.

Figure 6.8 *Contribution of RETs to meeting the target by 2013, and beyond*



One measure of the choice of technology is the marginal investment. The 'investment marginal' result parameter in Markal is not the same as the investment cost. Rather, it is the additional cost to the energy system of adding *another unit* of the particular technology. The model seeks an optimal, least-cost solution; the marginal investment is the *difference* between the cost of the technology considered and the cost of the technology it displaces in the base case. The base case optimises with fewer constraints, so the marginal investment represents the cost of adding a further constraint to the least-cost run. In the renewables policy case, the investment marginals for solar thermal electricity have reduced from R10 803 to R9 408 per kW for the parabolic trough by 2025, and similarly from R11 754 to R7 731 per kW for the 'power tower'. However, the cost difference between other renewable energy and the least-cost technology is even smaller at this point. Therefore, despite the reductions in the costs of solar thermal electricity, the technology does not compete on a least-cost basis within the 25-year period.

Overall, additional investment in electricity supply technologies is needed. Focusing only on the investment in supply technology shows an increase of R6 billion, but in the balance of the energy model the increase in total system costs is significantly lower at R1.9 billion. While this is a large amount, it is 0.03 per cent of the total system cost in the base case. For all policy cases, it should be remembered that the total system cost is large and absolute rand amounts should be understood in this context.

Local air pollution is reduced in the renewables policy case, in particular for sulphur dioxide and nitrogen oxides – sulphur dioxide emissions are 6 per cent lower than in the base case (197 kt), while 96 kt NO_x can be avoided (4 per cent).

Reductions of global GHGs contributing to climate change are achieved with renewables policy. GHG emissions in 2025 are 32 Mt CO_2 or 5 per cent lower than in the base case. Looking at the individual GHGs, the change is mostly in the form of a reduction of carbon dioxide (5 per cent). Nitrous oxide declines by 4 per cent as well but, despite its higher global warming potential, contributes less to the total GHG reduction. The reduction in the two gases outweighs a 2 per cent increase in methane, which results from the increase in biomass used in some of the RETs.

Considering the social dimension, all the policy cases assume that electrification rates increase as described in the base case. Urban households achieve higher rates of electrification by 2025, as shown in Table 6.6.

Table 6.6 *Share of households with access to electricity in 2025 for all policy cases (%)*

Electrified total	92
Electrified urban	96
Electrified rural	83

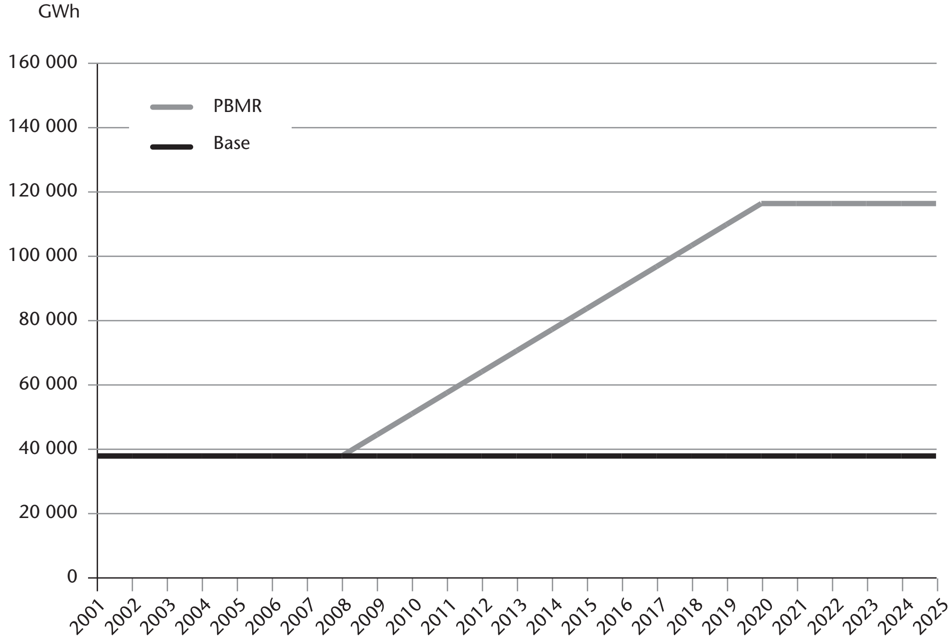
The social dimensions of sustainability – often with important qualitative dimensions – are discussed more fully in Chapter 7. The indirect effect of electricity supply options, via the price of electricity, is part of that discussion.

PBMR nuclear

The PBMR policy case required 4 480 MW of nuclear electricity-generation capacity to be built by 2020, with costs declining as more units are built. As expected, such a requirement would shift the fuel mix for electricity generation dramatically to nuclear energy, comprising a third of the total (34 per cent) by 2025. Figure 6.9

shows the increase of electricity generation in the PBMR case. Virtually all the displaced generation is coal-based for the PBMR policy case, with the share of RETs declining slightly from 1.0 to 0.8 per cent. Note that when the requirement is relaxed after 2020, nuclear generation capacity remains constant at the 2020 level.

Figure 6.9 *Nuclear energy (PBMR) for electricity generation, by policy case*



Greater diversity comes at a price. Annualising the investment costs for all electricity-generation technologies, and adding them up over the 25 years, indicates that 50 per cent *extra* would be invested in electricity supply technologies. For all electricity supply technologies, the cumulative investment cost would be R141 billion in the policy case, rather than R93 billion in the base case. However, again the balance of the electricity system means that investment costs are partly offset. The balance can only be struck partially, however, in the aggressive policy requirement for building nuclear capacity, and is forced initially to leave much of the PBMR capacity unused (see Figure 6.10).

Only as costs decline from 2015 onwards is the capacity utilised more effectively. The total cost of the energy system increases by R12 billion over the period, compared to the base case. The unused capacity suggests that the policy case may be too ambitious. At least, nuclear capacity should be phased in more gradually if it is built domestically at this scale.

Figure 6.10 *Unused capacity of the PBMR in the policy case*

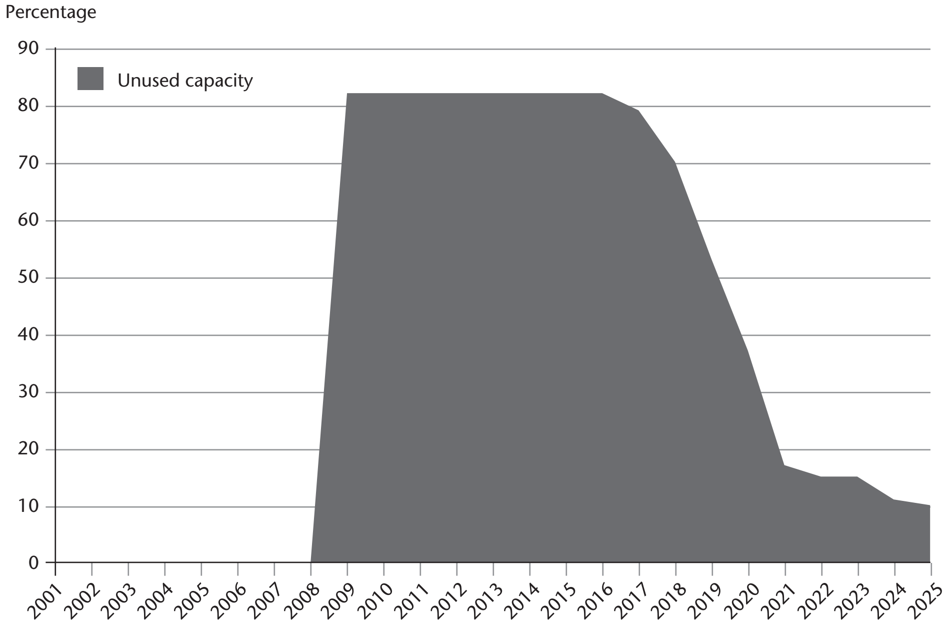


Figure 6.11 *Marginal investment required for more PBMR capacity*

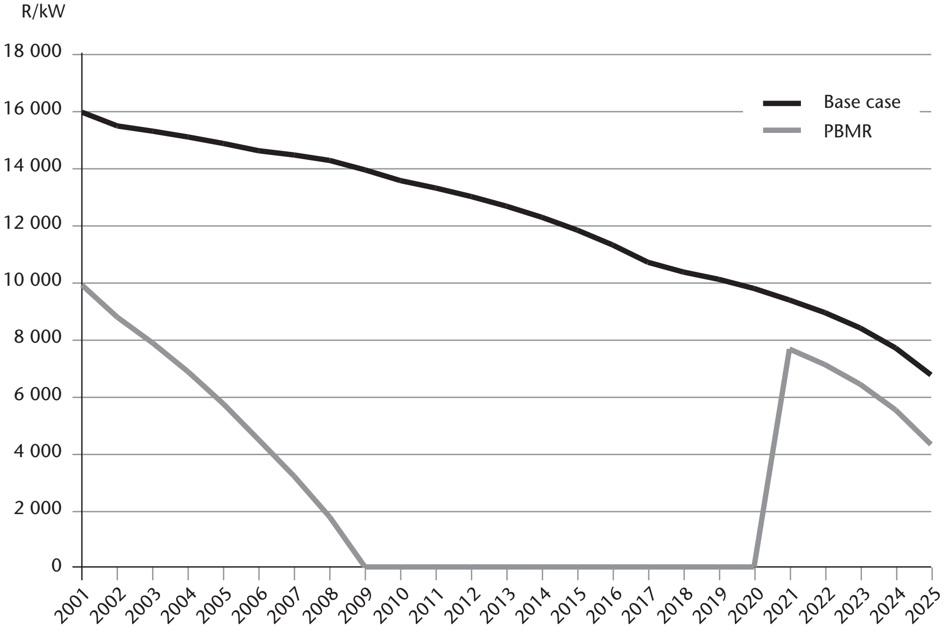


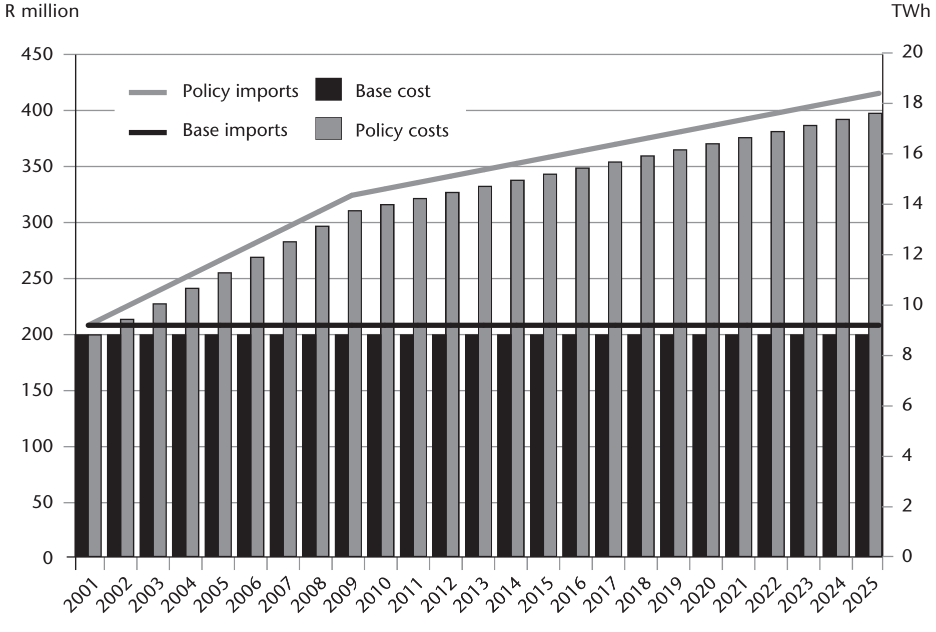
Figure 6.11 shows the marginal investment required in both the base and PBMR cases. In the base case it declines gradually, but in the policy case more sharply. It reaches zero in the policy case in years where actual investment takes place, but then rises again after 2020. However, the marginal investment remains below the base case throughout, given the favourable assumptions about decline in costs with domestic production.

The PBMR case avoids significant amounts of local air pollutants, notably 210 kt SO_2 (6 per cent less sulphur dioxide than in the base case), and 5 per cent nitrogen oxides (102 kt) in 2025. Thirty-three Mt CO_2-equivalent of global GHGs are reduced in that year, mostly in the form of carbon dioxide with a small reduction in nitrous oxides. As discussed, the PBMR policy case meets the same goals of increasing access to electricity as for all policy cases.

Importing hydroelectricity

The policy case of importing hydroelectricity from southern Africa increases the amount of hydroelectricity, almost doubling from current levels of 9.2 TWh to over 18 TWh by 2025. The imports incur a resource cost, as shown in Figure 6.12 by the bars measured on the left-hand axis, reaching R395 million by 2025. Analysis of the direct costs, however, only tells part of the story, with the reduction in investment in other supply-side options being the other part. The modelling framework shows that, over the period, cumulative investments in electricity supply technology are reduced by R11 billion. The reduction in total energy system costs, however, is much lower at R3 billion, offsetting the gains against import costs shown in the figure.

Figure 6.12 *Imports of hydroelectricity and import costs in the policy and base cases*

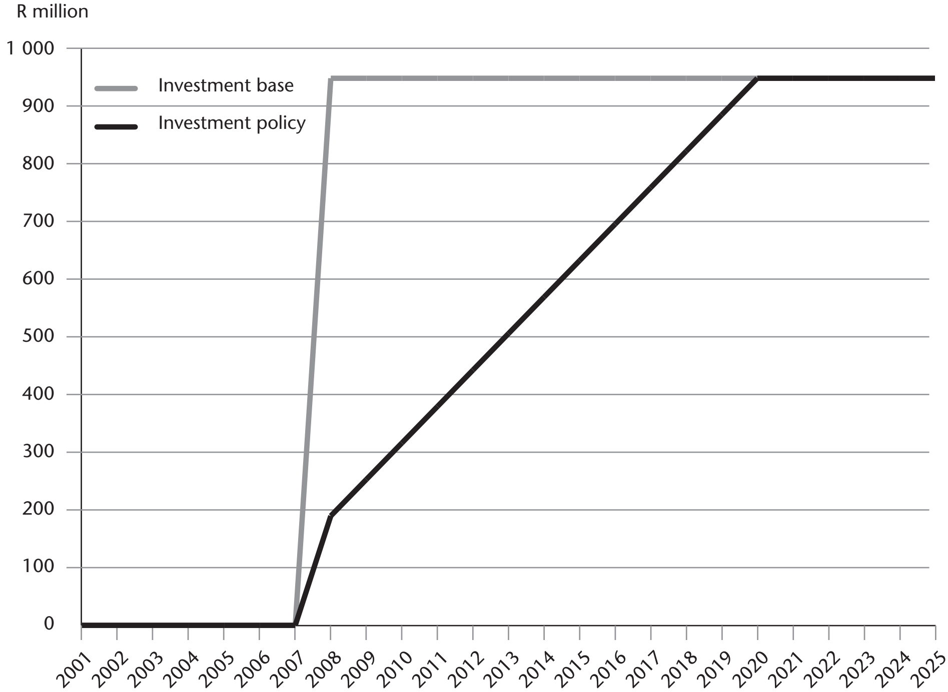


Extra imported hydroelectricity increases the share of renewables by one-tenth of a percentage point, but system changes reduce the share of coal-fired electricity from 88 per cent to 87 per cent. Reductions in local air pollutants amount to 142 kt SO_2 (4 per cent less than base case) and 70 kt NO_x (3 per cent). Total GHG emissions are reduced by 4 per cent or 22 Mt CO_2-equivalent. However, it should be noted that part of this is a reduction in methane emissions. The emissions of methane from large dams are subject to ongoing research (Dos Santos et al. 2006; IPCC 2001b), and the assumption that hydroelectricity is zero-emissions may change as more information becomes available.

Importing gas for electricity generation

The imported gas policy case reduces the overall system cost by R0.8 billion over the 25-year time horizon, compared to the base case. As with hydro, the costs of the imported fuel need to be taken into account. The shadow price of electricity is reduced by 0.5c per kWh, completing a picture where the reduced domestic investment costs outweigh the increase in expenditure on importing gas. These results are sensitive to the assumptions made about future fuel prices in Chapter 5. The natural gas price was assumed to be R21.5 per GJ (Table 5.4). The gas price was significantly higher in rand terms when the currency weakened against the dollar, apart from fluctuations in the dollar-denominated prices of oil and gas in international markets.

Figure 6.13 *Annualised investment in combined cycle gas in the policy and base cases*



The base case as reported in Chapter 5 reflected the plans of the NIRP and reflected some capacity invested in gas. The policy to import a fixed quantity of gas changes relatively little, but does optimise more effectively the use of the gas-fired capacity which is built. The NIRP brought in the full capacity in 2008, whereas in the policy case a more gradual introduction allows better adjustment (see Figure 6.13). In both cases, a lead time is required before the investment begins in 2008.

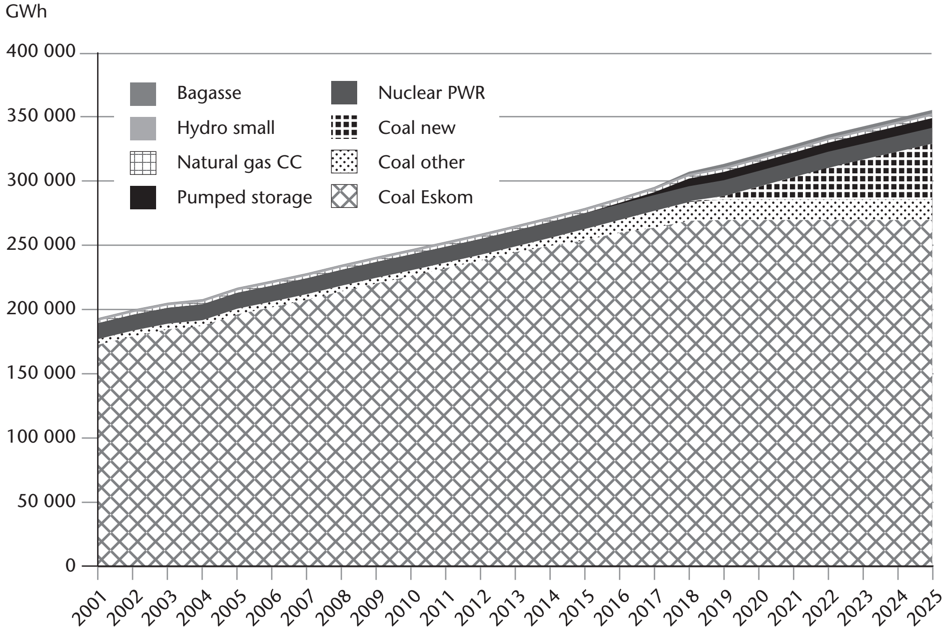
Importing gas makes no difference to the domestic fuel mix – the shares of electricity from coal (88.0 per cent), renewable energy (1.1 per cent) and nuclear energy (11.0 per cent) sources remain the same in percentage terms as in the base case. The share of natural gas used does not change significantly (less than 1.0 per cent).

Despite the small changes, gas is a cleaner-burning fuel than coal and some reductions in local and global air pollutants are observed. Relative to the base case, the reductions for sulphur dioxide, nitrogen oxides and GHGs are all 2 per cent lower for the policy case. The reductions amount to 83 kt SO_2, 42 kt NO_x and 14 Mt CO_2-equivalent.

Cleaner coal technology in the base case

Chapter 5 outlined that FBC, a technology using discard coal for electricity generation, is included in the base case and no separate policy case was constructed. Here, the contribution made by the technology is examined by briefly presenting results for a version of the base case that explicitly excludes electricity generation from FBC.

Figure 6.14 *Electricity generation without FBC*



Note: CC = combined cycle

Figure 6.14 shows electricity generation grouped by fuel, comparable to Figure 5.4 for the base case. By design, there is no discard coal, with the slack being taken up mostly by additional new coal-fired plants (10 650 GWh in 2025), with a small increase in bagasse (811 GWh).

The total system costs *with* FBC are R11 billion higher over the period; in other words, the removal of FBC electricity generation from the optimised case decreases costs. The higher cost of the alternative technology (pulverised coal) outweighs the reduction in fuel costs, since a discarded product is used for fuel. The fuel mix remains unchanged, as discard coal is replaced by new coal. While FBC contributes to removing stockpiles of discard coal, there are small increases in air pollutants. One factor contributing to this increase is the lower heating value in the poorer-quality coal; the other is that the modified base case is not fully optimised. Sulphur dioxide emissions with FBC increase by 62 kt; that is, the optimised base case has 2.0 per cent less sulphur dioxide emitted in 2025 than the case with FBC removed. Similarly, there is an increase of nitrogen oxides with FBC of 30 kt (1.4 per cent). Total GHG emissions, primarily in the form of carbon dioxide, increase by 9.4 Mt CO_2 or 1.5 per cent in 2025. A fuller investigation of cleaner coal technologies as a policy case would be a useful future piece of work; the approach here is to consider the take-up of FBC as part of the base case.

Conclusions on electricity supply options

The quantitative results of modelling electricity policy cases have been presented. Before turning to an evaluation of both residential and electricity policy cases against indicators of sustainable development, some findings from the results are summarised.

The renewables case demonstrated that a mix of RETs can supply ‘real’ electricity. The 2013 targets were met and continued beyond that year, driven by decreasing costs. Certainly the policy intervention incurred an increase in costs, but of the same order of magnitude as other policy cases. The mix of renewable energy included existing small hydro and bagasse, and brought in new bagasse co-generation and wind at various capacity factors. Despite declining costs, solar thermal electricity technologies did not enter the system over the 25-year period.

The PBMR policy case showed the increasing share of nuclear energy, up to a third of total electricity generation. This change reduces air pollution, but incurs large increases in cost above the base case. Building 32 modules (4 480 MW) into the system by 2020 is ambitious. Not only did investment level off after 2020, but the new capacity was underutilised. If built, the technology should be phased in more gradually.

Imports of gas should also be phased in, as shown in the gas policy case’s more gradual approach compared to the base case. Being an internationally traded commodity, the introduction of gas depends on fluctuations in market prices and is also sensitive to exchange rate variations. The other import, hydroelectricity, was successfully increased in the policy case. Its global environmental benefits assume that there are no methane emissions from large dams, which might change in future. The local impacts of large dams will be further discussed in Chapter 7. Brief consideration of FBC confirmed that it should be considered in the base case.

So far this section has considered the findings for individual policy cases; now it turns to the combined effect. As for residential policies, a combined case including four electricity policy options was developed. The combined electricity case includes renewable energy, PBMR nuclear, imported hydro and gas. In contrast to the residential policies, which were aimed at different end uses and were complementary to some extent, each of the electricity cases has the same aim, of supplying electricity to meet demand and increase access.

The share of renewable energy increases to 6 per cent, about half of the level in the renewables case. The share of nuclear is only slightly higher than in the base case, given the other requirements to meet targets for renewable energy and to import hydro and gas. Coal remains dominant by 2025, reduced by five percentage points from 88 per cent to 83 per cent.

Unsurprisingly, the combination of requiring several switches from the least-cost base case increases the avoided cost of electricity. The shadow price of electricity increases by 3c per kWh, more than in any electricity policy case on its own. In terms of investment costs, combining all the policies increases the total cost to the energy system by R11 billion. Most of the investment costs are for the PBMR, which itself had a slightly higher increase.

From an environmental point of view, the combined case does yield the most reductions of local and global emissions. The sum of the parts, however, is greater than the combined whole – that is, one cannot simply add up the emission reductions in the combined case, as different supply options compete. Nonetheless, the reductions of 245 kt SO_2 are higher at 7 per cent than in any single policy case, as are the 120 kt NO_x less than the base case in 2025 (6 per cent). GHG emission reductions add up to 40 Mt CO_2-equivalent in 2025 (6 per cent). Of these Mt, 39.6 are in the form of carbon dioxide.

Conclusion

The results of modelling energy policies – both residential demand and electricity supply options – yield useful quantitative information. They provide important input to the analysis of indicators of sustainable development, examined in Chapter 7. Further policy analysis of some issues that are not easily quantified will receive attention in Chapter 8, in the discussion of national climate policy.

A notable feature of the modelling results is that they tend to focus on the energy system and its economic and environmental dimensions. The social indicator of increased access to electricity is constant across the policy cases. The social implications of electricity supply options are less direct than those in the residential sector, where household energy use and expenditure is affected directly. Of course, the choices about electricity supply affect households not only through access to electricity, but also through the price. Hence, the differences in the costs to the energy system reported in this section have implications for the burden that expenditure on electricity places on household budgets. Modelling can provide some useful inputs, but more detailed policy analysis is required to compare the effects to total household income (see Chapter 7). The next chapter considers both residential and electricity policies against indicators of sustainable development.

Notes

1 All data in the tables and figures that follow in this and subsequent chapters are from the modelling analysis, unless otherwise stated.

2 The value of the parameter is a unitless 3.125 of fossil fuel energy per unit of solar energy; the same value is used throughout the model.

7 Indicators of sustainable development

This chapter evaluates the policies in the residential and electricity sectors against indicators of sustainable development. A working definition of sustainable development was outlined in Chapter 2. There is broad agreement that sustainable development has social, economic and environmental dimensions, and it is in these three categories that the evaluation is structured. The evaluation does not seek to define thresholds for each indicator that would be considered sustainable. Any particular definition of a level representing an end state of sustainable development could be contentious. In keeping with the methodology, the focus is on making development more sustainable. Hence the comparison is relative, using the base case as a benchmark to evaluate the sustainability of each policy case.

The modelling results presented in Chapter 6 are an important input to this evaluation. The analysis will show, however, that there are limits to the information obtained from the modelling. The discussion of indicators therefore includes aspects that are more difficult to quantify. The difficulty in describing the social implications of supply-side options is one example. Some of the more qualitative aspects are important in the policy analysis in Chapter 8.

Sustainable development indicators

The working definition of sustainable development in the energy context emphasised that energy consumption per capita is increasing over time *and* the increase is not threatened by 'feedback' from biophysical impacts (local air pollution, GHG emissions), economic disincentives (high costs) or social impacts (social disruption, lack of affordability).

A wide range of energy indicators has been developed by various institutions and some have been applied in South Africa (Bossel 1998; CSD 1995; Helio International 2000; IAEA et al. 2005; Spalding-Fecher 2003; UN DSD 1996; Villavicencio forthcoming). It is worth reflecting on the purpose of choosing a set of indicators.

Indicators should be accurate in assessing sustainability in the energy sector, representing the key dimensions of sustainable development (Spalding-Fecher 2002d). Each indicator is a single figure that expresses an aspect of a country's production and use of energy (IAEA et al. 2005). Taken together and assessing changes over time, the set of indicators can assist policy-makers in assessing progress (or lack thereof) in making development more sustainable.

Indicators should be representative of the major dimensions of sustainable development (Spalding-Fecher 2003). Some indicators focus on socio-economic aspects (for example, the delivery of essential services for reducing poverty), while others focus on environmental effects. The skill of the policy-maker will be to select and weight indicators as appropriate for the country situation so as to make development more sustainable (IAEA et al. 2005).

However, more indicators are not necessarily better, since indicators need to be intelligible to a range of stakeholders. Too many indicators can cause confusion – for example, the Commission on Sustainable Development has compiled a working list of more that 130 indicators, including social, economic, environmental and institutional aspects of sustainable development (CSD 1995). Such a broad list may be useful to enable countries to choose across all sectors, but seems too broad for application to a single sector and country. A smaller set of indicators can give a more concise message – but clearly the indicators need to be chosen with care. If indicators are to be tracked over time, the data should be relatively easy to gather (Spalding-Fecher 2002d).

The pragmatic approach taken in this book is to identify a small number of indicators for each of the economic, social and environmental dimensions. Particular indicators are chosen to both address sustainability and be relevant to development.

The motivation for particular energy indicators for sustainable development in South Africa is outlined in Chapter 3. The indicators should reflect the country's development objectives, be consistent with the energy policy goals spelled out there, and mark progress towards sustainability in its economic, social and environmental dimensions. Given this broad motivation, the specific indicators shown in Table 7.1 provide useful information on energy and development in South Africa.

For the development of the South African energy sector, access to energy services in general and electricity in particular is a major goal. One indicator is the share of households connected to the grid. Development could be made more sustainable if the services become more affordable. An indicator giving relevant information is the cost of energy services, for both electricity and other fuels. A more complete understanding of the burden on household incomes, however, will require further policy analysis.

Greater access to energy services can indirectly contribute to social sustainability. Better lighting, for example, assists with education, giving household members the ability to study at night. The initial cost of the options considered in policy cases needs to be affordable. Improved indoor air quality contributes to health effects – but only the former is quantified here, not the health impacts themselves.

Increasing diversity of supply is a major energy policy goal, seeking to reduce South Africa's dependence on a single fossil fuel, coal. Increased diversity can contribute to energy security, at least in one interpretation of the concept. In so far as these diversified sources are also domestic, as is the case with renewables and can be done with uranium, they avoid the imports of energy, with possible foreign exchange impacts. With the focus on electricity supply options, the fuel mix for electricity generation is an important indicator.

Greater shares of cleaner fuels contribute to an environmental indicator – managing the energy-related impacts on air quality. Energy supply and use contributes to both local and global air pollutants. Locally, reductions of indoor air pollution assist in lessening health impacts. Reducing GHG emissions contributes to mitigating climate change.

The policies are evaluated against the indicators of sustainable development shown in Table 7.1.

Table 7.1 *Indicators of sustainable development for energy policies*

Indicator	Units	Comments
Economic		
Total cost of energy system	R billions	Cumulative over the 25-year period
Marginal cost of electricity supply	c/kWh	Shadow price of electricity supply, 2025
Diversity of electricity fuel mix from domestic sources	%	Share of renewable energy, nuclear and coal, 2025
Environmental		
Local air pollutants in 2025		
sulphur dioxide	kt SO_2	
nitrogen oxides	t NO_x	
carbon monoxide	t CO	
Global GHGs	Mt CO_2-equiv.	
Social		
Fuel consumption in residential sector	PJ	By fuel type
Cost of energy services to households		
Shadow price of residential electricity	c/kWh	Not tariff, but opportunity cost
Shadow price of non-electric fuels	R/GJ	Coal, biomass, LPG, paraffin, candle wax
Initial investment for households	R/household	‘First cost’ of investment required
Monthly expenditure on electricity	R/household/month	Disaggregated by household type – RHE, RLE, UHE, ULE

Note: See the list of acronyms for explanations of the abbreviations in the last row.

There are important social dimensions in particular which are more difficult to measure with a single number from the model results of Chapter 6. Such issues include the burden that electricity places on household income, which is analysed further in Chapter 8. The impacts of economic measures on job creation would require either a detailed bottom-up study and/or the generation of employment multipliers through a social accounting matrix.

The partial ways in which health and education are addressed were described earlier. Other dimensions, such as the impacts on empowerment and participation of civil society, are not usefully quantified.

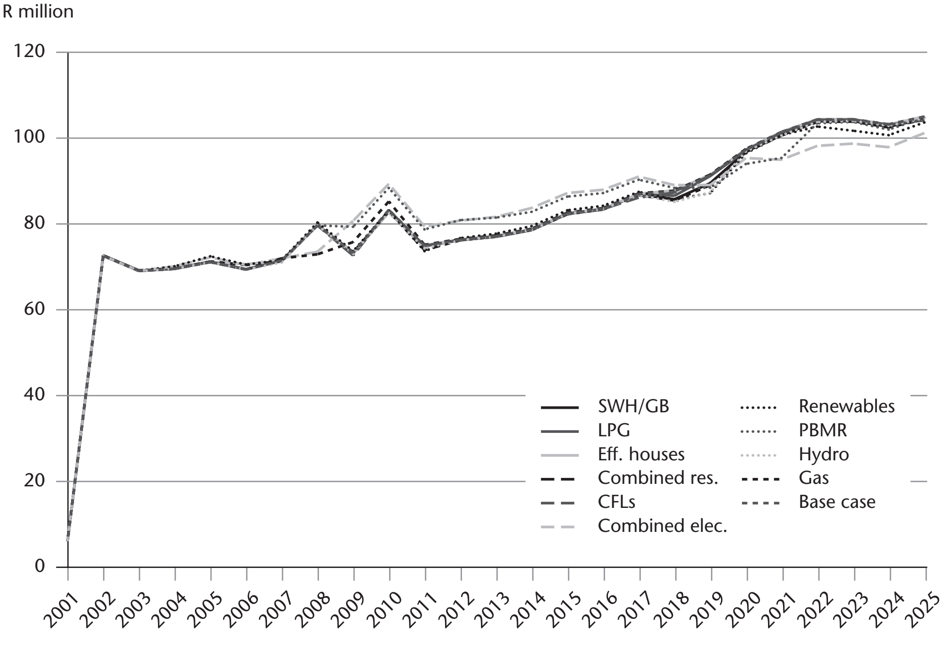
The chapter proceeds by evaluating the economic, environmental and social dimension in turn, using the indicators outlined in Table 7.1. The policy cases described in Chapters 5 and 6 are evaluated, excluding the FBC case for electricity supply, since this was found to be better represented in the base case (see Chapter 6). The overall comparison across all three dimensions and supply- and demand-side policies is summarised in Table 7.21 at the end of this chapter.

Economic

Overall investment levels

The levels of investment in supply and demand technologies in nominal terms rise sharply from the base year, and then increase gradually over the period (see Figure 7.1). The difference between the various policy cases is relatively small in the context of large absolute amounts of investment. Whether South Africa chooses a least-cost path, as represented in the base case, or particular policy interventions, a large amount of total investment in the energy system will be needed. The incremental costs of investment are not that large in relative terms and the costs reported in Figure 7.1 are undiscounted. Much of the further analysis will consider the costs to the entire energy system, which are discounted. As context, it is useful to have an impression of the scale of capital requirements.

Figure 7.1 *Undiscounted total investment in technologies, supply and demand*



Residential policies and savings in energy system costs

Residential policies have relatively little impact on overall energy system costs. The residential sector is a fairly small part of total demand. In the base case, residential demand accounted for 9 per cent of total fuel consumption (see base case in Chapter 6). It is not surprising, therefore, to see in Table 7.2 that the cost implications of policy cases are in the tenths or hundredths of a percent. Costs are dominated by supply and larger demand sectors.

Table 7.2 *Total energy system costs across residential policies*

	Unit	Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/ GB	Residential policies combined
Total cost of energy system, cumulative over the period	R billions	6 120	6 119	6 119	6 121	6 115	6 115
Change (policy – base case)	R billions		–0.9	–0.9	0.6	–4.6	–5.0
Difference to base case	%		–0.01	–0.02	0.01	–0.08	–0.08

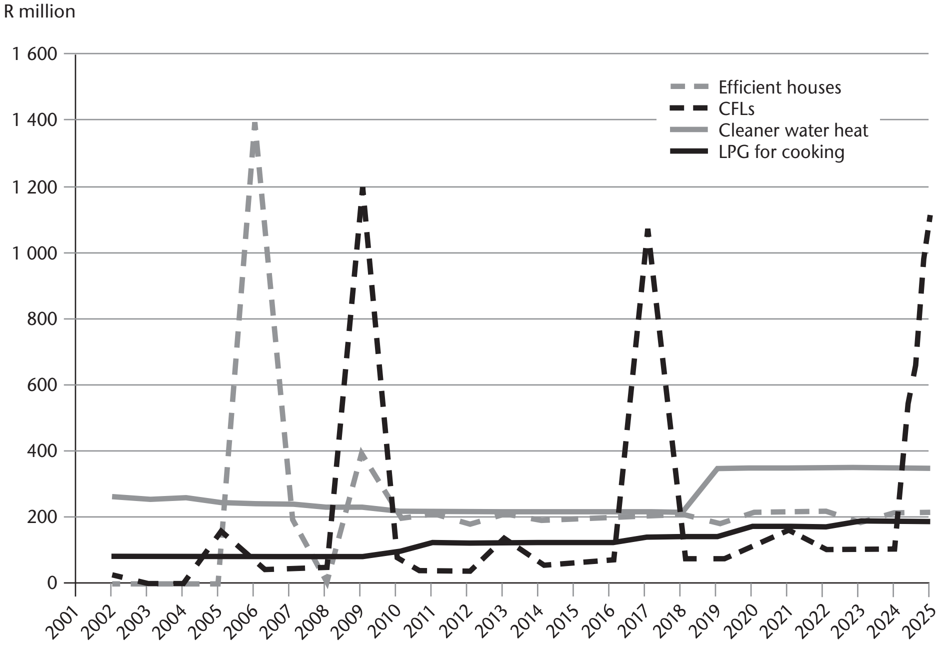
Since total costs are large, and the costs are considered over the 25-year period, the absolute changes amount to billions of rands. There are cost reductions for all policy cases except for LPG for cooking. The analysis in Chapter 6 indicated that the policy case increased fuel consumption, and that other fuel switches (for example to paraffin) also took place and changed relative prices.

Savings in the other policy cases range from R900 million to R5 billion. The largest reduction in costs for the energy system for a single policy comes from water heating, with the introduction of SWHs and GBs. The higher reduction reflects the high proportion of energy used for water heating, the large savings from SWHs and the low cost of GBs. The combined case does not simply add up these savings (and the higher cost of the LPG case), but considers the combined effects without double counting.

Investment requirements for residential policies

The investment costs of the four policy cases can be seen in Figure 7.2 for each year. Note that the order of magnitude is rand millions, since only the direct monetary requirements are reported here, not the discounted total system costs as above. The pattern of investments also differs markedly. Investment of efficient housing occurs early on and then declines. CFLs also show spikes, but investment is repeated as the lifetime of the bulbs is shorter than 25 years (unlike houses). Investment in water heating and cooking appliances and fuels is more evenly spread over time.

Figure 7.2 *Investment required for residential policies in the policy cases*



Financing residential policies

The residential efficiency measures are economically attractive, with SWHs/GBs standing out in particular. SWHs and CFLs have been identified as policy priorities already (see Chapter 4), with efficient housing receiving less attention. The investments required have to come from households, either those that can afford them or with government support. The key policy question is how to assist households to invest in the upfront costs.

Taking SWHs with the biggest reduction as an example, the question is what policies would promote greater uptake of the technology. In part, the design of the policy took these concerns into account by combining SWHs with a low-cost option, GBs. The analysis in Chapter 6 showed that SWHs were taken up primarily in higher-income urban households, which can afford the upfront costs. Chapter 8 examines options for financing investments in residential policies, using examples of subsidies for efficient housing and financing for SWHs.

Investments in electricity-generation technologies

The cost implications of different electricity supply options are an important indicator of economic sustainability. Given that previously built-up excess capacity has come to an end (see Table 3.2 and Figure 3.7), investment will be required in new capacity. Some 20 GW of new capacity will be needed over the next 20 years.

Eskom has announced investment plans of over R100 billion for initial additions, but now that it is no longer a parastatal, investment decisions will be even more closely scrutinised (see Chapter 3).

Table 7.3 shows the total cost of the energy system in all cases in absolute terms as well as the difference between base and policy cases. The changes expressed in percentages are small, relative to the large absolute sums.

Total energy system costs increase for PBMR and renewable energy. By contrast, importing gas or hydro reduces system costs. Domestic investment is reduced and the reduced expenditure is not made up by increased imports. However, the increased expenditure on imports may have foreign exchange implications. This issue also arises with the PBMR, for which processed fuel is expected to be imported despite the local uranium resource. As noted in Chapter 6 in the gas and hydro cases, the results are sensitive to the assumed costs of the imported fuels. The combined case is the second most expensive, as supply-side options compete to provide supply (unlike residential efficiency, where savings are highest in combination).

Table 7.3 *Total cost of energy system for electricity supply options*

	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined electricity*
Total energy system costs, cumulative over 25 years	R billions	6 120	6 119	6 117	6 132	6 122	6 131
Change (policy – base)	R billions		–0.8	–3.1	11.7	1.9	10.9
Difference to base case	%		0.0	–0.1	0.2	0.0	0.2

Note: *Combined electricity includes the imported gas, hydro, nuclear and renewables cases.

Beyond increasing and decreasing costs, one can note that importing hydroelectricity under the given assumptions would have the greatest reduction of energy system costs, larger than for gas. Similarly, the increase for the PBMR is significantly greater than for the renewables case. The PBMR is the most expensive individual option and slightly more costly than combining all cases – those with increased as well as those with lower costs than the base case. However, the changes in total costs should be understood in the context of different goals being set in each case. The electricity policy cases were designed as ambitious targets for the particular technology, within reasonable bounds.

Investment levels in the policy cases vary significantly. Smaller investments are required to meet lower targets and are associated with less installed capacity. Renewable energy, for example, in the policy case reaches the target of 10 000 GWh in 2013 and increases to 37 000 GWh in 2025. The additional cost to the energy system is R1.9 billion over 25 years. The PBMR case instals 4 480 MW, adding R11.7 billion to total system costs, but also generates 28 303 GWh in 2025 (see Table 7.4). Despite the different objectives, the PBMR is therefore more expensive in this comparison, as the ratio of additional costs is much greater than the electricity generated. An important reason is the unutilised PBMR capacity noted in Chapter 6.

Table 7.4 *GWh electricity generated by technology in its policy case*

GWh	Renewables	PBMR	Imported hydro	Imported gas
In 2025	37 058	28 303	18 400	1 367
Over 25 years	290 719	166 681	370 067	11 567

Two other means of direct comparison are available. The assumed costs per kW as *input* parameters (rather than results) are shown in Table 7.5, together with the fixed and variable O&M costs. The input parameter, however, does not take into account the opportunity cost – the electricity generated from renewable or nuclear energy displaces other, predominantly coal-fired, electricity. The marginal investment is a better reflection of the opportunity cost, but this measure is specific to each electricity-generation technology.

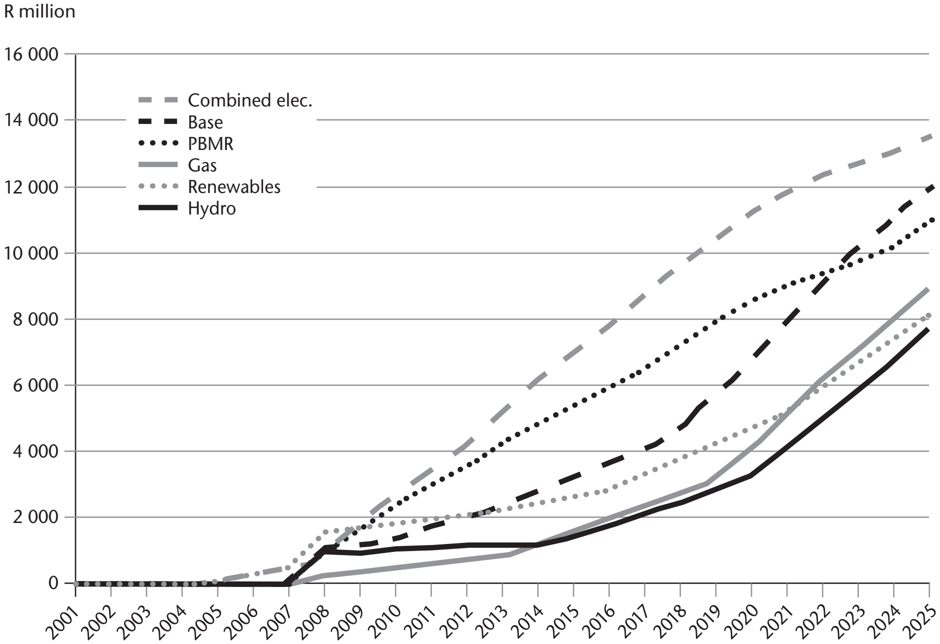
Table 7.5 *Costs of electricity supply technologies per capacity and unit of generation*

	Investment cost	Fixed O&M cost	Variable O&M cost
	R/kW	*R/kW*	*c/kWh*
Imported gas			
Combined cycle gas turbine	4 583	142	0.7
Open cycle gas turbine (diesel)	3 206	142	5.4
Imported hydro			
Imported hydro			2.1
Renewable energy			
Parabolic trough	18 421	121	0
Power tower	19 838	356	0
Wind turbine	6 325	289	0
Small hydro	10 938	202	0
Landfill gas (medium)	4 287	156	24.2
Biomass co-gen. (bagasse)	6 064	154	9.5
Nuclear			
PBMR initial modules	17 136	317	0.7
PBMR multi-modules	10 761	317	0.7
Coal			
New pulverised fuel plant	9 980	101	0.7
FBC (with FGD)	9 321	186	2.9
Storage			
Pumped storage	6 064	154	9.5

Note: The costs are input parameters, rather than results, and are included here to show differences in cost per unit of capacity (R/kW) and electricity generation (c/kWh).
Sources: Markal database for this model (Winkler, Howells & Alfstad 2005); NIRP database (NER 2004a); DME (2003d)

The pattern of investments over time is shown in Figure 7.3, where investments in new capacity have been annualised over the lifetime of the technology. All electricity technologies have a lead time, so investment picks up from 2005 onwards. The combined case has the highest costs for most of the period, with the PBMR next. The same caveats apply – namely, that the investment costs are achieving different objectives for each policy.

Figure 7.3 *Annualised investments in electricity supply technologies, by policy case*



There are no clear winners among the options and the trade-offs required are further considered in the policy analysis in Chapter 8.

Price of electricity

SHADOW PRICES AND MARKET PRICES

While data inputs to Markal are usually market prices, the model results are shadow prices. Least-cost optimisation draws on an economic theory that assumes perfect competition. It also assumes that actors have perfect foresight, minimising their costs over the entire time horizon of the model. In such a situation, market prices would reflect true economic costs. In reality these conditions seldom hold. Market prices are distorted by monopolies, external costs not internalised by markets, taxes, subsidies and other factors (Munasinghe 1992). With such distortions, market prices diverge from the shadow price, the future economic opportunity cost. Shadow prices represent the cost of the foregone alternative, if an additional unit of a technology is brought into the system.

For example, if the market price of electricity is subsidised for poor consumers, as in the poverty tariff, then the shadow price reflecting the opportunity cost would reflect the economic cost without the subsidy. In the South African electricity sector, prices are regulated – hence called tariffs – rather than being set by a competitive market. Even in situations of power sector reform, tariffs are likely to remain regulated, although possibly rationalised. Future tariffs might be adjusted more closely to the Long Run Marginal Cost, which can be defined as the 'incremental cost of optimal adjustments in the system expansion plan and system operations attributable to a small increment of demand which is sustained into the future' (Munasinghe 1992: 109).

SHADOW PRICE OF ELECTRICITY

The shadow prices for electricity are shown in Table 7.6 for the electricity policy cases for the end of the period, 2025. They are averaged across the six time slices in Markal and converted to cents per kWh. The shadow prices of electricity are broadly comparable, except for the combined scenario which is higher since it requires diversification in several directions. Importing gas or hydroelectricity reduces the marginal cost of electricity supply and the shadow price by 0.5c per kWh. These options would therefore provide the most favourable context for ensuring the financial viability of municipal or regional distributors.

Table 7.6 *Shadow price in c/kWh of electricity for policy cases, 2025*

Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Base without FBC	Combined electricity
19.3	18.8	18.8	19.3	19.3	19.3	22.3

Comparing policy cases in 2025, the prices in the PBMR and renewables cases are the same as in the base case. This is possible despite the large changes in energy system costs, since these were small in relative terms (see Table 7.3). Also, the shadow prices in this analysis are averaged across six time slices (day/night for three seasons – summer, winter and intermediate). The results indicate that the respective advantages of the different technologies balance out. Although significant investments are required, shifts to technologies other than coal are possible without large impacts on the shadow price of electricity. The combined case would increase the shadow price of electricity by 3c per kWh compared to the base case, an increase which would further exacerbate financial difficulties of distributors.

Diversity of electricity supply

The diversity of the fuel mix for electricity generation is shown in Table 7.7. There is little variation across the first three cases shown, with fuels grouped into renewable energy, nuclear and other, predominantly coal-based, electricity. Imported fuels do not change the domestic fuel mix. They do, however, contribute to reductions of local air pollutants (see below). Greater diversity of supply is achieved primarily through renewables or PBMR nuclear, in two different ways.

Table 7.7 *Diversity of fuel mix from domestic sources for electricity supply options by 2025 (%)*

Indicator	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined electricity (gas, hydro, nuclear, RE)
Share of renewable energy	1.0	1.1	1.1	0.8	11.0	6.0
Share of nuclear	11.0	11.0	11.0	34.0	11.0	11.0
Share of other (mainly coal)	88.0	88.0	88.0	66.0	78.0	83.0

Note: RE = renewable energy

Table 7.7 shows the fuel mix by grouped fuels, combining all renewable energy sources, nuclear and all others (mainly coal). The mix is based on electricity output (GWh), not installed capacity (MW). The PBMR case, with a larger investment in greater capacity, achieves the largest move away from coal. However, it is a shift to a single other fuel, with only renewable energy reduced to the lowest of all cases at 0.8 per cent. The renewables case achieves the best diversity across the three grouped fuel types. The renewables policy case has a lower investment requirement than PBMR and lower installed capacity. The combined policy case does not achieve greater diversity, either in terms of coal displaced or variety of fuel type.

The focus so far has been on the economic dimension of sustainable development. Markal is a least-cost optimising tool, and hence the results shown above indicate the least-cost options. Even with constraints in the policy cases, the target set will be met with the least-cost resource available.

Considerations other than cost, however, play an important role in shaping policy. The following sections turn to the social and environmental dimensions of sustainable development in the energy sector.

Environmental

Local air pollutants reduced by residential policies

Increasing efficiency and using cleaner fuels in the residential policy cases contributes to reducing local air pollutants. The largest changes were seen for sulphur dioxide and nitrous oxide; changes in carbon monoxide and NMVOC were less than a tenth of a percent below the base case. Efficient houses and water heating achieve a reduction of around 1 per cent from the base case for both sulphur dioxide and nitrogen oxides emissions (see Table 7.8). Efficient housing reduces 47 kt SO_2 and 24 kt NO_x in 2025, while SWHs and GBs can reduce 40 kt SO_2 and 19 kt NO_x in that year.

Table 7.8 *Local air pollutants in residential policy cases, 2025*

	Unit	Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
Sulphur dioxide	kt SO_2	3 571	3 568	3 524	3 559	3 531	3 517
Difference to base case	%		–0.1	–1.3	–0.3	–1.1	–1.5
Nitrogen oxides	t NO_x	2 156 438	2 155 275	2 132 925	2 151 339	2 137 627	2 129 828
Difference to base case	%		–0.1	–1.1	–0.2	–0.9	–1.2

The combined case considers only the *net* effect on emissions. The reductions of sulphur dioxide emission in the combined policy case are significant. Adding up the percentage reductions would have yielded –2.8 per cent from the base case, but the combined case only reports 1.5 per cent. An advantage of a modelling framework for such analysis is that the combined effects are not exaggerated. For both sulphur dioxide and nitrogen oxides, the combined case does slightly better than the best individual policy (efficient houses), but by a small share. Nonetheless, it illustrates the co-benefits of taking climate action in the residential sector, quantifying the reductions in local air pollution.

Table 7.9 shows total GHG emission in the base case and residential policy cases. The emission reductions are shown both as tons reduced from the base case and also as a percentage. The highest reductions of GHGs among residential policies are achieved by efficient houses, followed by SWHs and GBs. The reductions reflect the large share of household energy consumption for space and water heating. Lighting accounts for a much smaller share and the emission reduction is the lowest.

Table 7.9 *GHG emissions in residential policy cases*

	Unit	Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/ GB	Residential policies combined
Total GHG emissions, 2025	Mt CO_2-equiv.	634	633	626	632	628	625
Reduction from base case	Mt CO_2-equiv.		–0.4	–7.5	–1.4	–6.0	–8.3

	Unit	Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/ GB	Residential policies combined
Difference to base case	%		0	–1	0	–1	–1
GHG emissions by gas							
Carbon dioxide	kt CO_2	630	630	623	629	624	622
Methane	t CH_4	50 325	50 323	50 234	50 380	50 261	50 301
Nitrous oxide	t N_2O	8 171	8 165	8 065	8 149	8 082	8 052

The last three rows break down the total GHG emissions by gas. Most of the emissions in the residential sector are in the form of carbon dioxide. Greater efficiency in end uses avoids emissions upstream at the power stations. Methane and nitrous oxide emissions are associated in the model with residential use of other residential fuels, but they make up a small portion as electrification continues.

For avoided upstream emissions, it is important to avoid double counting when combining policies. If electricity has already been reduced through efficient housing shells, not the full amount would be reduced by also introducing efficient lighting. Adding up the emission reductions for GHGs would have given 15.3 Mt CO_2-equivalent, but the combined policy case only shows 8.3 Mt CO_2-equivalent – only 54 per cent of the sum. The combined effect of residential policy is significant but not overstated. The combined case does not increase emission reductions much beyond those of efficient houses.

Local air pollutants reduced by electricity policy

The reductions in local air pollutants from electricity policy cases are larger than for residential policies. Electricity supply is a much larger contributor to total air pollution, while households are one of the smaller demand sectors. Table 7.10 shows that both the PBMR and renewables policy cases achieve high levels of reductions for local pollutants, notably sulphur dioxide and nitrogen oxides – between 4 and 6 per cent below the base case.

Table 7.10 *Local air pollutants in electricity policy cases, 2025*

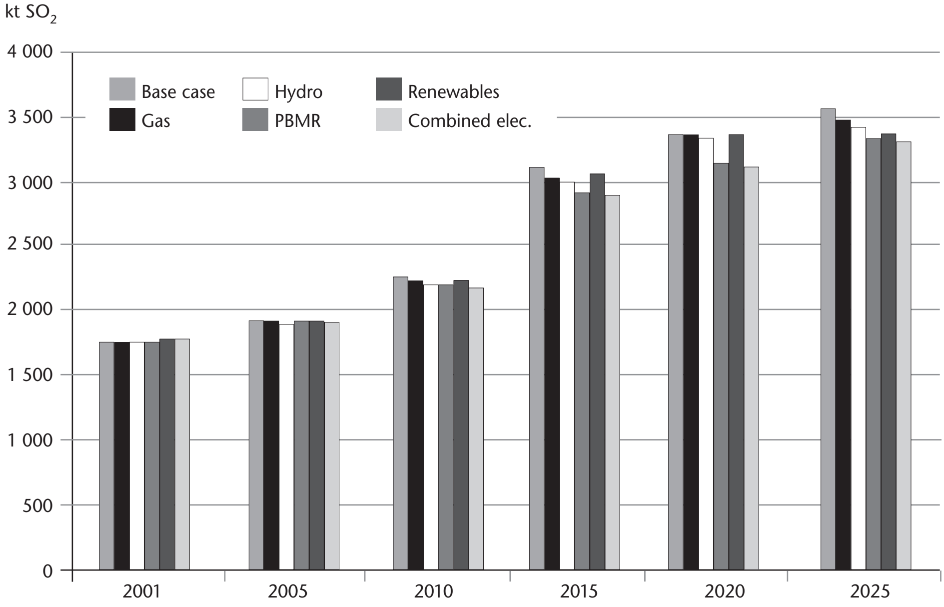
	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined electricity (gas, hydro, nuclear, RE)
Sulphur dioxide	kt SO_2	3 571	3 487	3 429	3 361	3 374	3 326
Difference to base case	%		–2	–4	–6	–6	–7

	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined electricity (gas, hydro, nuclear, RE)
Nitrogen oxides	t NO_x	2 156 438	2 114 198	2 086 086	2 053 462	2 060 563	2 035 692
Difference to base case	%		–2	–3	–5	–4	–6
Carbon monoxide	t CO	4 923 479	4 918 409	4 916 535	4 913 639	4 962 143	4 960 353
Difference to base case	%		0	0	0	1	1

Note: RE = renewable energy

The trends in sulphur dioxide emissions are illustrated in Figure 7.4. In the base year, emissions are close to 1 760 kt SO_2 in all cases, so that the variations in the policy cases appear small.

Figure 7.4 *Sulphur dioxide emissions in electricity policy cases over time*



Some of the reductions in absolute terms were reported in Chapter 6, with the PBMR case reducing 210 kt SO_2, renewables 197 kt and the combined case 245 kt SO_2 in 2025. Emissions of nitrogen oxides were lowered from the base case by 103, 96 and 121 kt NO_x for the respective cases.

Other local environmental impacts

The focus on air pollution, both global and local emissions, should not lead one to ignore the other environmental impacts of energy supply options.

Renewable energy is generally considered environmentally friendly but one should deal with its impacts like any other energy technology, even if they are at a smaller scale. Biomass should be sustainably harvested and not use up indigenous forest. The viability of growing fuel crops will depend on scarce resources of arable land and water. Using biomass for energy will compete with using it for food. Wind turbines face three main environmental concerns – sight pollution, bird strikes and turbine noise. For photovoltaics, it is not only the heavy metals in the panels, but also parts of the rest of the system, such as lead-acid batteries and light fixtures, that require careful disposal (ERC 2004a).

The environmental impacts of large dams – including flooding sensitive areas, displacement of people, possible seismic effects – have been outlined by the World Commission on Dams (WCD 2000). The largest of South Africa's hydroelectric facilities are Gariep (360 MW), Vanderkloof (240 MW) – both on the Orange River – and Collywobbles (42 MW) on the Mbashe River. None of these are very large by international comparison and others are 11 MW or smaller. Few sites exist for the development of large hydro facilities domestically; the potential lies in the southern African region. Nonetheless, the country has a unique biodiversity endowment and ecological sensitivity that necessitates stringent environmental measures even in the case of small hydro projects (ERC 2004a). The ecological reserve prescribed by the new Water Act (No. 26 of 1998) requires that sufficient water be left to maintain river ecosystems.

The higher efficiency of combined cycle gas turbines can reduce GHG emissions and local pollutants such as nitrogen oxides. However, the production, processing and transportation of gas by pipeline can also be a major contributor to GHGs in terms of fugitive emissions. With a high global warming potential, every ton of methane leaked has the equivalent effect of 23 tons of carbon dioxide. The social impacts of gas pipelines on communities over whose land they pass should also be taken into account.

The social and environmental impacts of nuclear energy technologies – waste disposal, security, and public acceptance – are discussed in Chapter 8.

Coal-fired power stations, which dominate the base case, have important local implications for water. Three main concerns are the effect of coal mining on water quality, that Eskom pays a price for water that is probably below the opportunity cost, and the quantity of water used by power stations (Spalding-Fecher, Afrane-Okese et al. 2000). Most of the coal stations dump their heat from the condensers in conventional cooling towers, which use between 1.8 and 2.0 litres of water for every kWh of electricity generated. However, fresh water is South Africa's most critical resource and so two stations, Kendal and Matimba, have dry cooling and use only 0.1 litres of water for every kWh (ERC 2004a).

While each energy technology should deal with its problems, the policy options examined here have important positive benefits. A large co-benefit of developing these energy technologies lies in reduced GHG emissions.

GHG co-benefits for electricity supply options

The electricity supply options were designed to meet development objectives – achieving universal access in all cases, meeting a renewable energy target, investing in the PBMR or importing energy. The co-benefits of electricity policy options in terms of reduced GHG emissions are summarised in Table 7.11. As would be expected, the emission reductions from the base case are larger than for the residential sector.

In terms of GHG emission reductions, both the renewables and PBMR cases result in approximately 5 per cent reductions from the base case in 2025. The PBMR achieves 1 Mt CO_2 more reduction in 2025 than renewables, but this must be considered against the larger capacity and investment of the PBMR policy case. The abatement costs are correspondingly lower for renewables (discussed below). The combined case does have the highest emission reduction, but at a unit cost almost double that of renewables. Gas is a cleaner fossil fuel than coal and so still reduces emissions, but the least among the policy options.

Table 7.11 *GHG emissions for electricity supply options*

	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined electricity (gas, hydro, nuclear, RE)
Total GHG emissions, 2025	Mt CO_2-equiv.	634	620	611	601	602	594
Reduction from base case			–14	–22	–33	–32	–40
Difference to base case	%		–2	–4	–5	–5	–6
GHG emissions by gas							
Carbon dioxide	Mt CO_2	630	617	608	597	598	590
Difference to base case	%		–2	–4	–5	–5	–6
Methane	t CH_4	50 325	50 035	49 941	49 811	51 352	51 262
Difference to base case	%		–1	–1	–1	2	2
Nitrous oxide	t N_2O	8 171	7 981	7 849	7 695	7 884	7 776
Difference to base case	%		–2	–4	–6	–4	–5

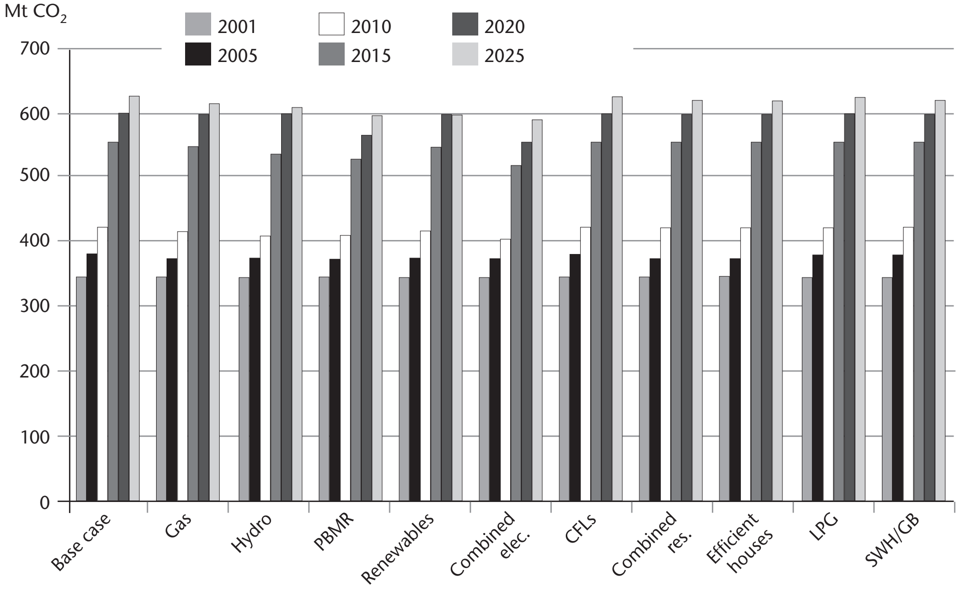
Note: RE = renewable energy

Renewables show an increase in methane, since biomass-based RETs contribute substantially to meeting the target. Counting the three major GHGs, however, the small increase in methane is more than outweighed by the reduction in carbon dioxide.

Emission trends and abatement costs

The upward trends in carbon dioxide emissions can be seen in all policy cases (Figure 7.5). The relative reductions of policy cases can be seen, as the level of the bars in later years is reduced for renewables, PBMR and combined electricity cases. The cost of reducing emissions from the base case is an important factor.

Figure 7.5 *Carbon dioxide emissions for all cases over time*



Detailed analysis of the costs of reducing emissions would require a separate study, drawing on the literature for detailed abatement costing (Fankhauser & Tol 1996; Halsnaes et al. 1998; IPCC 2001c; Krause et al. 2002; Markandya & Halsnaes 2001; OECD 2000; World Bank 1998). This is not the focus of the book and only a simple estimate of abatement costs is derived for comparison across policies. Table 7.12 shows the incremental investment costs in technologies in 2025. Only the investments required for technologies (supply and demand) are considered, not total system costs. Costs are discounted to present value, and the increment is the difference between each policy and the base case. Similarly, emission reductions are relative to the base case. The simple measure of abatement cost is the emission reductions divided by the incremental cost.

Table 7.12 *Estimate of abatement cost in policy cases*

Electricity supply options		**Imported gas**	**Imported hydro**	**PBMR nuclear**	**Renewable electricity**	**Combined (gas, hydro, nuclear, RE)**
Abatement cost	R/ton CO_2-equiv.	5.61	3.94	2.89	2.52	4.84
Rank (1 high, 10 low)		3	5	8	9	4
Emission reductions (policy – base case), 2025	Mt CO_2-equiv.	–14	–22	–33	–32	–40
Incremental costs of investment in technologies, 2025, discounted	R millions	–76	–89	–95	–80	–192
Residential policies		**CFLs**	**Efficient houses**	**LPG for cooking**	**Water heating – SWH/GB**	**Residential policies combined**
Emission reductions/ incremental cost	R/ton CO_2-equiv.	167.37	0.12	7.72	3.50	3.07
Rank (1 high, 10 low)		1	10	2	6	7
Emission reductions (policy – base case), 2025	Mt CO_2-equiv.	–0.4	–8	–1	–6	–8
Incremental costs of investment in technologies, 2025, discounted	R millions	–62	–1	–11	–21	–25

Note: RE = renewable energy

The range of costs is low, relative to a market price of carbon already reaching €10 per t CO_2 (R80 per t CO_2), and such prices are expected to be higher by 2025. Only the CFL case is above this range, given the small emission reductions.

The most cost-effective policy for abatement comes from the residential sector as well, namely in efficient housing. Renewable energy and the PBMR also have simple abatement cost estimates below R3 per t CO_2. SWHs and GBs cost about a rand more per ton. Imported gas and LPG become slightly more expensive. The overall implication, however, is that the residential and electricity policies examined have incremental abatement costs that are within the range of carbon prices.

Social

The social dimension of sustainable energy development can be assessed most directly in the residential sector. Earlier chapters motivated that analysis needs to be conducted at the level of the household, where many of the social interactions relating to energy occur. Following the indicators outlined above, the fuel consumption patterns for households are examined and changes in fuel prices and the implications for affordability are evaluated.

The approach taken in this book is to start from development objectives. Increased access to electricity is a key development objective for the residential sector in South Africa. Access is primarily provided through the grid but there are significant off-grid programmes in South Africa, which are not captured by this approach. Even if 350 000 SHSs were installed, however, they would provide some 0.2 per cent of electricity supplied by the grid to domestic customers (NER 2002a). Affordability of using electricity is important as well; hence physical connection to grid electricity is a necessary but not sufficient condition for development.

The implications of electricity supply for social sustainability are less direct than in the residential sector. Electricity supply, however, has important implications for the price of electricity in the residential sector. Decisions about energy supply are made implicitly by governments, utilities and investors, with less discussion of their social consequences than the indirect effects might merit. Electricity prices, expenditure and the burden it places on households are discussed later. First, however, the more direct social impacts of the consumption of household fuels and their prices are examined in the following two sections.

Fuel consumption by households

Chapter 6 showed how monthly fuel consumption varies substantially across household types (Table 6.5). Poorer, rural and non-electrified (RLN, ULN) households were found to consume only a fraction of the energy that richer urban and rural electrified (UHE, RHE) households use each month. For the evaluation in this chapter, the variation across policy cases is examined (see Table 7.13). When considering energy prices and affordability, the analysis returns to a consideration of household types.

Table 7.13 *Residential fuel consumption (PJ) by policy case*

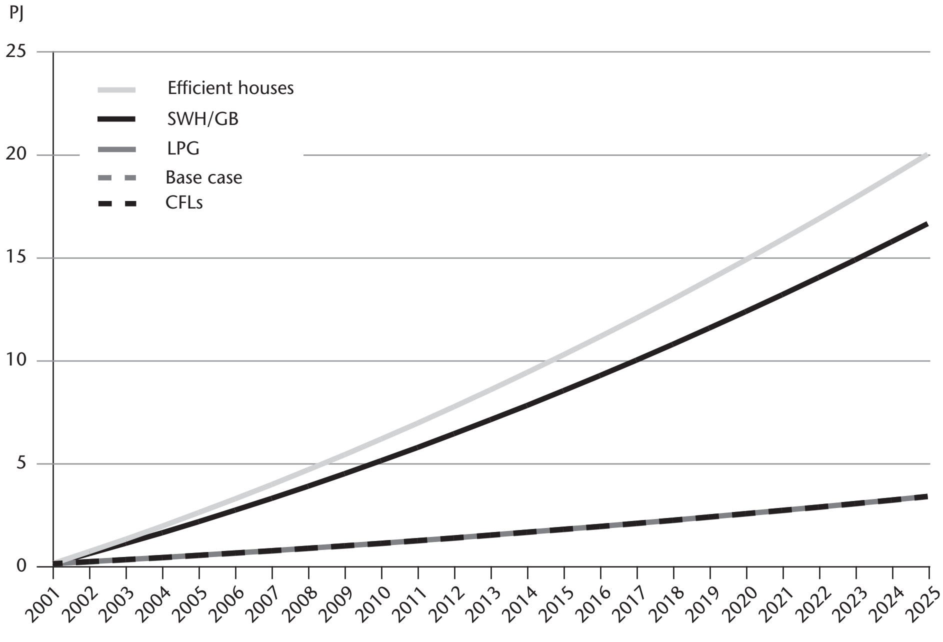
		Base case	CFLs	Efficient houses	LPG	Water heat	Combined res.
Electricity	2014	99	98	96	96	99	93
	2025	117	116	113	110	117	105
Liquid fuels	2014	52	52	41	52	43	43
	2025	59	59	36	59	39	39
Renewable energy	2014	1.7	1.7	9.5	1.7	7.9	7.9
	2025	3.5	3.5	20.1	3.5	16.7	16.7
Solid fuels	2014	49	49	49	52	48	51
	2025	34	34	34	42	34	41
Total fuel use	2014	201	201	195	201	198	195
	2025	213	212	202	214	207	202

Table 7.13 shows the fuel consumption for electricity, liquid fuels (such as paraffin and LPG), solid fuels (coal, candle wax), renewable energy and total fuel consumption. Electricity is the largest portion of total fuel supply across time and all policy cases, consistent with the assumptions about increasing electrification.

Relative to the base case, reductions in electricity consumption can be seen in the policy cases. The largest reduction in total fuel use by 2025 is achieved through efficient houses, consuming 11 PJ or 5 per cent less than in the base case.

Renewable energy increases in the case of SWHs and efficient housing, as well as the combined case. Rather than avoiding electricity use, SWHs and GBs displace the consumption of liquid fuels for water heating, since the model avoids the most costly alternative.

Figure 7.6 *Renewable energy use in residential policy cases*



In Figure 7.6, the two cases can be clearly seen above the others – LPG and CFLs show the same use of renewables as the base case. Efficient houses do not actively use any renewable energy source, but are considered a RET in the sense of 'passive solar design'. Certainly, better design and the installation of ceilings reduce other fuel use.

The type of fuel used has social implications in its own right. Electricity, while generating emissions upstream, is clean at the point of use. Renewable energy is clean both in its generation and its use, with environmental issues confined to balance-of-system issues. Household uses of paraffin and coal have significant impacts, such as indoor air pollution, paraffin poisoning and fires. Efficient houses and SWHs/GBs are found to be most effective in promoting cleaner fuel use.

Residential fuel prices

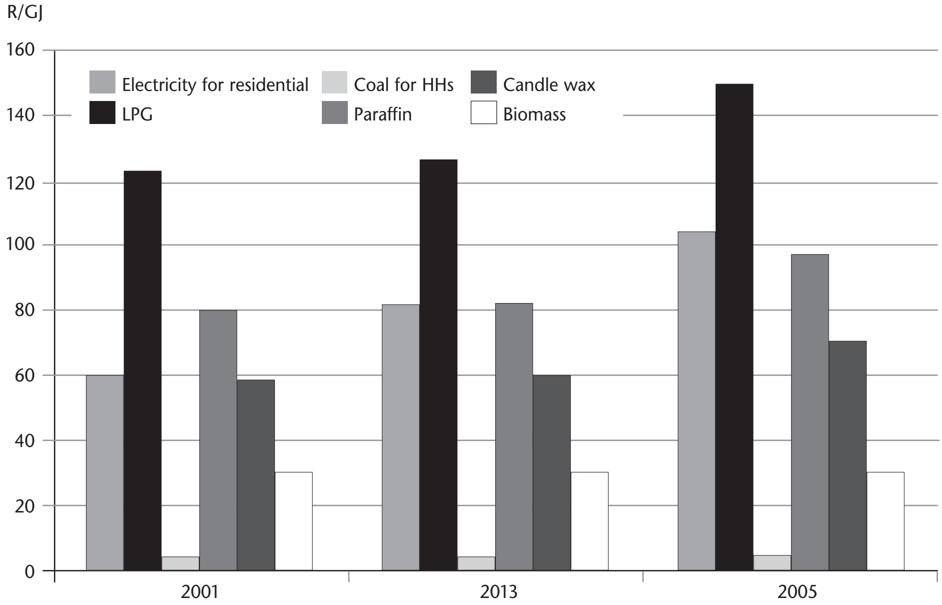
Access to cleaner fuels is one matter, being able to afford the use of such fuels another. The prices of cleaner fuels have to be brought down if households are to use them. Fuel prices are important socio-economic indicators with implications for households. The measure used for this indicator is the shadow prices of residential electricity (see Table 7.14). Earlier, the shadow price of *supplying* electricity was considered; here the indicator is the opportunity cost of the energy carrier used in the household.

Table 7.14 *Shadow prices of electricity and other fuels across policy cases*

		Base case	**CFLs**	**Efficient houses**	**LPG for cooking**	**Water heating – SWH/GB**	**Residential policies combined**
		Cost of energy services to households					
Shadow price of electricity in the residential sector	c/kWh	37.8	34.8	34.2	34.8	34.8	34.2
Electricity in common units	R/GJ	105.1	96.7	95.1	96.7	96.7	95.1
Shadow price of non-electric fuels in the residential sector							
Coal for households	R/GJ	3.5	3.5	3.5	3.5	3.5	3.5
Biomass		30.0	30.0	30.0	30.0	30.0	30.0
LPG		149.4	149.4	149.4	149.4	149.4	149.4
Paraffin		96.9	96.9	96.9	96.9	96.9	96.9
Candle wax		70.3	70.3	70.3	70.3	70.3	70.3

The prices of non-electric fuels do not vary across residential policies. CFLs use electricity and GBs reduce the electricity required to heat water; the efficiency of houses and water heating reduce the quantity of fuels used, but not their price; the LPG policy case allowed switching to the fuel, but did not alter the price. Figure 7.7 shows that the shadow prices for some of the non-electric fuels change over time. The opportunity costs of LPG, paraffin and candles increase over time, while biomass and coal remain constant.

Figure 7.7 *Shadow prices of energy carriers over time*



Note: HH = household

These trends are of some interest in themselves, but for comparison of policy cases the fuel of interest is electricity, which does have a different opportunity cost depending on the policy case. The shadow price of electricity in Table 7.14 is lowest for efficient houses at 3.6c per kWh less than the base case, a reduction of 9 per cent. The other residential policies (for CFLs, LPG and SWHs/GBs) achieve a slightly lower reduction, but still 3c per kWh. Overall, more efficient use of resources means that the opportunity cost of using electricity is reduced. Lower expenditure for the same amount of useful energy means that the cost of the more efficient service is lower. Therefore, the difference between that cost and the least-cost alternative is also reduced.

Table 7.15 *Initial investment in technology in its policy case*

	Total investment over 25 years, R millions	Per household (2025 estimate)
Investment in efficient houses	5 159	398
Investment in LPG cooking	2 793	216
Investment in cleaner water heating	6 193	478
Investment in CFLs	8 891	686

More important than shadow prices for poor households are the 'first costs'. Table 7.15 shows the total investment required in the appliances relevant to the policy case (for example, LPG in the LPG for cooking case). The values are summed for all households over the period in the first column and an indication of the cost per household taken in relation to the estimated 12.95 million households in 2025. For the poorest households, some assistance with initial costs might be required, but for middle- and upper-income households, costs in the hundreds of rands would be affordable.

Expenditure on residential electricity

What implications does a lower cost of electricity service have for household income? An indication would be the share of household expenditure that a household devotes to energy. The answer to this question cannot be addressed within the modelling framework. Markal does not include household income; indeed, households themselves occur only as units of flows of energy and money. Further analysis of the electricity burden is presented in the following tables. The focus is on electricity, since its shadow price varies over time and it relates to the other focal supply sector of this book.

Electricity expenditure is the product of consumption and price. Table 7.16 shows the monthly consumption of electricity for each household type. The initial rows show the consumption for each end use, which is added up in units of MJ per household per month. The 'intensity' of energy consumed per household per month does not change significantly from the base year in the model, except for a small change in electricity.[1] Electricity prices in 2001 do not diverge by policy case, so the analysis here focuses on the end year.

Table 7.16 *Electricity consumption by household type*

	RHE	RLE	UHE	ULE
Cooking	49	11	313	54
Lighting	261	99	156	136
Other electric	261	6	290	8
Space heating	84	7	330	123
Water heating	169	32	469	271
Total electricity (in MJ)	824	156	1 559	591
In kWh	229	43	433	164

Notes: Units = MJ per household per month.
See list of acronyms for explanations of column headings.

The shadow prices for residential electricity are different from those of electricity in general. In the same units as Table 7.14, they are R105 per GJ for the base case, R95.1 for efficient housing and the combined case, and R96.7 for the other policy cases for 2025. They are shown in units of R/MJ across the second row of Table 7.17.

Consumption is shown in the second column, and the monthly expenditure per household on electricity in the body of the table.

Table 7.17 *Monthly expenditure on electricity, by household type and policy case*

	Consumption (MJ/HH/ month)	Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
Price (R/MJ)	*x*	*0.1051*	*0.0967*	*0.0951*	*0.0967*	*0.0967*	*0.0951*
RHE	824	87	80	78	80	80	78
RLE	156	16	15	15	15	15	15
UHE	1 559	164	151	148	151	151	148
ULE	591	62	57	56	57	57	56

Notes: Unit of expenditure = R/household/month, 2025.
See the list of acronyms for explanations of the abbreviations in column one.

Table 7.17 demonstrates that all the residential policies reduce expenditure compared to the base case. Since shadow prices of electricity vary by policy case, the expenditure patterns vary across policy cases as well. However, the rand amounts are not large, with the largest reduction (efficient houses for UHE) amounting to R16 per month. For RLE households, off a low base of consumption, the savings are one or two rand per month. The larger energy savings in efficient housing and water heating carry through to the household level. The savings amount to a 9.5 per cent reduction from the base case, whereas other individual policies achieve 8.0 per cent.

Assessing affordability: Electricity burden

The electricity burden is defined for this analysis as expenditure on electricity divided by the total average household expenditure. The electricity expenditure above was derived from model results for each household type. To understand the social implications of electricity expenditure, it needs to be placed in the context of household income. Here the analysis goes beyond the modelling framework. As noted earlier, Markal does not include household income; households themselves occur only as units of flows of energy and money.

Statistics South Africa provides data on household expenditure for 2000 (Stats SA 2002).[2] The data shown in Table 7.18 were used in Chapter 6 to define poorer and richer households, with the bottom two quintiles taken as poorer. The table shows average annual expenditure, also disaggregated by type of dwelling and rural/urban households.

Table 7.18 *Average annual expenditure for various household types*

Quintile	Expenditure in 2000 (R/household/year)	Place of residence	R/household/ year	Type of dwelling	R/household/ year
5 (bottom)	<7 547	Urban	66 000	House	66 000
4	7 547–12 295	Non-urban	29 000	Informal dwelling	20 000
3	12 296–20 450			Traditional dwelling	18 000
2	20 451–41 040				
1 (top)	41 041+				

Source: Stats SA (2002: Tables 3.1 and 4.2)

For rural households, the average annual income of 'poorer' households can be taken as R7 547 (break point between bottom two quintiles) and R41 040 (upper point of quintile 2). Urban lower-income households will tend to have incomes at the high end of the range of poorer households, confirmed by the much higher expenditure shown for urban than non-urban households in the table. ULE households are likely to have a higher share of informal dwellings, with much lower expenditure (R20 000) than the urban average. The higher expenditure of R66 000 is influenced by the higher proportion of richer households in urban areas. The approach is to assume an average income for ULE households at the top of the fourth quintile, and to adjust the UHE income to reflect the greater share of higher-income households. The monthly and annual household expenditures used in the analysis are shown in Table 7.19.

Table 7.19 *Derived average annual and monthly expenditure, by household type*

	R/HH/ month	R/HH/ year
RHE	3 420	41 040
RLE	629	7 550
UHE	7 642	91 705
ULE	1 025	12 295

Notes: HH = household
See the list of acronyms for explanations of the abbreviations in column one.

The electricity burden has been calculated as a share of monthly electricity expenditure (Table 7.17) over total monthly household expenditure (Table 7.19). The results are shown in Table 7.20, for each household type and policy case.

Table 7.20 *Share of monthly household expenditure spent on electricity (%)*

	Base case	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
RHE	2.5	2.3	2.3	2.3	2.3	2.3
RLE	2.6	2.4	2.4	2.4	2.4	2.4
UHE	2.1	2.0	1.9	2.0	2.0	1.9
ULE	6.1	5.6	5.5	5.6	5.6	5.5

Note: See the list of acronyms for explanations of the abbreviations in column one.

The electricity burden varies by household type, being relatively higher for ULE households. The burden reflects the lower assumed income of this household group, but increasing levels of consumption of electricity. Given that these are poorer households, residential policies could contribute to socially sustainable development if focused on this group. Comparing ULE to RLE households, the low consumption levels of the rural households keep the electricity burden lower. UHE households consume more electricity per month, but household incomes are higher by a larger ratio.

Comparing the impact of policy cases on the electricity burden, it can be seen that in *all* policy cases the electricity burden of households is reduced. The reduction in the burden is highest among the individual policy cases for efficient houses. The burden in this case is 9.5 per cent lower than in the base case. Only the combined case, which includes efficient housing, matches this reduction. Other individual cases still achieve an 8.0 per cent reduction compared to the base case.

Comparisons and conclusions

In least-cost energy models, the assumption is typically that increases in average per capita consumption will improve the lives of most or all individuals. Efficiency implies maximisation of output (or minimisation of cost) subject to resource constraints. But if the distribution of consumption worsens, total welfare might be declining (Munasinghe & Swart 2005). The methodology adopted in this book combines least-cost energy-economic modelling with indicators of sustainable development and policy analysis. The interactions between social equity and economic efficiency deserve particular attention, since conflicts arise between them.

Hence this chapter has attempted to examine issues of social equity more closely, focusing on the residential sector. The quantifiable indicator for increasing access to *affordable* energy services was a reduced electricity burden for households. The analysis proceeded on a household basis, drawing fuel consumption and electricity price information from the modelling framework. Outside of the model, the expenditure on electricity was expressed as a share of average household expenditure.

Table 7.21 *Evaluation of all policies across three dimensions of sustainable development*

	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined elec. (gas, hydro, nuclear, RE)	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
Economic												
Total cost of energy system, cumulative over the period	R billions	6 120	6 119	6 117	6 132	6 122	6 131	6 119	6 119	6 121	6 115	6 115
Difference to base case			–0.8	–3.1	11.7	1.9	10.9	–0.9	–0.9	0.6	–4.6	–5.0
Shadow price of electricity, 2025	c/kWh	19.3	18.8	18.8	19.3	19.3	22.3					
Diversity of electricity fuel mix from domestic sources by 2025												
Share of renewable energy	%	1.0	1.1	1.1	0.8	11	6					
Share of nuclear energy	%	11	11	11	34	11	11					
Share of other (mainly coal)	%	88	88	88	66	78	83					
Environmental												
Local air pollutants, 2025												
Sulphur dioxide	kt SO_2	3 571	3 487	3 429	3 361	3 374	3 326	3 568	3 524	3 559	3 531	3 517
Difference to base case	%		–2	–4	–6	–6	–7	0	–1	0	–1	–2
Nitrogen oxides	t NO_x	2 156 438	2 114 198	2 086 086	2 053 462	2 060 563	2 035 692	2 155 275	2 132 925	2 151 339	2 137 627	2 129 828
Difference to base case	%		–2	–3	–5	–4	–6	0	–1	0	–1	–1

→

→	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined elec. (gas, hydro, nuclear, RE)	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
Carbon monoxide	t CO	4 923 479	4 918 409	4 916 535	4 913 639	4 962 143	4 960 353	4 923 416	4 921 832	4 923 237	4 922 246	4 921 730
Difference to base case	%		0	0	0	1	1	0	0	0	0	0
Global GHGs, 2025												
Total GHG emissions, 2025	Mt CO_2-equiv.	634	620	611	601	602	594	633	626	632	628	625
Difference to base case	%		–2	–4	–5	–5	–6	0	–1	0	–1	–1
Reduction from base case			–14	–22	–33	–32	–40	–0	–8	–1	–6	–8
Social												
Fuel consumption in residential sector (PJ)												
Electricity	2014	98.9						98.3	96.4	95.9	98.9	93.1
	2025	116.8						115.5	112.6	110.3	116.8	104.9
Liquid fuels	2014	51.9						51.9	41.3	51.9	43.0	43.0
	2025	58.9						58.9	36.1	58.9	39.3	39.3
Renewable energy	2014	1.7						1.7	9.5	1.7	7.9	7.9
	2025	3.5						3.5	20.1	3.5	16.7	16.7
Solid fuels	2014	48.6						48.6	48.6	52.0	48.0	51.3
	2025	34.4						34.4	34.3	41.7	34.0	41.3
Total fuel use	2014	201.1						200.5	195.2	201.5	197.8	195.3
	2025	213.5						212.3	202.1	214.4	206.8	202.3 →

	Unit	Base case	Imported gas	Imported hydro	PBMR nuclear	Renewable electricity	Combined elec. (gas, hydro, nuclear, RE)	CFLs	Efficient houses	LPG for cooking	Water heating – SWH/GB	Residential policies combined
Cost of energy services to households												
Shadow price of electricity in the residential sector	c/kWh	37.8						34.8	34.2	34.8	34.8	34.2
Electricity in common units	R/GJ	105.1						96.7	95.1	96.7	96.7	95.1
Shadow price of non-electric fuels in the residential sector												
Coal for HHs	R/GJ	3.5						3.5	3.5	3.5	3.5	3.5
Biomass		30.0						30.0	30.0	30.0	30.0	30.0
LPG		149.4						149.4	149.4	149.4	149.4	149.4
Paraffin		96.9						96.9	96.9	96.9	96.9	96.9
Candle wax		70.3						70.3	70.3	70.3	70.3	70.3
Monthly expenditure on electricity (R/HH)												
RHE		87						80	78	80	80	78
RLE		16						15	15	15	15	15
UHE		164						151	148	151	151	148
ULE		62						57	56	57	57	56

Notes: HH = household; RE = renewable energy; see the list of acronyms for explanations of the other abbreviations.

Even this analysis remains partial and represents a narrow definition of social equity. Not only are other fuels not included, but broader dimensions such as empowerment and participation defy quantification.

The analysis of the electricity burden gives only one indication of the contribution that residential policies can make to social sustainability. Other dimensions of social sustainability would include job creation and empowerment through participation, which are more difficult to quantify. In addition, access to cleaner and more efficient energy services can contribute to respiratory health and promote literacy through enhancing educational opportunities. Reducing the pressure on household budgets is important, particularly for poorer households, and hence is the one analysed here.

Chapter 6 outlined the results for the modelled policy cases. This chapter has examined indicators for each of the dimensions of sustainable development in turn. The key indicators are summarised in Table 7.21, drawing on the data presented in the text. The policy cases can here be compared across economic, social and environmental indicators. The focus in the table is on quantifiable indicators. Some of the less easily quantified dimensions of energy policies will be picked up in Chapter 8.

The electricity supply options fall into three broad categories. Coal dominates the base case and remains the largest fuel over the 25 years in all policy cases. Importing either gas or hydroelectricity can be achieved at a reduction in the costs to the energy system, compared to the base case. The third category comprises two domestic options – the PBMR nuclear and RETs.

Table 7.21 shows that both domestic options increase the total energy system cost. For the PBMR, the cumulative discounted energy system costs rise by R11.7 billion for the period; costs rise by R1.9 billion for renewables. Only the combined case, requiring diversification in several directions at once, requires significant investments.

For the PBMR and renewables, the different levels of investment and capacity of each policy case must be borne in mind. Even after adjusting for the greater capacity of the PBMR, however (see earlier discussion), the PBMR is more expensive than the renewables case. The investment costs per unit of installed capacity differ for the various technologies used in policy cases (see Table 5.14). The ambitious introduction of 32 modules within this time period results in unutilised PBMR capacity. In the case of renewables, Chapter 6 noted that investment went to existing technologies plus new wind and bagasse co-generation, but the more expensive solar thermal options did not enter the policy case.

The indicators for diversity of energy supply yielded results with two aspects. Clearly, the larger investment and capacity in the PBMR case achieved the greatest share (a third) of electricity generation from non-coal technologies. The rapid transition to one other fuel meant that the resulting system was dominated by two fuels. The renewables case achieved a better mix of three fuel groups. The renewable case, with lower capacity and investment than the PBMR, still had greater dependency on coal.

From an environmental perspective, the two domestic policy cases show significant reductions for both local and global air pollutants. The largest reductions are achieved by the renewables and PBMR cases, with 6 per cent less sulphur dioxide than in the base case, and 4 per cent and 5 per cent respectively for nitrogen oxides.

Both domestic electricity cases also achieve significant reductions of GHG emissions against the base case. By 2025, the renewables policy case emits 32 Mt CO_2-equivalent less than the base case, and the PBMR 33 Mt. While this is a 5 per cent reduction from emissions in the base case, it is 10 per cent of the 345 Mt CO_2 emissions in 2000 (WRI 2003). It is a case not so much of emission reductions, but of avoiding future emissions. Renewables achieve a similar reduction in GHG emissions with lower capacity and investment. A simple estimate of abatement costs suggests that the incremental costs of emission reductions are correspondingly lower for renewables than for PBMR.

The social dimensions of sustainability are reflected in indicators for the residential sector. Two residential policies stand out across economic, social and environmental criteria – efficient houses and cleaner and more efficient water heating. The two policies make the greatest fuel savings in 2025, with efficient housing saving 11 PJ more than in the base case and SWH/GB saving 7 PJ.

It can be seen in Table 7.21 that the reduction of energy use translates into cost savings. In aggregate terms, water heating reduces total system costs, being a large residential end use. Introducing SWHs and GBs can reduce system costs by R4.6 billion over 25 years. However, Table 7.17 records reduced energy expenditure in all policy cases, even though the others are smaller in rand terms. Comparing the economic impact in terms of shadow prices of residential electricity, the reduction for efficient houses at 3.6c per kWh is again the highest.

Some additional analysis was conducted to quantify the contribution of policies to reducing the electricity burden. In all policy cases, the share of household expenditure devoted to the electricity burden is reduced. The efficient housing policy case reduced the burden by the largest relative amount. More significant than variation across policies were the results for different household types. The electricity burden for urban lower-income electrified households was the most encouraging, being a household type with increasing electricity use and low income. If poverty alleviation were a key policy consideration, this household type would be a priority target group for residential policies.

Efficient houses and SWH/GB contribute the most to cleaner fuel use. Contributing to diversity on the demand side, the two cases are the ones among residential policies which increase the use of renewable energy – water heating in the active sense of using solar energy and efficient housing through passive solar design.

Efficient houses and water heating achieved a similar percentage reduction for local air pollutants in the form of sulphur dioxide and nitrogen oxides emissions. Combining all policies increases the reductions only a little. Efficient housing would be the best option if the primary concern were local air pollution. The same pattern is followed for emissions of GHGs, most of which are in the form of carbon dioxide.

The combined case served in a number of instances to illustrate the value of considering individual policies in the context of the whole energy system. Often policies are considered in isolation. If several policies are implemented at the same time or in sequence, the combined effect is not simply the sum of the individual policies. The combined case showed higher levels of avoided emissions, for example, but not the amount if emission reductions from individual policies were added up. The lesson for policy-makers is that the cumulative effects of energy policies require attention through integrated assessments.

The evaluation of residential policies has revealed more insights into social dimensions of sustainability, while the larger investments in electricity supply options have a bigger impact on economic factors. Changes to the costs of the energy system are generally larger from the electricity policies (ignoring combined policies). However, since two of the electricity policies involve imports and therefore less capital expenditure domestically, they have cost reductions. The large increases in system costs are associated with the PBMR and renewables cases, whereas the largest reduction is through SWHs and GBs.

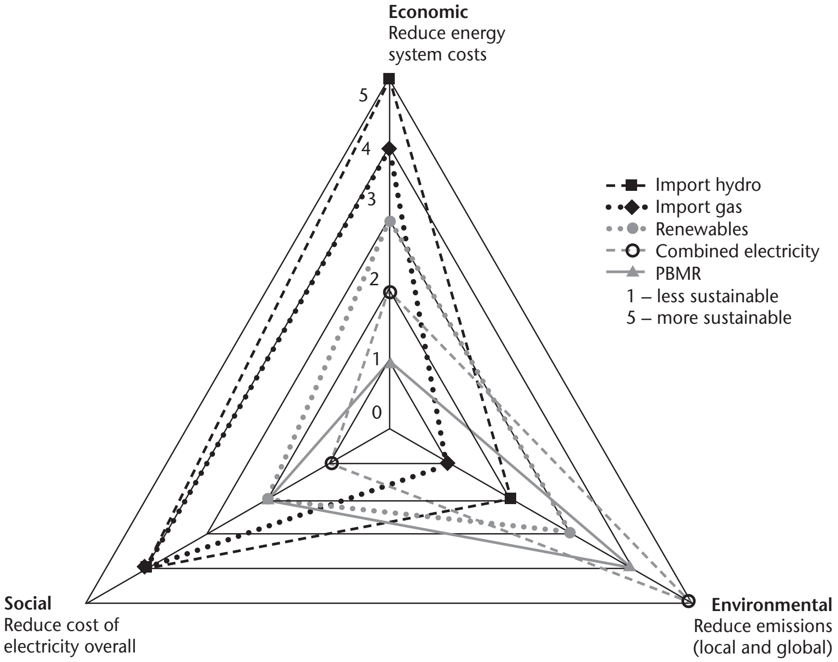
Both electricity supply and residential demand policies can assist in reducing environmental impacts. Reductions of emissions are consistently larger for electricity policy cases. The pattern holds true for both reductions of local air pollutants (sulphur dioxide and nitrogen oxides) and avoided GHG emissions (carbon dioxide, methane and nitrous oxide).

Comparing policies across dimensions of sustainable development

Do any of the policies satisfy the definition of sustainable energy development from Chapter 2? The working definition was that a set of 'development indicators' is increasing over time. The increase in electricity consumption is not threatened by 'feedback' from either biophysical impacts (local air pollution, GHG emissions) or from social impacts (social disruption – for example, if services are unaffordable). Indicators would be drawn from social, economic and environmental dimensions, but different stakeholders might emphasise various criteria.

For the electricity supply options, there are no clear winners. Figure 7.8 draws together the evaluation of social, economic and environmental indicators. The policies are ranked for a single indicator in each dimension – socially for reducing electricity costs, economically for reducing system costs and environmentally for reducing emissions (local and global are same rank order). Only rank orders are shown, with 1 representing low *reductions* of emissions, and 5 high. In other words, policy cases at the outside of the triangle are ranked higher in that dimension. There is no attempt to define sustainability, merely an indication that one policy case makes residential energy development more sustainable than the others. Where one triangle completely contains another, it would be higher-ranked in all three dimensions. The triangles overlap in Figure 7.8, so there are trade-offs.[3]

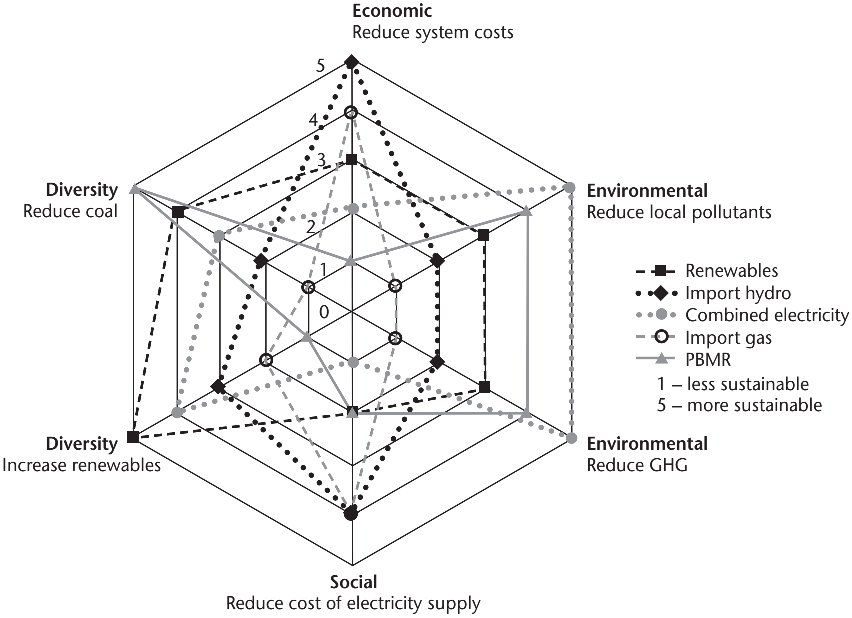
Figure 7.8 *Electricity supply options ranked by economic, social and environmental indicators*



If the priority were to reduce energy system costs, the importing of gas or hydroelectricity should be favoured, as that dimension is at the outer edge of the triangle for them, representing a relatively more sustainable policy. Both imports reduce domestic capital expenditure and overall system costs. Priorities of reducing emissions in South Africa would favour the two domestic options, even though these show increases of costs. Of the two domestic options, the PBMR is more expensive than renewables. The combined case might look attractive, except that it scores poorly on costs, making emission reductions expensive. Diversity of supply is shown in the figure only by the increased share of renewables. The renewables case still achieves a better mix among the other fuels, but one would need another indicator (for example, reduction in coal) to show that the PBMR achieves the greatest diversity of supply in moving away from coal dependency. Both domestic options reduce local air pollutants and GHGs by similar percentages from the base case – the simple ranking here puts the PBMR's 33 Mt CO_2 above renewables' 32 Mt. Figure 7.8

cannot show all dimensions shown in Table 7.21 – for example, the lower abatement costs of renewables are relevant. More indicators for each of the three dimensions of sustainable development are shown in Figure 7.9 for the same set of options. The figure does not have clear social, environmental and economic 'corners', but ranks the same options in more ways.

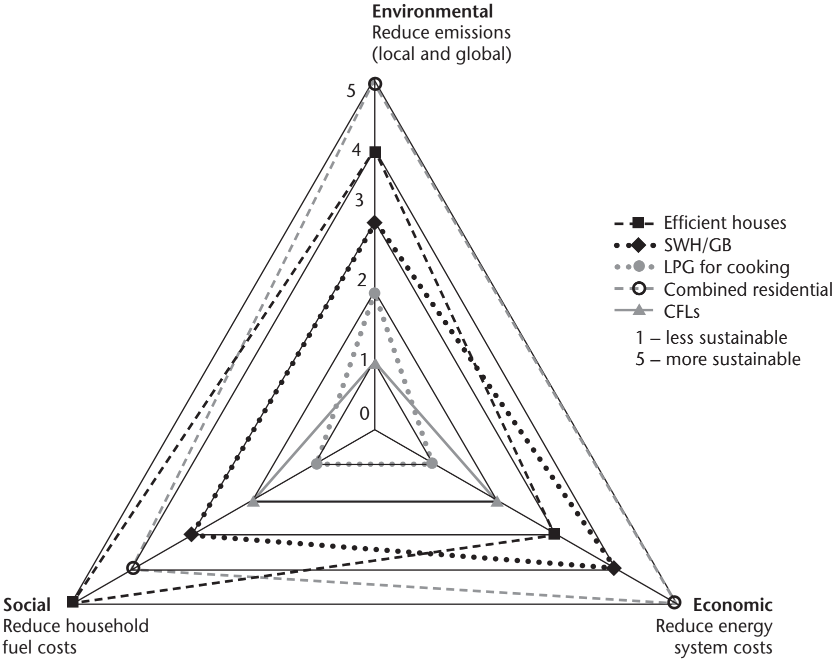
Figure 7.9 *Electricity supply options ranked against more indicators*



A clearer picture emerges for residential policies (Figure 7.10). For all policy cases, access to electricity is increasing. Within the context of meeting this basic energy development objective, two residential policies go furthest in making development more sustainable in all dimensions. Visually, the triangles for efficient houses and SWH/GB completely contain those for CFLs and LPG for cooking; that is, they are ranked on each of the dimensions shown. Efficient houses and SWH/GB make the greatest fuel savings and thus save the most energy costs for households. The policies reduce the electricity burden for households, particularly for poorer urban electrified ones. Increased affordability makes social disruption (for example, through protests against electricity cut-offs) less likely. Efficient houses and SWH/GB also contribute the most to cleaner fuel use and improve environmental quality.

Figure 7.10 appears skewed towards efficient houses, showing that this policy case scores high in all respects. SWHs rank next highest among individual cases. For residential policies, combining works well as shown by the bulge towards that end. LPG and CFLs look flat.

Figure 7.10 *Residential policies ranked by economic, social and environmental indicators*



Having compared both residential and electricity policies against each of the dimensions of sustainable development, Figures 7.8 and 7.10 have given a representation of the synergies and trade-offs (without being able to show all the indicators at once). The analysis against multiple criteria shows that there are clear win-win cases for residential policies, but more trade-offs in electricity supply between the indicators of sustainable development. In either case, however, policies developed theoretically by modelling or indicators need to be implemented in reality. Some of the factors required to implement energy policy cases are considered in Chapter 8.

Notes

1 A useful future extension of the work would be to examine possible changes, although this will require assumptions about changes in consumer demand for energy services, as well as residential appliance efficiency.

2 The electricity expenditure is for 2025, while expenditure is for 2000, one year before the base year. No equivalent reports for 2001 were found. The approach taken is rather to report the burden in relative, percentage terms, not rand amounts. The alternative to removing the inconsistency would have been to assume an increase in average household expenditure by 2025, or to adjust it by the ratio of electricity prices (2025/2001).

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

8 Developing sustainable energy for national climate policy

To answer the overall research question whether there are energy policies to make the development in South Africa's residential and electricity sectors more sustainable, policies need to be formulated and consideration given to what is required to implement them. This chapter elaborates how a policy focus on energy for sustainable development can be implemented to provide a sound basis for climate policy in South Africa.

The chapter addresses the implementation of those policies identified in Chapter 7 as having greater potential for making energy development more sustainable. Efficient houses and cleaner, more efficient water heating stood out in the evaluation of residential policies against indicators of sustainable development. Renewable energy had multiple benefits among electricity supply options, but the trade-offs with the lower costs of imports require consideration. The chapter discusses factors that promote the implementation of these energy policies, including institutional capacity, access to finance and demonstration of innovative technologies.

The second part of the research question related to whether sustainable energy policies also reduce GHG emissions. Placing climate change squarely in the broader context of development, the policies elaborated in this chapter can provide the core for national climate change policy.

What factors are needed to implement policies that make development more sustainable? In general terms, one could say that policy implementation requires enough money, good people/effective institutions and inspiring demonstrations (GEF 2004). Policies in the sense of regulation may include legislation, standards and certificates. Effective institutions are needed to implement policy – both organs of government and good business infrastructure. Access to adequate financing is a factor that is necessary for all successful policies. In many cases, financial instruments and mechanisms need to be designed to increase access to finance. Practical demonstration of innovative technologies and successful projects can provide inspiration for higher levels of implementation.

This chapter explores concrete examples of what is needed to implement the residential and electricity policies identified in the previous chapters. How could more efficient housing be financed? What can government do to promote the uptake of RETs?

Implementing sustainable residential energy policies

The evaluation of residential energy policies in Chapter 7 concluded that efficient housing and cleaner and more efficient water heating through SWH/GB ranked highly in all dimensions of sustainable development. The finding does not suggest that CFLs and LPG should be ignored, but perhaps that efficient housing and SWH/GB have priority for *policy* interventions.

CFLs certainly have important benefits, but not only is the consumption of energy for lighting smaller than for water heating and cooking, but substantial progress has already been made in disseminating CFLs. Increased penetration rates were seen in the base case, that is, under least-cost optimisation, particularly in higher-income households. Further dissemination can be expected to occur through the market. Other policy cases may need more intervention for social and environmental benefits. Policies to promote LPG for cooking require a more detailed study of relative price changes, and possibly some form of subsidy or means of making the fuel more accessible.

Among a good set of residential policies, efficient housing and SWH/GB stand out with highest energy savings, greatest reduction of the electricity burden, uptake of cleaner fuels and improvement in local environmental quality. Policy-makers should give priority to these policies or to a set of combined residential policies.

Inspiring demonstrations for residential policies

Demonstration projects exist for residential policies for efficient housing, SWHs and lighting. The Efficient Lighting Initiative aimed to instal some 18 million CFLs and brought down the price through a subsidy programme (see Chapters 4 and 6; pers. comm. Bredenkamp 2005[1]). An LPG challenge has given initial consideration to means of making the fuel more accessible (IES & AGAMA 2004). A number of housing projects have sought to include energy-efficiency measures, particularly in low-cost (RDP) housing (SEED 2002). There have been several successful projects – such as the Lwandle hostels-to-homes, the Shayamoya social housing scheme in Cato Manor, the Midrand Eco-City project in Ivory Park, the Missionvale project in Nelson Mandela City, the Moshoeshoe ecovillage and Eco-Homes project in Kimberley and the All Africa Games village in Alexandra (PEER Africa 1997; SEED 2002; Spalding-Fecher, Williams et al. 2000; Van Gass 1999) – but there are very few large-scale efforts at improving housing. South Africa's first registered CDM project at Kuyasa in Khayelitsha, Cape Town, has combined efficient design, SWHs and CFLs (SSN 2004). Some 2 300 low-cost houses are to be built more efficiently, increasing the scale of implementation to some extent. Yet the challenge remains to scale up good demonstration projects through implementation of a broader policy – one that could apply to the 2 or 3 million new houses that need to be built.

The results in Chapter 6 demonstrated energy cost savings for households as well as the energy system as a whole, accompanied by reduced local and global pollution. The policy question is how to turn the economic theory into practical adoption. A first step is to set standards.

Mandatory standards for efficient housing

Political will is required to increase the share of housing that is built efficiently. The general subsidy to build low-cost housing is subject to detailed and intense negotiations. Money for efficiency measures in this context is not easily obtained from the general housing subsidy of R17 500 per household (EDRC 2003b). An important signal from government would be to make housing guidelines mandatory.

Voluntary guidelines for efficient housing have existed for some time in the form of the South African Energy and Demand Efficiency Guidelines (DME 1999). Guidelines could be made mandatory for new housing, in particular some measures that require no expenditure but simply better planning and design. These include orientation of the house with the longer axis oriented east/west, positioning windows on the north to allow solar heat to penetrate the glazing during the winter months, and designing roof overhang for shade in summer. A further set of measures has a modest upfront cost, such as installing ceilings of long-lasting material (for example, gypsum board) and adding a layer of low-cost insulation above the ceiling and on the walls (see Holm 2000; Winkler, Spalding-Fecher, Tyani & Matibe 2000; Winkler, Spalding-Fecher, Tyani & Matibe 2002).

Both zero- and low-cost measures could be made mandatory for all new subsidy-supported housing, based on the results in Chapter 6. In addition, separate codes would be needed for middle-upper-income housing. The latter could be expected to pay for these measures themselves upfront and reap the benefits of energy savings in future years. For poorer households, financing will be required and the upfront costs need to be made affordable for households.

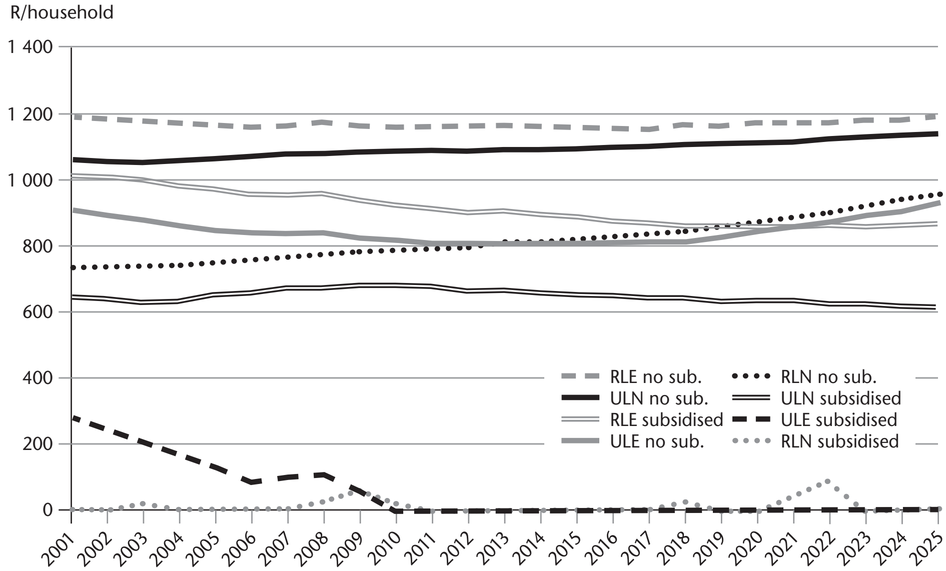
Subsidies for efficient houses

While energy efficiency makes sense from a societal perspective for low-cost housing, poor households cannot afford the upfront costs of better thermal design or more efficient lighting and water heating (Winkler, Spalding-Fecher, Tyani & Matibe 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 per cent (no subsidy) to 10 per cent ('subsidised'), the general discount rate for the model. In other words, the case examines what would happen to investment in efficient housing if poor households were more willing to invest now for future savings.

The lower discount rate approximates a subsidy, in the sense that the energy savings (which happen in the future) are now valued more highly and the upfront costs are valued correspondingly less. The change was made only for efficient houses. The results shown in Figure 8.1 are only for the poorer household types, since UHE and RHE households already had the 10 per cent discount rate.

The figure shows that for each household type, the marginal investment required (rand per household) is lower for the subsidised case than without the subsidy. In two cases, ULE and RLN, the marginal investment reaches zero in the subsidised case. In other words, no additional investment is required and efficient houses would be built for these household types. For RLE and ULN households, the marginal investment needed to build efficient houses is reduced, but not sufficiently to lead to investment.

Figure 8.1 *Marginal investments required for efficient houses at 30% and 10% discount rates*



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'. It should be remembered, though, that the marginal investments in Markal represent shadow prices or opportunity costs, not the prices of a real, imperfect market.[2]

Table 8.1 *Subsidy required to make efficient housing affordable*

	2001	2014	2025
RLE	–169	–267	–326
RLN	–739	–818	–958
ULE	–618	–811	–930
ULN	–407	–432	–531

Notes: Unit = R/household
The values in technical terms show the reduction in marginal investment as a result of lowering the discount rate for poor households from 30 per cent to 10 per cent.
Values are shown as negative values, the difference between the marginal investment with a low discount rate ('subsidy') and a high discount rate ('no subsidy').
See the list of acronyms for explanations of the abbreviations in column 1.

As Table 8.1 shows, the reduction in investment needed is larger for the RLN and ULE, the two household types which showed investment in efficient housing in Figure 8.1. The order of magnitude of the subsidy required to make efficient housing as affordable for poorer households as for richer ones is in the hundreds of rands (less than a thousand rand). A relatively small additional investment in housing for poor communities creates more comfort, reduces household energy costs, and cuts emissions from the residential sector. An extension of this policy could improve the energy efficiency and save households money. Energy efficiency in RDP housing is an area where a policy of direct state financial support to promote energy efficiency seems warranted.

In practice, instead of changing the discount rate itself, a financial mechanism would be used to make available the necessary upfront capital to poorer households. Municipal government could play an important role in administering a subsidy scheme.

Affordability and household types

The question of where subsidies might be targeted can be further illuminated in relation to SWHs and GBs. The context for the example is the finding throughout Chapter 6 that energy savings are largest for UHE households. The water-heating policy was a clear example, where SWH/GB reduced expenditure on other fuels overwhelmingly in the UHE household category.

The largest savings are made by those who least need to spend less, while the poorest households consume little energy and cannot save large amounts. A quandary for policy-makers arises – should the policy focus be on the households where the greatest energy saving can be made, or on those who have the greatest need?

The inclusion of GBs was intended as an option that might work better in lower-income electrified households. The much lower investment cost of GBs means that total investment is smaller than for SWHs (see Table 8.2).

Table 8.2 *Cost of saved energy for SWHs and GBs*

	Saved energy (policy – base case)	Total investment in policy case	Cost of saved energy	
	PJ	*R million*	*R/GJ*	*c/kWh*
GB	4.9	7.6	1.5	0.6
SWH	13.3	331	25.0	9.0

GBs account for a good part of the energy savings. The cost of saved energy for GB is below 1c per kWh, while it is 9c per kWh for SWH. The lower cost – both upfront and per unit of energy saved – suggests that GBs are more affordable for poorer electrified households.

The greater energy and cost savings in UHE households reflect only one perspective. The analysis of the electricity burden in Chapter 7 showed that, in relative terms, ULE households benefit the most from SWH/GB (at 5.6 per cent reduction below base case, compared to 2.0 to 2.3 per cent for other household types). Policies that seek to address affordability have a major aim of alleviating poverty. From this perspective, it would be most beneficial to prioritise poorer urban households.

Some limitations of the analysis of energy burden by household type should be noted at this point. The innovation of including six household types extended the boundaries of previous national energy modelling, but still simplifies the complexity of residential energy use. Not only would a large research effort be needed to model 60 household types (for example, with geographic disaggregation or more income groups), but some of the data are not available. Energy-use patterns for rich rural households, for example, are poorly understood. Even if these can be surveyed, some data will remain unknown – for example, the split of fuels used for different end uses. Markal as a tool is limited in its representation of households, which can only be represented directly (rather than as energy demands or units), with loss of resolution on the time of use. Yet affordability is a critical policy issue. Hence the quantitative results from modelling and the analysis against indicators in Chapter 7 must be supplemented by policy analysis.

Of course, the discussion assumes that the policy needs to be targeted. If sufficient funds were available, *all* households should be targeted. With limits to government budgets, different financing mechanisms could be considered. Donor funding for subsidies for SWH/GB in poorer households would be an option, at least in the process of establishing a viable local SWH manufacturing sector. For higher-income households, SWHs could be made mandatory but the financing spread out through green bonds (EEU 2000). Effectively, policy could provide direct financial support for poorer households, but offer only bridging finance for those who can afford to invest upfront for future energy savings.

Making LPG more accessible

Affordability is an issue that applies to LPG as well as to electricity. LPG is a desirable thermal fuel, yet little switching from other fuels to LPG has been observed in South Africa (IES & AGAMA 2004). Several barriers exist to the greater use of LPG. The government is still in the process of formulating a clear enabling policy and regulatory environment promoting LPG for the poor. Promotion of LPG is a 'poor cousin' to the intense focus on electrification. For customers, the affordability of LPG is a key issue, with the overall costs for boiling two litres of water being 25c, compared to 20c for electricity and 13c for paraffin (IES & AGAMA 2004: v). For rural areas, comparative energy costs for cooking were estimated at 48c per kWh-equivalent for LPG, compared to 30 to 40c for electricity (lower with the poverty tariff) and 28c for paraffin (EDRC 2003b: 26). Fuel costs make part of the difference, but the deposit on cylinders and the higher appliance cost (compared to paraffin) compound the lack of affordability.

From the industry side, distribution systems are needed to increase retailer networks and bring these closer to end-users. Currently, most customers have to manage the final delivery themselves, incurring transport costs and physically having to carry cylinders. LPG customers have little choice of retailers, in contrast to paraffin which is sold at many outlets. Finally, negative perceptions of LPG (for example, the feeling that gas is dangerous and can explode) need to be addressed through raising awareness of the safe use of LPG, as well as the comparative costs of energy choices, health and safety issues, and practical information (EDRC 2003b).

The issue of affordability can be addressed through removal of VAT on LPG, increased competition, incentives to switch fuels, and reducing costs of appliances (IES & AGAMA 2004). Reducing costs needs to be accompanied by measures that facilitate access to LPG – establishing better delivery networks and encouraging more retailers by reducing barriers to entry.

Energy centres can play an important role in facilitating access to LPG and reducing costs. Existing rural energy centres have demonstrated that it is possible to sell LPG at lower prices than current ones, due to bulk buying and modest profit margins (EDRC 2003b). Energy centres also make physical access easier and have worked on supplying cylinders in smaller sizes. Smaller cylinders are easy to carry physically and allow purchase of smaller quantities for poorer households. Energy centres may also be able to buy appliances in bulk. Together, measures that increase access and promote affordability can help reduce energy poverty.

Poverty tariff: Making electricity use more affordable

Policy to directly address the affordability of electricity has begun to be implemented through the poverty tariff. From 2004, government committed itself to implementing a free supply of electricity for basic needs (DME 2004c); (see details of the policy in Chapter 4).

The affordability of using electricity is a problem of poverty. Policy solutions limited to the electricity sector – for example, the poverty tariff and weak grid – can only address the problem partially. An overall solution must be part of a broader, cross-sectoral approach to poverty eradication. Changes in the economy at large, such as job creation and higher incomes, will be important in addressing affordability in its wider sense. President Mbeki in 2004 re-emphasised the 'central importance of the state as a social agent to effect the necessary resource transfers, and ensure their productive utilisation' (Mbeki 2004b). A year later, he more concretely indicated that government would 'complete discussions with Eskom, the provincial governments and local municipalities to ensure that free basic electricity is provided to all with the minimum delay' (Mbeki 2005).

The analysis in Chapter 7 found that policies could reduce the electricity burden between 2 and 6 per cent, depending on policy and household type. This is similar to the relative reduction found by analysing the impact of the poverty tariff – which saw a reduction of 6 percentage points – for poor households (Prasad & Ranninger 2003). A recent study in poor areas of Cape Town showed that electricity consumption rose by 30 to 35 kWh per month per customer after the introduction of the poverty tariff, a substantial rise against an average consumption ranging from 100 to 150 kWh per month (Borchers et al. 2001). This rise is less than the full 50 kWh allocated per month, suggesting that households make greater use of electricity but also value some saving on their energy bills (Cowan & Mohlakoana 2005).

A combination of the poverty tariff (aimed at social sustainability) and the residential policies outlined in this book could improve affordability for poor households in two ways. The residential policies reduce the consumption of energy needed to deliver the same service, while the poverty tariff makes the price of electricity cheaper. Together, the policies have the potential to address the difficult issue of affordability. Instruments and mechanisms to finance such policies will be needed.

Financial instruments and mechanisms to support residential policies

Addressing the affordability of energy services requires setting up financial instruments and mechanisms. Support for individual policies can be differentiated, as suggested with bridging finance for SWHs in richer households, but direct subsidies for poorer ones. Financing can help to promote efficiency in two major ways: firstly, by funding the costs of efficiency programmes, and secondly, by helping to finance the upfront costs for those who cannot afford them.

Specific funding for end-use energy efficiency could be drawn from the general fiscus or raised through a charge. To sustain investment in socially beneficial efficiency programmes – even under power sector reform – the regulator could introduce a charge on all electricity sales. This non-bypassable charge, sometimes called a ‘wires charge’, would be dedicated to funding public benefits including energy efficiency (Clark & Mavhungu 2000; Winkler & Mavhungu 2001, 2002).

Financing is an essential element of promoting greater efficiency in the use of electricity. Direct financial support, such as subsidising efficient housing, is one means of contributing to efficiency. Tariff structures that appropriately reflect costs in the price of electricity are equally important.

Business capacity to manufacture locally

Institutional capacity to implement policies is required in both the public and private sectors. The need for government to set mandatory standards was outlined earlier but, as noted, government can also assist with setting up financing mechanisms for residential policies more broadly. Institutional capacity is also needed in the business sector, however, as the example of SWHs illustrates.

Adequate business infrastructure is needed for introducing vacuum tube technology, which should reduce costs of SWH systems by almost half. Chapter 6 assumed some cost reductions will occur, but in practice a step-change is needed to import technologies. Import of vacuum tubes becomes economical at a certain scale. Aggregation among suppliers of SWH systems would help, as might assistance from government with establishing trade.

The local component of SWHs would benefit from the development of a local manufacturing industry. If using imported vacuum tubes, locally manufactured components could be combined in assembly with the imported tubes. The policy case of SWH/GB requires a public–private partnership. Much as business capacity needs to be built to grow markets, institutional capacity is needed in government for residential policies.

Government capacity to administer residential policies

Residential policies form part of the Energy Efficiency Strategy (DME 2005a), have a basis in broader energy policy (DME 1998a) and may soon be covered in a new national energy Act (pers. comm. Surridge 2005[3]). Policy and strategy, however, require people and institutions to implement them.

Institutional capacity could be established to benefit all residential policies. Capacity is needed not only to develop and enforce codes and standards, but also to promote policies. A national energy efficiency agency has been researched in a feasibility study but has not been established. Cooperation between agencies (DME, NER, Eskom) has many advantages, but a dedicated agency might provide clearer leadership if it had sufficient authority and adequate, consistent streams of funding. In short, an institutional home for public-benefit energy efficiency needs to be found.

The CABEERE (Capacity Building in Energy Efficiency and Renewable Energy) initiative within the DME has provided some focus for energy-efficiency research and projects, but a secure institutional home has not been established. The organisational structures of the authorities, notably the DME and NER, are important for public benefits, particularly in the context of power sector reform. With the EDI undergoing restructuring, the pressures to compete are likely to increase. Energy-efficiency measures reduce sales revenues and therefore the protection of public benefits is needed (Clark & Mavhungu 2000; Philpott & Clark 2002; Winkler & Mavhungu 2001).

Conclusions

An approach to sustainable development that emphasises durability would require growth (for example, in terms of access). Rather than insisting on strict economic optimality, however, more flexibility can be shown in making some trade-offs. In the residential sector, this approach has been implemented by building the key development objective of increased access into all cases. The optimising framework ensures that goals are reached cost-effectively.

Considering a durability approach, some trade-off of economic optimality might provide greater social benefits. An equitable distribution of energy services is important for social sustainability, adding a further dimension to the priority often given to economically efficient delivery. The residential policy cases illustrate that there is potential for policy-makers to achieve benefits in all dimensions. More could be achieved if some measure of economic optimality is traded off for other benefits – for example, in the case of LPG for cooking.

The largest absolute energy savings (and associated emission reductions) will not occur in the residential sector. Levels of energy consumption are relatively low, not only in unelectrified households but also in newly electrified households. However, the residential sector is critical for social development. Changing development paths in this sector will need to focus on multiple issues, including more efficient use of electricity and switching to other fuels.

Increasing access to finance is critical for implementing policies. Several supportive policies are needed. Subsidies of less than R1 000 per household should be sufficient to promote an individual policy such as efficiency in the housing shell. Judging from a case with reduced interest rates, it appears that such subsidies would make efficient housing attractive to ULE and RLN households (in addition to UHE, who take up this intervention in the base case).

The household type with the largest savings need not always be the target group for policy intervention. Policy analysis of water heating showed that while UHE have larger absolute energy savings, the reduction in the electricity burden is proportionately greater for ULE. Low-cost measures such as GBs can be aimed at poorer household types – and have a lower cost of saved energy than SWHs.

A combination of the poverty tariff and residential policies could work together to reduce the consumption of energy needed to deliver the same service, while at the same time making the price of electricity cheaper. Financing instruments, from the general fiscus to funding for residential policies from systems charges, should be examined.

Institutional capacity is needed in business to develop local manufacturing and to reduce costs. Capacity in government is needed to enforce policy and a dedicated energy agency might provide an important focal point.

Choosing electricity supply options for sustainability

The policy challenge for electricity supply includes the need to:
- increase diversity of supply and lessen dependency on coal;
- reduce emissions of local and global air pollutants; and
- increase access to affordable energy services (DME 1998a).

The comparative analysis of electricity policies against sustainable development indicators in Chapter 7 (see Figure 7.8) did not show clear ‘winners’ in economic, social and environmental terms, unlike the residential sector. The policy questions for electricity options relate to trade-offs of different aspects, as well as specific requirements for implementation.

The next section briefly reviews the policy choices that need to be made in comparative perspective. Each electricity supply option faces specific issues, which are outlined next. The longer-term perspective of durability, introduced in Chapter 2, is revisited. On this basis, the challenge of making near-term changes to meet long-term goals is outlined.

Policy choices

Policy statements on future electricity supply have tended to emphasise that all energy sources would be used (Mlambo-Ngcuka 2003, 2005). In practice, choices are being made about investments in capacity, initially to meet peaking demand (NER 2004a). The analysis in Chapter 7 suggested that choices of electricity supply options have advantages in different dimensions – there are trade-offs to be made.

On cost, imported options (gas or hydro) look attractive. Similarly, considerations of security of supply might lead South Africa to look to domestic options. Coal will continue to provide a large share for the next 20 years, as the base case and all policy cases illustrate. Of the other two domestic options, the PBMR performed poorly in terms of cost, even more expensive than a combined case. A mix of renewable energy options was more attractive.

With the assumption in all cases that electrification would increase, the social implications of electricity supply are mainly through the price. Measured by the shadow price, the combined case was clearly most expensive, followed by the PBMR and renewables in joint second place. Imports provided the lowest opportunity cost.

Environmental concerns of reducing local and global air pollutants would favour the two domestic options (apart from coal), renewables and the PBMR. While the PBMR had high reductions, renewables achieved similar reductions at lower cost. In this dimension, imports of gas or hydroelectricity did not compare favourably, with the lowest reductions of both local and global emissions.

Specific policy issues

MARKETS TO SCALE UP RENEWABLES

In Chapter 6, the results for the renewables case showed that the target could be met. Electricity generation from renewable energy sources increased beyond 2013, as technology costs declined. The mix of renewables was primarily supplemented by bagasse co-generation and wind, in addition to existing small hydro and bagasse. The environmental performance in reducing local and global air pollution was good, second only to the PBMR and at lower cost.

The policy challenge for renewables is to achieve the voluntary target. Institutional capacity, as for residential policies, will be needed in both the public and private sectors. Government needs to engage key stakeholders, including Eskom, in the challenge to meet the target. Setting up a well-regulated market is important for business and for scaling up the capacity of renewables. Key policy issues to achieve this are financing (subsidies and appropriate tariffs), ensuring markets that include IPPs, power purchase agreements and tradable permits.

The energy minister's 2003 budget speech indicated 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: i) investment subsidies, as an upfront grant, given per unit of installed capacity; or ii) production subsidies, through a rebate per kWh of renewable electricity produced.

While investment subsidies have the advantage of reducing the high upfront investment costs of RETs, the major drawback is that facilities may be built to get the subsidy but not be maintained to generate any electricity. Production subsidies more directly reward the ongoing production of electricity from RETs (EDRC 2003a). During 2005 the DME set up an office for subsidies to renewables (see Chapter 5).

The tariffs that producers of renewable electricity receive will be critical to their financial viability. The NER would play a key role in overseeing the process of setting tariffs. Standard contracts or power purchase agreements would set tariffs and guarantee a market for renewable IPPs. Some observers suggest that establishing long-term power purchase agreements for IPPs could tie government and consumers into non-competitive prices for years to come (Clark 2001a; Eberhard 2000). They are, however, essential if renewable IPPs are to have security that they will be able to recoup their high initial investment costs.

Indeed, power purchase agreements need to be specifically structured to reflect the cost structure of renewables. To avoid the lock-in to fixed prices, it might be desirable to limit the agreements to small-scale projects, such as renewable energy projects smaller than 50 MW (and energy-efficiency equivalent to less than 10 MW). The assumption would be that, as renewable IPPs become commercialised and grow, they are able to compete with other technologies, but that while the technologies are still going through learning curves and reducing costs, they need the security of fixed contracts.

The Darling wind farm has negotiated a preferential tariff of 50c per kWh with the City of Cape Town (CCT 2004; CCT & SEA 2003). Once the facility comes on-stream, the city would offer customers the option of buying electricity from a renewable source, at a premium. Available electricity would be 3 GWh per year, a small contribution to the 9 000 GWh consumed by the city (CCT 2004). There would be some marketing of green power. More generally, IPPs reportedly state that they require a tariff of 31c per kWh to be financially viable (pers. comm. Blignaut 2004[4]).

The NER has a policy on IPPs that aims to encourage multiple players to enter the market (NER 2003b). With Eskom having operated as a virtual monopoly and continuing to exercise market power, access to the single transmission system (often termed a natural monopoly) must be made available on fair terms. IPPs should enjoy non-discriminatory access to the grid, paying a system charge rather than the full-avoided cost of electricity otherwise generated.

Subsidies, tariffs and power purchase agreements contribute to setting up a market for renewable electricity governed by clear rules. Market rules for IPPs using renewable energy sources are being developed for government. Such rules – including grid access, power purchase agreements and certification procedures – in the long term need to form part of a larger electricity market (Sad-elec 2003). Such business infrastructure will be critical if renewables policy is to be implemented.

ADDRESSING THE ISSUES OF NUCLEAR ENERGY

The PBMR faces a different set of issues to renewables. The results of the policy case in Chapter 6 showed that a substantial diversification was possible, with reduced local and global air pollution. However, this came at a high cost and with underutilised capacity.

The key policy questions that will need to be addressed for nuclear technology are waste disposal, security, public acceptance and the economic viability of the technology.

The economics of the PBMR have been debated in the literature, with proponents claiming low costs (PBMR Ltd 2002), but others claiming that these are severely understated (Auf der Heyde & Thomas 2002). The debate will likely only be settled in practice. However, before the first module can be constructed domestically, the Environmental Impact Assessment approval is required (see Chapter 4). Initial plans for the PBMR appeared to rely on export of PBMR modules, but with the entry of China into PBMR production (AEJ 2005), the possibility for competition for exports of the technology has increased. Beyond the cost of the initial units, the decline in costs assumed in the policy case is related only to *domestic* production (unlike the renewables case, where it is a function of doubling of *global* capacity).

Security of PBMR installations appears to be an issue which has received less attention than it deserves. One of the attractions of the relatively small modules is the potential to spread them across several sites.[5] While providing benefits of avoiding transmission losses, each new site and transport route would have to be secured, in turn adding to costs.

While costs of decommissioning have been included in the cost estimates for the policy case, the issue of waste disposal remains to be addressed. A requirement of the Environmental Impact Assessment approval was that the DME promulgate a policy on radioactive waste; such a policy was approved by Cabinet in 2005. The first national principle adopted in that policy is the 'polluter pays principle', stating that generators shall bear the financial burden for management of radioactive waste (DME 2005b).

The PBMR, like nuclear technologies in general, faces difficulties with public acceptance. Nuclear power and its high-level radioactive waste have attracted the attention of academics, NGOs and the press (Auf der Heyde 2000; Gosling 1999; Law & McDaid 2001; SECCP 2002). Whether the initial costs of developing the PBMR should be written off, as implicitly assumed in the policy case, would be a major policy decision. Critics of the PBMR have suggested that funding of a particular technology at a larger scale than others, notably renewables, is inequitable.

IMPORTED GAS AND HYDROELECTRICITY

The policy issues for imports related primarily to prices and the security of receiving the imports consistently. Chapter 6 suggested that imports of gas should be phased in more gradually, while imports of hydroelectricity can be expanded as in the policy case.

Policy interventions to promote gas-fired power plants are mostly not in the electricity sector itself. Apart from the regulation of gas pipelines, gas prices are a critical factor determining viability. Fuel prices are set in international markets, beyond the control of national policy. The anchor customers for gas from Mozambique are Sasol and industrial users in Gauteng, so that policy on liquid fuels and industrial development influences the availability of gas. Another option is importing LNG by tanker, which requires significant investment in re-gasification plants.

Hydroelectricity is already imported from Mozambique on a contract highly favourable to South Africa, and this option can be expanded with Mepanda Uncua. The large future potential, however, lies at Inga Falls (see Chapter 4). If the large potential in the Democratic Republic of Congo is to be tapped, the interconnections between the national grids within SAPP would need to be strengthened. A Western Corridor project plans to connect South Africa, Namibia, Botswana, Angola and the Democratic Republic of Congo with transmission lines. Several of the initiatives under Nepad are interconnectors (Nepad 2002).

The prospect of increased interconnection and trade of electricity across borders requires regulation. Different operating systems, markets, tariffs and policies need to be harmonised sufficiently to allow trade. A Regional Electricity Regulators' Association was formally approved by SADC energy ministers in July 2002. Members are Malawi, Namibia, South Africa and Zambia, with observers from the regulatory authorities of Angola, Lesotho, Mozambique, Tanzania and Zimbabwe and support from the SADC's energy technical support unit (NER 2002e).

Political stability in the Democratic Republic of Congo is an important – but highly uncertain – prerequisite for using this option. In the Zambezi River basin, closer to South Africa, there is the potential for an additional 6 000 MW_e. Technical problems would be sufficient transmission capacity and line losses over long distances, but these could be overcome (Kenny & Howells 2001). More important are political uncertainties and reaching agreement on contracts that promote the interests and development of all countries involved.

With no single policy emerging as a 'win-win' option in a least-cost framework, the policy approach should consider durability over a longer time frame.

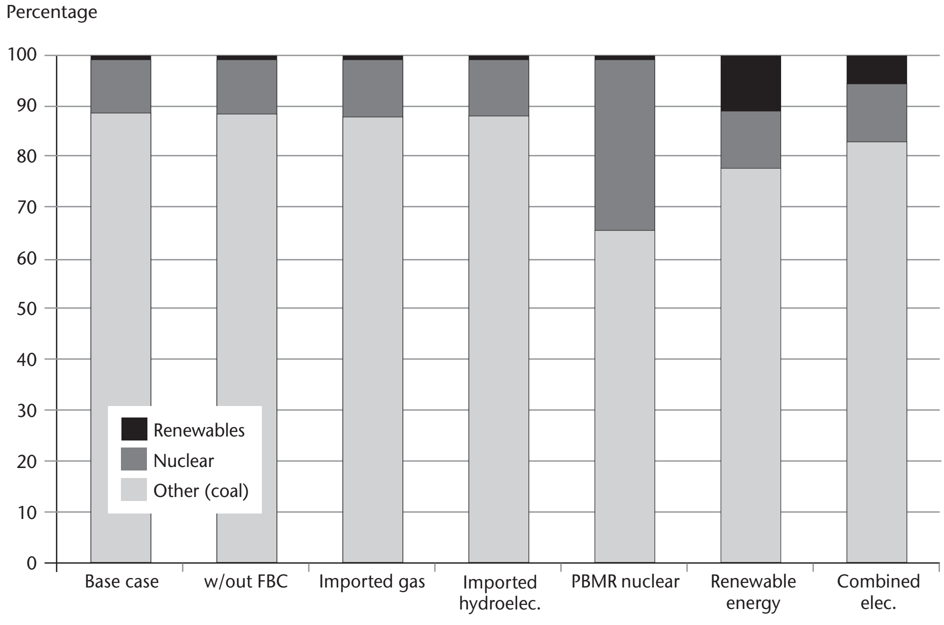
Durability: Considering challenges over longer time frames

The methodology of this book made a distinction between optimality and durability (see Chapter 1). The Markal modelling tool is fundamentally an optimising one, although social and environmental dimensions can be included, as demonstrated in Chapters 7 and 8. However, they remain side constraints to the objective function of minimising costs.

Durability favours development paths that permit growth, but does not insist on economic optimality. There is more willingness to trade off some economic optimality for greater safety or for a system that has higher resilience to external shocks. The difference, however, is one of emphasis and perspective – optimality and durability have different emphases, but can complement one another (Munasinghe & Swart 2005).

An example in the South African energy system is diversity of supply. The base case showed that coal would remain the least-cost option over the 25-year period. Cleaner coal technologies were included in the base case. Policy considerations would be to ensure that all FBC complies with emissions standards. Such standards can be set under the new Air Quality Act (No. 39 of 2004), with mandatory and public reporting. Yet a key challenge remains to reduce the dependency on a single fuel. The energy objective of ensuring security of supply through diversity is critical.

Figure 8.2 *Diversity of fuel mix from domestic sources for electricity supply options by 2025*



Note: The data underlying Figure 8.2 are shown under the indicator 'Diversity of electricity fuel mix' in Table 7.21. Shares are based on electricity output, not installed capacity.

The analysis of diversity of supply in Chapter 7 showed two distinct dimensions. The move away from coal (dominating 'other fuels' in Figure 8.2) is clearest for the PBMR, albeit at a higher investment cost. The balance of different fuel types, however, is more diverse in the case of renewables. The bar for renewables in Figure 8.2 shows three distinct components, while the first five cases have a barely visible sliver of renewable energy.

Greater diversity of supply has other advantages – improving energy security and reducing environmental pollution. More diverse systems are more resilient to external shocks. In the case of electricity supply, reliance on a single fuel increases vulnerability to shocks to that single resource. Possible shocks might include factors such as volatility in the politics of southern Africa for hydro imports, or future carbon constraints for coal.

A more diverse mix of fuels for electricity supply provides a greater chance that difficulties in one sector can be balanced by other ones. An approach focusing on durability should both lessen dependency on coal and maximise the number of other fuels used. Such changes in energy infrastructure require a longer-term perspective.

Short-term changes for a long-term transition

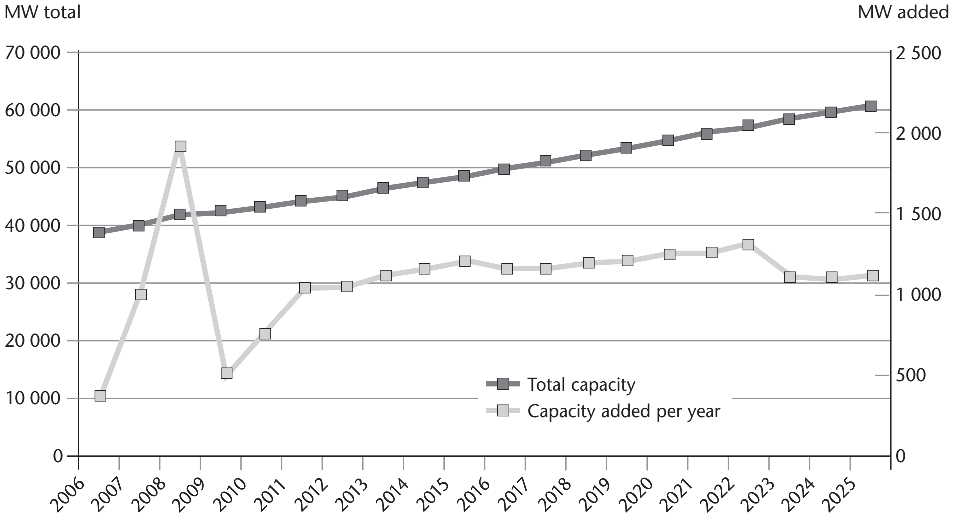
The time frame for the analysis has been 25 years, typical for energy and electricity planning. There are two major reasons to look at longer time frames. Increasing diversity of electricity supply involves replacement of infrastructure with long lifetimes. Secondly, challenges such as climate change involve long-term changes. While impacts of present policies at times seem far away, critical choices for the rest of the twenty-first century need to be made over the next 10 to 30 years (Nakicenovic 2000). Capital turnover of power plants, refineries and other energy-related infrastructure is slow.

The power plants included in the NIRP have lifetimes of between two and four decades – 20 years for wind, 25 years for gas turbines, 30 years for solar thermal electricity and new FBC coal, and 40 years for PBMR nuclear plants (NER 2004a). Electricity-generation plants coming online in 2007 can be expected to still be emitting local pollutants and GHGs in 2037 if they are fired by fossil fuels. On the other hand, an efficient house constructed today will still be saving energy in 30 years, when South Africa may face restrictions on carbon emissions.

These considerations emphasise the importance of 'lock-in' to chosen technologies (Kartha et al. 1998). Changes to the existing coal-based energy economy and electricity sector require planning for a 100-year time frame, but inform critical choices in the next few years. To change the direction of large systems requires smaller changes in the short term to enable larger future changes.

For the electricity sector, the need to replace electricity-generation capacity is a challenge that presents the opportunity for changing course. Not only will new capacity be needed urgently in the next few years, but replacement of existing stock will continue into the mid-term as power stations come to the end of their life. The additional capacity required in the 20 years from 2005[6] to 2025 amounts to 22 750 MW of added capacity, as shown in Figure 8.3.

Figure 8.3 *Total capacity for electricity generation and additions per year*

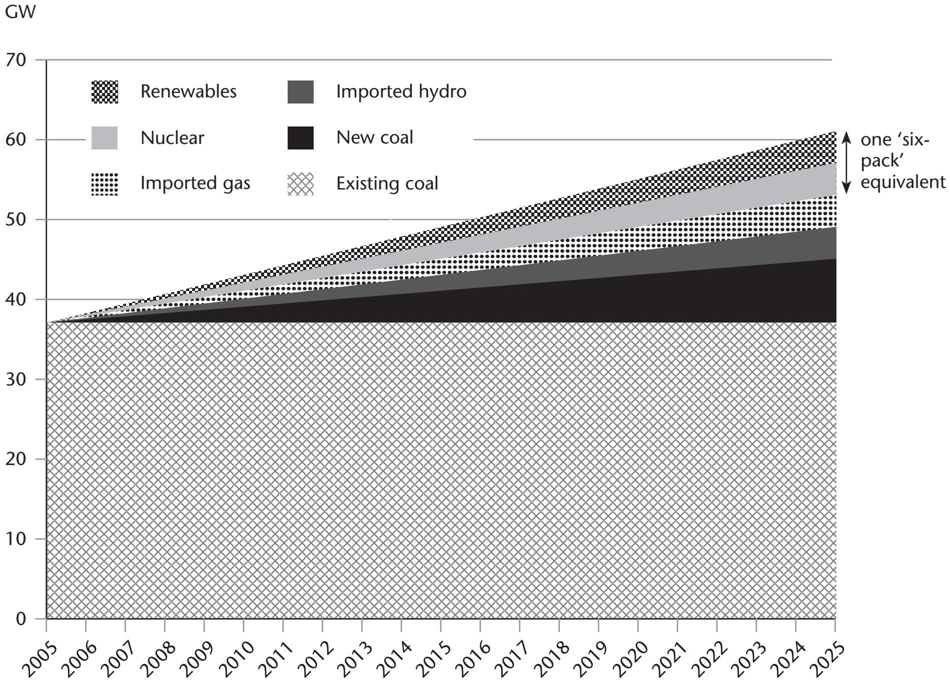


The total capacity (measured on the left-hand y-axis) increases from 40 to 60 GW over the 20 years. The added capacity (measured on the right-hand y-axis) is somewhat lumpy, with the peak of 1 950 MW representing the investment in a combined cycle gas turbine. On average, just over 1 000 MW are needed per year.

The replacement of major infrastructure offers the opportunity to change direction. The new capacity could be met by six new coal-fired power stations. These pulverised fuel stations, known as 'six-packs', have capacity of around 3 600 MW each. If only two of the six were replaced by other options in the next two decades, this would represent a major shift in South Africa's energy development path. In fact, as shown conceptually in Figure 8.4, capacity in each part could build up gradually over the initial 20 years.

If, for example, one 'six-pack' equivalent were to be from renewables and another from PBMR or imported electricity, significant institutional capacity would have been developed in the local electricity supply industry. Longer-term goals of three 'six-packs' over 30 years and five over 50 years might seem achievable. Changes in the next two decades will be critical in shaping not only energy policy, but also South Africa's response to climate change mitigation.

Figure 8.4 *Wedges of electricity capacity equivalent to one 'six-pack' each over 20 years*



Note: The diagram draws on the concept of wedges for stabilising carbon dioxide emissions using existing technologies (Pacala & Socolow 2004).

Options for South Africa's mitigation policy

South Africa's climate change policy is still in the early stages of formulation and is influenced by views from different interest groups. Early climate mitigation policy took a strict 'no regrets' approach, refusing to contemplate any actions other than those that were beneficial even without climate change. Recently, the National Climate Change Response Strategy (DEAT 2004) put sustainable development at the centre, providing the basis for a more proactive engagement with the international climate framework (Van Schalkwyk 2005a).

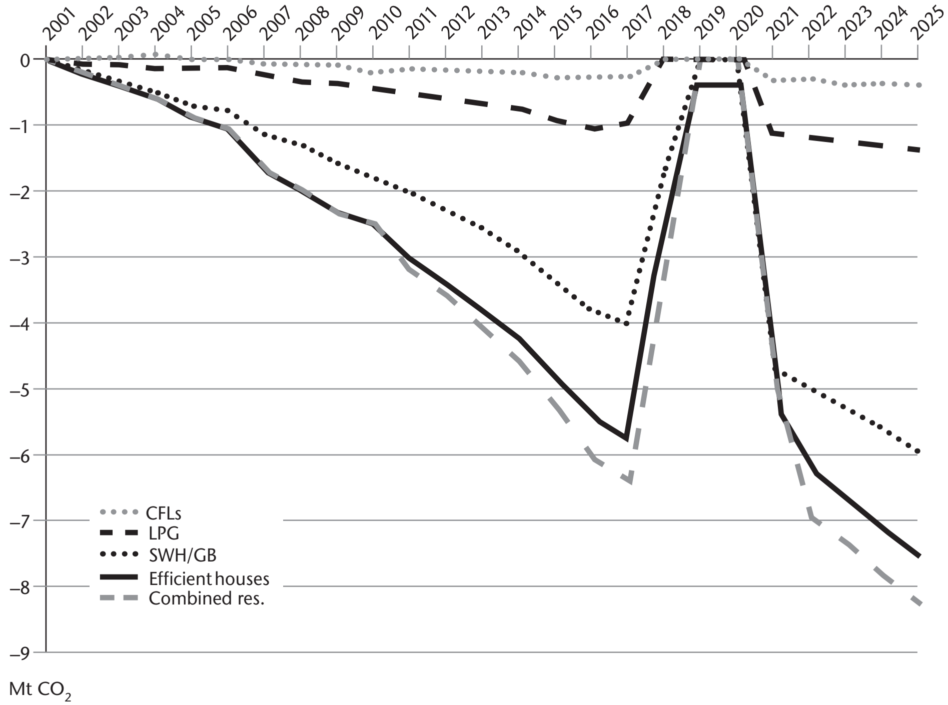
South Africa's Climate Change Response Strategy (DEAT 2004) is centred on the concept of sustainable development. The analysis in this book suggests specific ways in which this policy can be realised. Policies that make energy development more sustainable are the core of the national climate change mitigation policy proposed here. The earlier sections of this chapter summarised the choices available in the residential demand and electricity supply sectors. Together with similar policies in other economic sectors, these could constitute national climate policy.

To be called sustainable, climate policy must take a long-term view and consider the durability of the proposed solutions. South Africa's climate policy will be more 'durable' (Munasinghe & Swart 2005) if it does not give sole priority to reducing costs, but also achieves social and local environmental benefits. The policies modelled, evaluated and analysed in the preceding chapters can make important contributions to both energy and climate policy.

Figure 8.5 shows the emissions avoided in each of the residential policy cases – that is, reduced from the emissions level in the base case. The upwards movement in all cases between 2018 and 2020 seems to be an artefact of a sharp increase in generation from two pumped storage plants (Steenberg and Palmiet). The largest reductions are seen in the combined, the efficient housing and the SWH/GB cases, in that order. In the simple estimate of abatement costs in Chapter 7, the efficient housing case was also the most cost-effective.

The efficient housing and SWH/GB cases are 'win-win' opportunities, reducing local air pollutants, economic costs and the burden on households. What can be seen from Figure 8.5 is that emissions in the order of 1 to 10 Mt CO_2-equivalent per year can be avoided through these policies.

Figure 8.5 *GHG emissions avoided in residential policy cases*

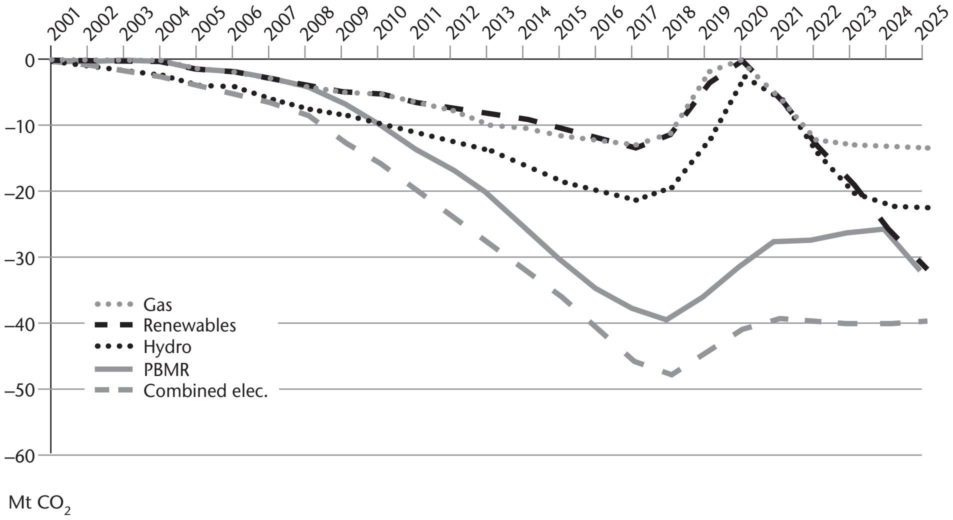


The avoided emissions in the case of efficient houses constitute 1.2 per cent of the emission of GHGs (carbon dioxide, methane and nitrous oxide) compared to 2025 emissions in the base case. For comparison, they amount to 1.9 per cent if divided by 2001 emissions in the base case. Energy policies such as efficient housing and SWH/GB should make up an important component of South Africa's climate policy. They are cost-effective and address social sustainability, local environmental issues and GHG emissions.

The scale of emission reductions that might be required in the future, however, will need to come from higher-emitting sectors. Emissions in the base case are projected to increase 80 per cent from 2001 to 2025. The electricity supply sector is central in this regard, accounting for 48 per cent of South Africa's carbon dioxide emissions and 37 per cent of all GHGs (RSA 2004; Van der Merwe & Scholes 1998).

Avoided emissions for electricity supply options are shown in Figure 8.6, again showing the difference of emissions between policies and the base case. The scale of avoided emissions is indeed larger, reaching up to 50 Mt CO_2 per year in the combined case. If South Africa is to make a contribution to the emission reductions of 50 to 70 per cent *from current levels* which the science tells us is required (IPCC 1995), then changes in this sector will be needed.

Figure 8.6 *GHG emissions avoided in electricity policy cases*



The combined policy case shows the largest absolute emission reductions, followed by the PBMR. As will be recalled from Chapters 7 and 8, however, the investment costs associated with these two cases are larger than for others. The two domestic cases reduce 5 per cent of the emissions projected for the base case in 2025.

Simple estimates of abatement costs indicated that renewables are most cost-effective in achieving larger-scale emission reductions, slightly cheaper at R2.5 per t CO_2 than the PBMR at R2.9. Even the relatively higher costs of the combined case (R4.8) and the two import cases (R3.9 for hydro and R5.6 for gas) are well below market prices for carbon.

Table 8.3 *Order of magnitude of carbon revenues for different carbon prices*

		2005	2010	2015	2020	2025
Avoided emissions from both combined cases	Mt CO_2	4	18	41	41	48
Revenue at €10/t CO_2	R million	355	1 444	3 315	3 245	3 840
Revenue at €20/t CO_2	R million	710	2 887	6 629	6 491	7 680
Revenue at €30/t CO_2	R million	1 065	4 331	9 944	9 736	11 520

The first row of Table 8.3 adds up the values of avoided emissions from the two combined cases – in other words, avoiding double counting of reductions. The carbon price is set at three values, with €10 per t CO_2 being close to 2005 prices, and expected higher levels in future represented by modest increases to €20 and €30 per t CO_2. Further assuming a fixed exchange rate at R8 per €1, revenues in the order of rand millions to rand billions per year are possible (over R10 billion in 2025 at €30 per t CO_2).

What is not clear is whether South Africa would be able to sell credits for avoided emissions as currently through the CDM. By 2025, South Africa might need to reduce emissions to meet a future commitment of its own. This question raises the implications of the policies described so far for the future of the international climate change regime, which is considered in Chapter 9.

The implications of energy policies for sustainable development for domestic climate policies are twofold. Firstly, residential energy policies permit the growth of energy services and reduce the costs of those services, but also reduce local environmental pollution and provide social benefits. These policies, in particular efficient housing and SWH/GB, can contribute to a thrust of climate policy that is strongly allied to social sustainability and poverty alleviation. By including these policies in an overall portfolio, climate policy will be made more relevant to local development.

Since the absolute emission reductions achievable in this way are not adequate to the task, a second component is needed. In the electricity supply sector, there is potential to make development more sustainable but no clear 'winners' emerge that are superior in every dimension. A long-term climate perspective is one reason to make short-term changes to begin a long-term transition. Greater flexibility will be needed in trading off some degree of economic optimality, in favour of both local and global environmental benefits.

Recent analysis suggests that there may be means to soften the trade-offs. This book focuses on the direct costs of energy policies. Complementary recent work

(Van Heerden et al. 2006) has examined the broader economic effects of climate policies, including direct GHG taxes or energy taxes, using a CGE model. The use of a CGE model means that not only direct costs are counted, but also the indirect economic benefits and costs. However, note the limitations on the approach to GHG analysis, as discussed in Chapter 4. The authors argue that energy in South Africa is complementary to capital and that this factor, together with tax recycling that increases unskilled labour demand, can produce a double or even 'triple dividend'. They find that recycling environmental tax revenues through reduction in food costs is particularly effective in achieving carbon dioxide reduction, economic growth and poverty alleviation (Van Heerden et al. 2006). Macroeconomic analysis thus provides an indication that there may be synergies at the societal level, yet climate policy would affect individual sectors, with winners and losers. Hence a degree of trade-off is likely to remain.

The need for trade-offs should not be taken to suggest that no attention is paid to economic costs. The electricity supply policies described in this book provide options to meet environmental goals cost-effectively. And there are significant synergies that remain, even if not all dimensions can be optimised at once. Synergies exist in meeting goals for improving local air quality and reducing GHG emissions. Local benefits also accrue from greater diversity, both in lessening dependence on coal and increasing resilience by increasing the number of alternatives.

Combining residential and electricity policies would provide a mix that overall provides a durable balance of economic development, social sustainability, and both local and global environmental benefits. Together with other sectoral policies that are not the focus of this book, an approach that starts from meeting sustainable development objectives can form the core of national policy on climate change mitigation. A strong national approach can also make a major contribution to the multilateral effort to mitigate climate change, as the next chapter argues.

Notes

1 B Bredenkamp, Efficient Lighting Initiative, Eskom manager.

2 The subsidy levels found here are consistent with earlier studies that used market prices (Holm 2000; Irurah 2000; Spalding-Fecher et al. 2001; Spalding-Fecher, Clark et al. 2002; Winkler, Spalding-Fecher & Tyani 2002). However, none of the previous work disaggregated results by household type or considered the feedback effects in the context of national energy models.

3 AD Surridge, Director: Coal and Gas, Department of Minerals and Energy.

4 J Blignaut, Professor of Economics, University of Pretoria.

5 Another attraction of the modular design is that units can be built to more closely match supply – investment is not as 'lumpy' as for a PWR such as Koeberg (which has a capacity of some 15 PBMRs). The same applies to any smaller electricity-generation options.

6 There are no investments in the first years of the model run, which starts from 2001, due to lead times.

9 Implications for international climate change negotiations

Much of this book so far has focused on policies at the national level – a sustainable development approach to climate change mitigation has clear benefits at that level. A major advantage lies in capturing the co-benefits of climate change, whether they lie in reduced local air pollution, savings through energy efficiency or providing services to local communities. The question we now turn to is how such an approach could be integrated into the multilateral framework to address climate change.

This chapter does four things. First, it sets out a variety of approaches to the future of the climate regime, focusing particularly on dimensions of equity and development. Second, it sets out an approach (sustainable development policies and measures, or SD-PAMs) to international negotiations that integrates the national approach into those negotiations. Third, some brief evidence is presented that SD-PAMs make a difference. And finally, the approach is contextualised in the broader discussions about the future of the climate change framework.

Proposals on the future of the climate regime

In the international context, South Africa increasingly seeks to play a bridge-building role (Van Schalkwyk 2005b; Winkler & Vorster 2007), and an approach built around sustainable development provides for important first steps towards a commitment by developing countries such as South Africa. Forward-looking approaches have great potential to leverage funds to promote energy policy objectives such as increasing access and diversity of supply, stimulating economic development and managing energy-related environmental impacts.

A wide variety of approaches for the architecture of the climate regime up to and beyond 2012 have been proposed. Some of these include extending fixed targets Kyoto-style; universal carbon taxes; allocations of emissions per capita (Aslam 2002; Gupta & Bhandari 1999; Meyer 2000); the Brazilian proposal which allocates emissions allowances in relation to the contribution to change in temperature (Brazil 1997; La Rovere et al. 2002; Rosa Pinguelli & Kahn Ribeiro 2001); common but differentiated convergence (Höhne et al. 2006); emissions intensity (Chung 2007; Herzog et al. 2006; Kim & Baumert 2002); sector-based CDM (Samaniego & Figueres 2002; Sterk & Wittneben 2006); technology agreements (Edmonds & Wise 1998); various sectoral approaches (Ellis & Baron 2005; Schmidt et al. 2006; Ward 2006); Triptych approach extended to the global context (Den Elzen et al. 2007; Groenenberg et al. 2001); converging markets (Tangen & Hasselknippe 2004; Victor et al. 2005); safety valve approaches (Philibert 2002); greenhouse development rights (Baer et al. 2007); and SD-PAMs (Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002; Winkler, Howells & Baumert 2007). The preceding list does not necessarily cover all proposals put forward in the burgeoning literature. The literature is extensive enough to have produced a number of overviews of approaches, including those by Bodansky et al. (2004), Höhne and Lahme (2005), and Boeters et al. (2007), as well as a website collecting the various proposals.[1]

Relatively few of these proposals originate from developing countries (officially or unofficially), and an even smaller subset has been formally proposed by developing countries as Parties to the Convention. The Brazilian proposal stands out as a major exception, having been formally tabled prior to Kyoto (Brazil 1997). At the time, it took a scientific approach to burden sharing among Annex I Parties, calculating the contribution to temperature increase and hence responsibility for mitigation. By focusing on responsibility, the Brazilian proposal had a strong basis of equity. It also had a strong scientific basis, since the key factor determining temperature change was cumulative emissions rather than annual ones.

Per capita approaches are favoured by some developing countries. While there is an extensive literature formulating climate regimes based on this principle, Parties thus far have tended to focus on the principle of each person having an equal entitlement, rather than on detailed proposals. For example, the Indian prime minister indicated at the eighth session of Conference of the Parties (to the UNFCCC) in Delhi that 'we do not believe that the ethos of democracy can support any norm other than equal per capita rights to global environmental resources' (Vajpayee 2002). The essential equity-based argument is that each person should have the same right to use the absorptive capacity of the atmosphere.

For yet other developing countries, the key concern relating to equity relates to development. This approach draws on Article 2 of the Convention, in particular that climate protection should occur in a manner that 'enable[s] economic development to proceed in a sustainable manner'. More broadly, it argues that sustainable development in developing countries, including its ecological and social dimensions, is indispensable for an equitable solution, given that developed countries went through their process of industrialisation without carbon constraints. In the Convention Dialogue, South Africa put forward the approach of SD-PAMs (RSA 2006a).

The literature also includes an evaluation of several proposals focusing specifically on adequacy and equity (Baer & Athanasiou 2007). There have been processes bringing together perspectives from north and south, including the South-North Dialogue (Ott et al. 2004), an ongoing future action dialogue among selected negotiators (CCAP 2007) and the Sao Paolo Proposal (BASIC Project 2006). The IPCC's Fourth Assessment Report (AR4) assessed the proposals and Table 13.2 in the report (IPCC 2007e: 770–773) provides probably the most authoritative overview of recent proposals for international climate agreements, at least up to the cut-off date (mid-2006) for literature assessed.

Some approaches are top-down, in that they focus on the allocation of a certain carbon budget among countries. Others are more bottom-up in nature, starting from the activities that generate emissions.

Examples of top-down approaches include per capita entitlements (Agarwal & Narain 1991; Aslam 2002; Meyer 2000; Miketa & Schrattenholzer 2006), which divide 'allowable' emissions by population, essentially arguing that each person has an equal right to use the absorptive capacity of the atmosphere. The Brazilian proposal (Brazil 1997; Den Elzen & Schaeffer 2002; La Rovere et al. 2002; Rosa Pinguelli & Kahn Ribeiro 2001) uses a complex set of formulas to attribute the responsibility of each country for the change in temperature. Historical cumulative emissions are the key indicator in this regard. The Kyoto Protocol set fixed targets, expressed as a percentage reduction or limitation against emissions in a historical base year.

Bottom-up approaches, by contrast, set no global emissions budget but start from the mitigation actions that countries can undertake. An early approach proposed for developing countries was emissions intensity, in which emissions per unit of economic output (CO_2/GDP) were the key measure (Baumert et al. 1999; Herzog et al. 2006; Kim & Baumert 2002). As economies grow, the emission target is increased, thus allowing space for development. Other bottom-up approaches focus even more explicitly on human development (Pan 2002) or development rights (Athanasiou 2005).

Note, however, that one cannot assess effectiveness based on the form of a package alone, without also specifying its stringency in terms of the numerical targets it encompasses (Winkler & Vorster 2007). For example, it is at least conceptually possible to construct a very stringent collection of bottom-up actions, which is more effective in reducing GHG emissions than a top-down approach with very low levels of ambition.

Bottom-up approaches have more focus on development. Apart from the SD-PAMs approach elaborated below, Jiahua Pan has focused explicitly on means of quantifying basic human needs and the associated emissions (Pan 2002). This approach lays the basis for distinguishing between a minimum level of emissions that each person might require and those for luxury consumption. It implies an approach to climate governance without spelling out an explicit architecture.

The Greenhouse Development Framework elaborates an overall framework, designed to both 'support an emergency climate stabilization program while, at the same time, preserving the right of all people to reach a dignified level of sustainable human development free of the privations of poverty' (Baer et al. 2007: 17). It develops a framework that includes both the right to development (a stronger right than the Convention principle of the right to promote sustainable development) and to stabilisation to keep temperatures below 2°C. Starting from a stabilisation pathway, it quantifies national responsibility and capacity to act, calculating national obligations to pay the costs of mitigation and adaptation on this basis. In doing so, it goes further than the South-North Dialogue proposal (Ott et al. 2004) in addressing costs in particular. Rather than outlining an architecture to negotiate, the Greenhouse Development Framework seeks to outline the standard that an equitable agreement must meet, both in terms of climate and development.

The SD-PAMs approach, outlined in more detail below, does not claim to be a reference framework, but an approach that could be negotiated with the Convention. It would provide a starting point for more ambitious climate action in the context of development.

Sustainable development policies and measures

The policies examined here have been called SD-PAMs (Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002). The SD-PAMs approach suggests a way of linking national sustainable development policies into the multilateral climate regime under the UNFCCC. The approach has been put forward by South Africa for consideration in the UNFCCC process (RSA 2006a, 2006b).

The steps involved in the SD-PAMs approach are similar to the methodology for this book. The SD-PAMs approach starts with the development objectives and needs of developing countries. Countries begin by examining their development priorities and identifying how these could be achieved more sustainably, either by tightening existing policy or by implementing new measures. The next step is to identify synergies between sustainable development and climate change – that is, those SD-PAMs that also result in reductions of GHG emissions. To obtain a realistic picture of the impact of a basket of SD-PAMs, those policies and measures that increase GHG emissions also need to be identified (Winkler, Spalding-Fecher, Mwakasonda & Davidson 2002). What the SD-PAMs concept offers is the formalisation of the pledge to make development more sustainable, in an approach that can be negotiated.

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

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

Energy-efficient low-cost housing in South Africa is one example of a SD-PAM. Further examples are the use of case studies in China's energy sector (Kejun et al. 2006), including China's efforts to reduce air pollution in the process of motorisation (Wei-Shiuen & Schipper 2005). In the Brazilian case (La Rovere et al. 2006; Moreira et al. 2005), the ethanol programme produces approximately one-third of Brazil's transport fuel, has saved $100 billion in foreign currency expenditure, has created over a million rural jobs and has climate co-benefits estimated at 574 million tons of carbon dioxide over the lifetime of the programme. Without the biofuels programme, Brazil's cumulative emissions of carbon dioxide from 1975 to the present would have been 10 per cent higher (Moreira et al. 2005: 24). Case studies on climate and development are not limited to large developing countries, but have also considered electrification in rural Bangladesh (Rahman et al. 2006) and the impact of power sector reform in Senegal (Thiam 2006).

Formalising the pledged commitment could take two possible forms. The initial register could simply be a list of countries that wish to record their existing contribution through sustainable development and pledge further implementation. This could be recorded, for example, in a new Annex III to the Convention. It has the advantage of simplicity and of giving recognition. By choosing to join Annex III, developing countries would no longer be defined by what they are not ('non-Annex I'). Instead, Annex III Parties would define themselves in terms of what they are doing, notably making their development more sustainable. This would avoid the impression that only Annex I Parties are acting to mitigate climate change. This would provide a set of Parties – Annex I and Annex III – which have in common that they are taking action, but which are differentiated in the way in which they are contributing to action on climate change.

Another option would be a register of pledged policies and programmes. This approach has the advantage of specifying in more detail the actions to which countries are committing. However, reporting in common sustainable development units may pose some political and methodological challenges.

The two approaches are not mutually exclusive – there could be an initial list of countries, with a register of SD-PAMs maintained, for example, by the Secretariat.

SD-PAMs commitments would initially be voluntary, although they could be made mandatory for at least some developing countries. To formalise the approach, some need for reporting and oversight through the Convention would be necessary. Reporting would assist in monitoring whether SD-PAMs are actually implemented and this would require some institutional capacity in the pledging country. At the same time, reporting can help to correct the misperception that developing countries are doing nothing on climate change. As outlined in Chapter 2, the associated changes in GHG emissions are quantified.

While the SD-PAMs commitment would initially be voluntary, a simple reporting system should be established in order to formalise the commitment of those countries that pledge to implement SD-PAMs. National capacity to monitor, report and verify that targets are being met would be an important dimension of the country's capacity to implement SD-PAMs. Institutional arrangements clearly vary dramatically across developing countries.

Yet previous work has shown that national capacity exists at least in some cases, which could provide the basis for monitoring implementation and reporting on SD-PAMs. In the case of energy efficiency in South Africa, reporting requirements on an energy-efficiency pledge could build on existing systems for measurement and verification. The international community might want to supplement this system, but would not need to start from scratch (Winkler & Van Es 2007).

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

Reporting would primarily review progress assessed in sustainable development units, which could have specific metrics. For efficient housing, for example, the pledge could be to implement a national programme building 100 000 houses more efficiently per year. In the electricity sector, implementing and reaching the renewable energy target of 10 000 GWh could be the SD-PAMs pledge.

Reporting would assist the joint assessment of pledged actions. Associated GHG abatement could also be reported, in order to change the perception of some Annex I countries that developing countries are not participating in climate protection. This reporting would be similar in spirit to Article 12.4 of the Convention, where developing countries may voluntarily propose mitigation projects. The proposed reporting would extend to all SD-PAMs, including those that are not project-based. In order to assess progress against SD-PAMs pledges, a system of indicators for sustainable development could be adapted.

Reporting of SD-PAMs could be included in national communications. This would have the advantage that the information would be addressed in the in-depth reviews. However, the process of national communications has become highly politicised, in particular around the provision of technical and financial resources (see the language in UNFCCC 1992: Article 12.7). Given that some developing countries are not submitting their initial national communications, it might be preferable to separate the register of SD-PAMs from this process.

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

The issue of increasing access to finance has been raised for residential policies, and the PBMR and renewable electricity supply options clearly have incremental costs above the base case. Formalising the SD-PAMs approach would offer the opportunity to channel funding for climate change into policies that meet *local* sustainable development objectives.

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

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

SD-PAMs with GHG reduction potential could receive climate-change-related funding, including investment through the CDM, climate change funds through the Global Environmental Facility (GEF), and the funds established at Marrakech under the Convention (Special Climate Change Fund, Least Developed Country Fund) and the Protocol (Adaptation Fund). Some of these funds would be most suited to projects (CDM), others to enabling activities (GEF) or policy changes (for example, under sectoral CDM).

SD-PAMs that reduce GHG emissions are likely to be good candidates for investment under the CDM. The CDM requires that projects reduce emissions and promote the sustainable development objectives of the host country, implying a clear synergy with the SD-PAMs approach. Through the CDM and the certified emission reductions generated, developing countries would have some link to the emerging market for carbon credits. However, the SD-PAMs approach would be broader in scope, including emissions reduction due to policies (such as changes in prices of energy) that could not qualify as CDM projects, which tend to focus on investment in technologies, infrastructure or programmes.

The methodology adopted in this book explicitly started from development objectives. Much of the contribution that this approach can make lies in considering the specific energy policies that can meet national development objectives. Reaching them in a more sustainable manner has co-benefits for climate change, as seen above. The approach to climate change mitigation, then, is not one that seeks the least-cost solution to reducing GHG emissions from the energy sector. A durable approach is one which combines 'win-win' policies with those that trade off some economic optimality for local and global environmental benefits. The approach explored in this book provides a solid basis for South Africa to engage in the next round of negotiations under the UNFCCC.

Would SD-PAMs make a difference?

The concept of SD-PAMs may be appealing, but would they make any real difference? The previous section pointed to a range of case studies of policies that could be registered as SD-PAMs – efforts by China to reduce local air pollution and thereby also GHG emissions; energy-efficient housing initiatives in South Africa; ethanol production in Brazil saving both foreign exchange and emissions; and the accelerated introduction of renewable energies in India.

Other evidence comes from work using national energy modelling. This has been applied to SD-PAMs using the example of industrial energy efficiency. In brief, the study showed that the combined effect of these energy policies could *reduce* total energy system costs over the period by about R16 billion relative to the base case. At the same time, local air pollutants such as NMVOC, nitrogen oxides, sulphur dioxide and carbon monoxide were reduced. The climate co-benefits of the combined policies were avoided carbon dioxide emissions of 142 Mt CO_2 for 2025, or 24 per cent lower than in the base case (Winkler 2006: 172).

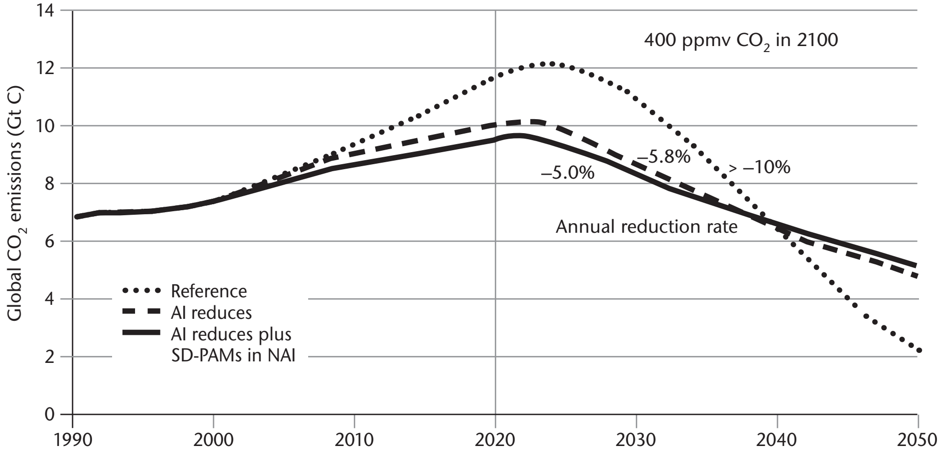
For international climate negotiations, however, it needs to be shown that SD-PAMs could contribute to reducing emissions below their baseline. The atmosphere understands only one language – tons of carbon. In this context, Höhne and Moltmann (forthcoming) consider what contributions – in line with their national objectives and circumstances – developing countries could make to the global climate regime post 2012. Sustainable development objectives examined include energy security, sustainable economic development, technology innovation, job creation, local environmental protection and enhancement of adaptive capacity to climate change impacts.

Höhne and Moltmann (forthcoming) put the impact of a set of SD-PAMs in the energy sectors of seven developing countries into a broader international context. The policies differ by country, from Annex I-like commitments to moderate supported emission reductions. Roughly speaking, the non-Annex I countries achieve around 10 to 20 per cent reductions in carbon dioxide emissions compared to the reference case until 2020.

These policies are analysed with the following further assumptions: i) *Reference scenario*: an assumed reference case of the IPCC's A1B scenario (IPCC 2000) for all countries till 2020; carbon dioxide only; ii) *Annex I reduces*: Annex I countries; Annex I emission reductions of –30 per cent below 1990 level by 2020, except for the United States which returns to 1990 levels; iii) *Annex I reduces plus SD-PAMs for non-*

Annex I: in addition to the above reduction of Annex I countries, the non-Annex I countries achieve the 10 to 20 per cent reductions in carbon dioxide emissions through SD-PAMs until 2020; constant LULUCF (land use, land use change and forestry) emissions at 1 gigaton carbon between 2000 and 2020; after 2020, for all three cases global carbon dioxide emissions (all sources and countries together) decline so that carbon dioxide concentration in 2100 is below 400 ppmv (although the concentration first overshoots till 430 to 460 ppmv in around 2040) (for details, see Höhne & Moltmann forthcoming).

Figure 9.1 *Alternative global CO_2 emission pathways for 400 ppmv*



Notes: Alternative global carbon dioxide emission pathways leading to carbon dioxide concentration of 400 ppmv in 2100 (including a rise till 430 to 460 ppmv in around 2040) for: i) a reference scenario; ii) Annex I countries' reductions; and iii)Annex I reductions plus SD-PAMs for non-Annex I countries' reductions. The annual reduction rates after 2020 are given here in order to reach the carbon dioxide concentration target.
NAI = non-Annex I
Source: Winkler, Höhne et al. (2008)

The results in Figure 9.1 show that SD-PAMs in the energy sector from the seven countries reduce emissions to a lower level than Annex I reductions alone. To get from the A1B reference case in 2020 to the chosen stabilisation level of 400 ppmv carbon dioxide, emissions would have to decline by more than 10.0 per cent per year after 2020. The assumed Annex I reductions reduce this to 5.8 per cent per year, still a very demanding task. Adding sustainable development policies and measures in the energy sectors of seven larger developing countries reduces the required rate of reduction to 5.0 per cent per year. Together with stringent reductions of Annex I countries, the combined package might be sufficient to keep the global average temperature increase below 2°C, but only if followed by substantial global reductions of the order of 5.0 to 10.0 per cent per year after 2020 (Höhne & Moltmann forthcoming). In addition, meeting 2°C also depends on assumed contributions of other GHGs and the uncertainty range of the climate sensitivity.

The study illustrates that SD-PAMs can make a contribution to a common effort of climate change mitigation. Together with the proposals for formalising SD-PAMs (discussed earlier), this provides a strong case for taking action and for giving recognition to actions by developing countries through the Convention and its instruments. All of these considerations feed into the broader discussions around the future of the climate change framework, beyond 2012 when the first commitment period under the Kyoto Protocol comes to an end.

The future of the climate change framework

In this context of approaches to the future of the climate regime up to and after 2012, SD-PAMs offer a development-focused approach. On their own, SD-PAMs would likely *not* solve the climate problem. But changing development paths is likely to be as important as climate policy. Hence several approaches will need to work together.

Policies that make South Africa's energy development path more sustainable are a good approach to climate policy as well. Not only do they provide a firm basis for domestic climate policy, but SD-PAMs could also provide a new strategic approach in the multilateral climate negotiations. This chapter has argued that SD-PAMs can indeed make a meaningful contribution, both to local sustainable development and to avoiding GHG emissions. It has placed the approach in the broader context of the future of the climate change framework beyond 2012.

SD-PAMs are not a panacea. In particular, they do not change the need for industrialised countries to lead with explicit action to mitigate their own GHG emissions. By itself, the approach may not guarantee a particular environmental outcome – although this would depend on the number and ambition level of the policies implemented. The approach, however, is aimed at mobilising action, by turning climate change from a 'threat' to development into genuine opportunity to make development sustainable for developing countries. The approach does not require an entire new Protocol or mechanism, but 'only' a decision by the Conference of the Parties.

While the IPCC's AR4 has underpinned the importance of changing development paths, it also makes abundantly clear that more urgent climate action is needed. IPCC AR4 made clear that the science is unequivocal (IPCC 2007c), impacts are already being observed (IPCC 2007d) and little time is left to bend the curve of GHG emissions downward. Climate change threatens environmental damages and social disruption and is a fundamental challenge to economic development. AR4 pointed out that stabilisation will require urgent action, and it is clear that – even while per capita emissions in developing countries will remain lower and historical cumulative emissions are less than in the north – two-thirds to three-quarters of future carbon dioxide emissions are likely to come from developing countries (IPCC 2007e: 30). While AR4 demonstrates again that the potential for mitigation is high in many sectors, and that potential and technologies exist to deal with the problem, the time available is short. The pace of climate negotiations is increasingly out of step with the urgency of action required by science.

Perhaps a first change to the pace started in Bali in December 2007, when the framework for the next two years was outlined. It has become increasingly clear that SD-PAMs are only one of several approaches being considered for more urgent mitigation action by developing countries. Such approaches, together with other options such as reducing emissions from deforestation in developing countries, domestic sectoral targets and extensions of market-based mechanisms such as the CDM, are to be considered under the category of 'measurable, reportable and verifiable' mitigation actions (with the same criteria applied to financial and technological support to developing countries) (UNFCCC 2007). The Bali Action Plan also sets up negotiations for 'all developed countries', allowing space for more urgent domestic action by the United States. In the meantime, the industrialised countries that are part of Kyoto are being challenged to reduce emissions in a range of 25 to 40 per cent below 1990 levels by 2020 – that is, make deeper cuts than in the first commitment period of the Kyoto Protocol.

Combined, these decisions were labelled the 'Bali Roadmap', which is to agree on the future of the climate regime by 2009. The Bali Roadmap outlines what has been called an 'Ambitious Transitional' package (Winkler & Vorster 2007). This package increases the urgency of action but still remains transitional, essentially because the current United States administration is still not fully engaged. What is still lacking is a 'trigger from the north', that is, a clear commitment from the United States to legally binding, absolute emission reductions. If and when such a trigger materialises, a multi-stage approach might become politically feasible.

Multi-stage means that countries progress from one level of participation to another through different stages. While the definition of stages differs in various proposals (Den Elzen et al. 2006; Höhne et al. 2003; Ott et al. 2004), the rules for successive stages are always more stringent. The full multi-stage idea could reflect increasing stringency for developing countries further along the path of 'bending the curve' of emissions – for example: i) growth without a carbon constraint (no new commitments); ii) slow emissions growth (for example, participate in the CDM; pledge to implement measurable, reportable and verifiable mitigation actions under an SD-PAMs approach, including reducing emissions from deforestation and adopting energy efficiency and renewable energy targets); iii) some commitment to stabilise emissions (for example, a growth target); and eventually iv) quantified emission limitation or reduction commitments.

In such a conception SD-PAMs, as outlined in this book, would still play a role, but now framed as the second step in a progression towards stabilising and eventually reducing emissions. Two central issues to this package are *ex ante* agreement on a set of indicators that provide an equitable basis for negotiating who does what (Winkler & Vorster 2007). Once a country reaches the benchmark for the next level, this triggers *ex post* negotiation of the move rather than automatic graduation.

In a multi-stage approach seeking to address the urgency of action required by science, the SD-PAMs considered in this book would need to be both broadened and deepened. Broadening would involve other sectors, certainly including electricity and residential sectors, but also industry, transport, commerce and liquid fuels. And if multilateral agreement to halve global emissions by 2050 is achieved, then developing countries like South Africa will need to contemplate emission reductions beyond the relatively modest ones considered here. But then again, the time frame for such a target is longer than the analysis conducted here. More long-term mitigation scenarios for South Africa will be needed.

Note

1 See www.fiacc.net.

10 Conclusion

The overall question that this book set out to address was whether there are energy policies to make the development in South Africa's residential and electricity sectors more sustainable economically, socially and environmentally – particularly in the local environment – while also producing GHG emission reductions as co-benefits.

The first step in answering the research question was to start with a review of the concept of sustainable development as applied to the energy sector. A literature review provided a working definition of sustainable development. Sustainable energy development was taken to mean that a set of 'development indicators' is increasing over time, contributing to economic welfare, without being threatened by 'feedback' from either biophysical impacts or social disruption, so making it durable or sustainable.

Against the background of the development objectives for the broader South African energy system, key energy policies were identified. The particular focus for making energy development more sustainable was the residential and electricity sectors. Chapter 4 emphasised the priority given to the energy policy goal of affordable access, to which any future policy in the sector will have to contribute.

A review of current energy policy issues laid the basis for identifying potential future ones for modelling. Tools for modelling energy policies were critically reviewed, and an energy-economic-environmental framework chosen. Policy options were identified that can make energy development in the residential and electricity sectors more sustainable, and were implemented in an energy-economic model. Policy options thus included both demand- and supply-side interventions, short-term opportunities as well as interventions – such as changes in the fuel mix – that require longer time frames.

The book first examined the results of modelled policies one by one, and then against a set of indicators of sustainable development. The results laid the basis for the policy analysis that showed how policies in the residential demand and electricity supply sectors can help move South Africa's energy sector onto a more sustainable path. Detailed policy analysis outlined what would be needed for implementation.

Overall, then, the book argues that there are indeed policies that meet local sustainable development objectives and also deliver GHG co-benefits. It finds that the residential sector is of particular importance for social sustainability. Extending access to affordable, modern energy services is a policy imperative which all energy policies have to follow. The challenge of access, it is contended, increasingly also has an economic dimension, as issues of affordability come to the fore. This argument has particular bearing in South Africa where high emissions intensity (per GDP and per capita) presents major problems, but will resonate with many middle-income nations where increased energy consumption drives growing emissions without noticeable progress in meeting development targets.

The analysis of the residential sector identified opportunities that are sustainable economically, socially and environmentally. Many of the near-term opportunities for contributing to climate change mitigation lie in efficiency. CFLs provide efficient lighting, LPG allows better cooking, houses can be designed with better thermal properties, and SWHs use a cleaner energy source and produce hot water more efficiently. The residential sector, it is argued on the basis of the analysis, has some clear ‘winners’ that rank higher than alternatives in all dimensions of sustainable development.

The book finds that solar water heating and efficient housing are durable policies for sustainable development. Not only do they achieve the greatest fuel savings in aggregate, but they also save the most energy costs for households. The latter is significant in reducing the electricity burden, particularly for poorer urban households. The two policies contribute most environmentally by promoting cleaner fuel use, which helps to reduce local air pollution and GHG emissions. It is also found that it is possible to combine residential policies in a combined case that yields more benefits than any individual case. However, care should be taken to carry out integrated assessments, such as in a modelling framework, to avoid double counting and obtain an accurate picture of the cumulative effects. The whole is typically smaller than the sum of the parts.

The greatest energy savings from efficiency were consistently found in UHE households, which have higher consumption. The book argued, however, that this should not automatically lead to a policy conclusion to target this household type. Taking into account the reduction in the energy burden for households, the social benefits of promoting interventions in poorer households become more apparent. The social benefits of savings from better water heating and improved indoor air quality would motivate this policy among ULE households, rather than least-cost optimality. Interventions that address energy poverty promote a more equitable distribution of energy services, which would favour social sustainability and help reduce inequality. For richer households, interventions such as CFLs that can be promoted through market mechanisms were found appropriate. The book argued that low-cost measures such as GBs could be aimed at poorer household types.

The investment requirement is relatively modest per household, with less than R1 000 per household making efficient housing attractive to ULE and RLN households, as well as to UHE. The book suggested that subsidies and direct financing for residential energy policies could work together to alleviate energy poverty.

Considered in the context of the broader energy sector, the residential sector will not deliver the largest absolute energy savings (and associated emission reductions). Levels of energy consumption are relatively low, yet the sector is critical for social development. Changing development paths in this sector will need to focus on multiple dimensions. The book argues that policies in the electricity sector will also be important for climate policy based on energy for sustainable development. In this sector, the challenges are longer term and more trade-offs are required. Not all solutions are economically optimal; not all policies can be 'win-win'.

The base case for the electricity sector shows that South Africa will clearly remain dependent on coal for electricity generation up to 2025. Cleaner coal technology in the form of FBC also enters the base case. Four major supply options were analysed – renewable energy, PBMR nuclear, and importing hydro or natural gas.

The book argues that a cleaner fuel mix can make a major contribution to managing the environmental impacts of electricity generation. While the social dimensions of choices about electricity supply are not always readily apparent, the impacts on access and on affordability through the electricity price are considerable. South African policy-makers will have to consider whether the lowest-cost option, coal, is to be pursued exclusively, or whether investment in other options increases durability.

The two domestic electricity supply options increase energy system costs over the coal-dominated base case. Importing gas or hydroelectricity reduces domestic capital expenditure and overall system costs. Of the two domestic options, the PBMR is more expensive than renewables. It may offer a transitional solution, while RETs are scaled up rapidly to provide a solution that is sustainable in the long term.

The PBMR achieves the greatest diversity of supply in moving away from coal dependency, but the book argues that it should be phased in more gradually than building 32 modules by 2020 to avoid underutilised capacity. Given the remaining issues of security, waste disposal and decommissioning, this book argues that plans should also include a phasing out – in other words, PBMR is a transitional option. The renewables case achieves a higher diversity among the non-coal fuels. They are environmentally sound technologies and the real challenge lies in scaling them up sufficiently, and in adjusting the electricity grid accordingly with sufficient storage.

Both domestic options achieve reduced local air pollutants and GHGs by similar percentages from the base case. The abatement cost of renewables appears to be lower. While showing increased costs, these were of the same order of magnitude as other policy cases. The renewables case demonstrated that a mix of RETs could supply 'real' electricity. The 2013 targets were met and continued beyond that year, driven by decreasing costs. RETs come closest to the working definition of sustainable development outlined in Chapter 2, in that they can improve present quality of life with lower resource use, while leaving enhanced stocks of assets for future generations, without side effects that might diminish those generations' opportunity to further improve their quality of life.

South Africa needs to replace significant parts of its electricity-generation capacity over the next few decades *and* provide for growing demand. The investments required present an opportunity to 'lock in' to a cleaner energy development path. This opportunity was conceptualised in the form of six 'wedges', each equivalent to a coal-fired power station. The book argues that making two of these wedges something other than coal would represent a major shift to sustainability in the electricity sector.

The challenge for electricity supply options, then, is not to pick a single energy source to supply all future needs. Rather, diversity should be sought in both moving away from over-reliance on a single source, coal, and diversifying the alternatives as much as possible. It may help to distinguish alternatives that are transitional from those that offer long-term solutions. A transition to a more sustainable electricity supply sector will take several decades. Long-term goals help set a direction. Yet changes in the near term are needed as capacity begins to be replaced. Given the long lifetimes of energy infrastructure, choices made in the near term will shape the system for several decades.

The book argues that changes in the electricity supply sector need to consider changes in the short term to initiate a long-term transition to sustainable development. The long lifetimes of power plants mean that decisions have implications well into the future, when South Africa will likely face some kind of carbon constraint. Small changes in the near term can create the basis – institutionally and technologically – for larger changes in the future. This applies in particular to RETs, which start from a small base and need rapid scaling up.

The evaluation against indicators of sustainable development showed that no single electricity supply option is preferable economically, socially and environmentally. One implication is that more trade-offs are required. Another is that short-term economic costs cannot be the only factor in providing solutions that are durable in the longer term.

Based on the findings for both the residential and electricity sectors, the book contends that the appropriate starting point – conceptually and methodologically – for both energy and mitigation policy is sustainable development. Climate change mitigation policy specifically, it is argued, should start with *local* sustainable development rather than with goals set in climate terms.

The analysis in this book suggests concrete ways in which South Africa's climate change response strategy, based on sustainable development, could be implemented. Emissions in the order of 1 to 10 Mt CO_2-equivalent per year can be avoided through efficient housing and SWH/GB cases. These reductions are relative to the reference case, an approach which the book argues is critical for developing countries (as distinct from absolute emission reductions for industrialised countries). Sustainable residential energy policies should make up an important part of South Africa's climate policy, addressing the social, environmental and economic dimensions of sustainability. By including residential energy policies, the overall climate change mitigation portfolio will be made more relevant to local development. Pursuing a goal motivated by development policy is more appropriate for developing countries like South Africa.

However, the scale of emission reductions required will need to come from the larger emitters. Electricity supply options could avoid emissions of up to 50 Mt CO_2 per year in the combined case. However, electricity policy cases are not easily combined and the combined case carries the highest absolute cost; similarly, the highest-reducing single policy case, the PBMR, has the highest cost. By simple estimates of abatement cost, renewables are found to be most cost-effective. Revenues from selling emission reductions in the emerging carbon markets are found to be in the order of rand millions to rand billions. Synergies with improving local air quality while reducing GHG emissions should also be taken into account. A durable approach to the development of the critical electricity sector should promote local sustainable development and contribute to climate change mitigation.

In Chapter 9, a fresh approach in the multilateral climate negotiations, SD-PAMs, was proposed. Taking the national approach of starting from development into the international arena can assist in capturing the co-benefits of climate change. Countries would pledge to implement and accelerate national sustainable development plans – initially as voluntary actions, although the approach could become mandatory for some countries. Monitoring, verifying and reporting on the implementation of pledged policies would build confidence that SD-PAMs are making a real difference – contributing both to local sustainable development and to mitigation. The SD-PAMs approach provides a conceptual framework to elaborate national climate change policy and how this might be integrated into the international climate framework.

The SD-PAMs approach is one of several options for more urgent mitigation action by developing countries. In 2008, it represented one option with an 'Ambitious Transitional' package (see Chapter 9). Depending on how the negotiations unfold in the two years up to 2009, and particularly the level of American re-engagement, a multi-stage approach might eventually be adopted, in which SD-PAMs could be one step towards other forms of commitments.

The policies analysed in this book can make energy development more sustainable. Combining residential and electricity policies would offer a mix that overall provides a durable balance of economic development, social sustainability, and both local and global environmental benefits. Much of what is good for sustainable development in the national energy system also has global benefits in mitigating climate change. The approach has been demonstrated for South Africa, but will resonate with other rapidly industrialising developing countries. This book demonstrates that there are indeed policies that meet local sustainable development objectives and reduce GHGs as a co-benefit.

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