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Changing development paths: From an energy-intensive to low-carbon economy in South Africa

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Climate change mitigation poses significant challenges for South Africa and its energy development, historically highly energy intensive. At the same time, the country faces a host of daunting development challenges, exacerbated by the legacy of apartheid. Examining both challenges, this paper considers how alternative conceptions of a development path can be achieved. In the short term, energy efficiency provides large potential for mitigation – and energy savings at the same time. Changing South Africa's fuel mix, dependent to three-quarters on coal, is at least a medium-term challenge. The minerals–energy complex is so central to the economy that it is likely to take decades to change dramatically. The most transformative change is to an alteration in economic structure, likely to take long to achieve. The article examines specific policy instruments that might be implemented to achieve such a transformation. A transition to a low-carbon economy will require a paradigm shift in industrial policy. It will require considered provision for sectors sensitive to changes in energy prices. Building up new, climate-friendly industries will be needed to sustain employment and investment. To enable a just transition, provision will have to be made for emissions-intensive sectors, if they are to be phased out over time. South African government has adopted a vision, strategic direction and framework for climate policy. Policymakers have begun to understand that the future will be carbon constrained and that South Africa's emission will have to stop growing, stabilize and decline before mid-century. The challenge of climate change is a long-term challenge, requiring immediate action. This article examines actions at near-, medium- and long-term timescales. Its focus is on the most transformative change, that of seeking to shift development paths.

Keywords: climate change mitigation; development; industrial policy; low-carbon economy; South Africa; sustainable development

1. Introduction

Climate change mitigation poses significant challenges for South Africa and its energy development. Not only does South Africa have an extremely energy-intensive economy based primarily on coal leading to relatively high emissions, but it simultaneously faces a host of daunting development challenges, exacerbated by the legacy of apartheid. Challenges for development include a dramatic gap between rich and poor, a heritage of racial oppression and inequality, a lack of infrastructure, high levels of unemployment and urbanization, an economy adjusting to globalization, and the new challenge of AIDS. Given the challenges of development to meet basic needs, mitigation policies and measures have to be integrated with development goals. While South Africa's traditional development path, based on energy- and capital-intensive megaprojects is unfavourable for mitigation strategies, it may be possible to incorporate sustainable development goals with mitigation.

This paper presents a case study of South Africa, how various measures can contribute – on different time and spatial scales – to changing development paths. Since it is concerned with development, it begins by outlining the key

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challenges that the country faces and the history of recent responses in development policy. Section 3 moves to climate change, in particular a brief profile of greenhouse gas (GHG) emissions. The largest share of emissions comes from the energy sector, which is profiled in section 4. Section 5 discusses the context and development of South African energy and climate change policy, and implications for climate change. This leads to the discussion in section 6 of meeting climate change goals in the context of development. Energy efficiency in the short term, changes in the fuel mix in the medium term and structural changes in the long term frame the major categories of mitigation actions.

2. Overview of South African development challenges

2.1. The legacy of apartheid

South Africa has an estimated population of 47.9 million people (July 2007),[1] of which 57.5% live in urban areas. South Africa has historically followed a capital- and energy-intensive development path, driven by resource extraction and the development of an associated set of interrelated economic activities termed the 'minerals–energy complex' by Fine and Rustomjee (1996). This complex comprises mining, minerals processing, the energy sector and associated industries linked to these sectors, based initially on mining and then on beneficiation, underpinned by some of the cheapest electricity in the world (Figure 1).

Although South Africa is a middle-income developing country, its economic and social development was highly uneven due to apartheid, finally abolished in 1994. This left a legacy of extreme inequality, leading commentators to speak of 'two economies', or 'two worlds'. In the most recent Human Development Report (UNDP, 2007), South Africa's Gini coefficient ranked the country 117th most economically unequal out of 126 countries for which data was available. Likewise, South Africa's ranking according to the Human Development Index is 121 out of 177 countries (most developed=1), whereas in GDP per capita (PPP) terms, South Africa is ranked 53rd (UNDP, 2007), indicating the significant disparity between economic wealth and development in South Africa. While the affluent sectors of South African society have access to infrastructure (including power, water and sanitation) and economic and social facilities comparable to most developed countries, poor communities suffer from lack of basic infrastructure, social and economic marginalization, unemployment and high levels of violence, and bear the main burden of diseases such as AIDS and tuberculosis. Moreover the population grew from around 40 million people in 1994 to nearly 48 million

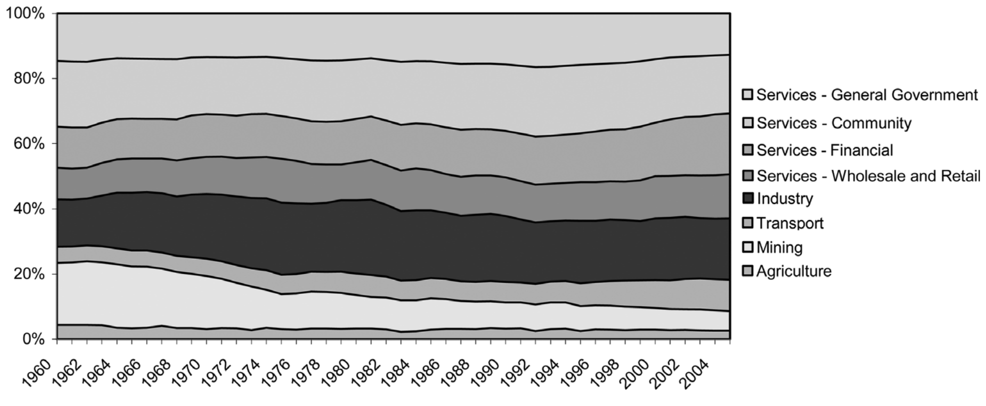

FIGURE 1 Sectoral contribution to economy, 1946–2005

Source: South African Reserve Bank Quarterly Bulletin.

people in 2007 (SSA, 2007b), and the number of households grew faster than the population, from 8.7 million in 1994 to 13.3 million in 2007 (SSA, 2007a), posing additional challenges for infrastructure development. In the same period, South Africa's HDI value declined from 0.745 in 1995 to 0.707 in 2000, and further to 0.674 in 2005 (UNDP, 2008).

2.2. Development policy frameworks

The post-1994 government's broad policy framework has been based on two sets of principles: first, resolving the macroeconomic problems existing at the end of the apartheid era, and second, providing services and employment for the majority of the population. Contrary to popular expectations, the macroeconomic policy framework has been quite conservative, with a strong emphasis on macroeconomic stability. Central aims have been to resolve the financial crisis which the apartheid state found itself in at the beginning of the 1990s, and to promote a developmental agenda aimed at accelerating economic growth and meeting basic needs. One of the key areas to be addressed has been the apartheid-linked infrastructure backlog. These development aims are encapsulated in three successive policy frameworks: the 1994 Reconstruction and Development Programme (RDP), the 1996 Growth, Employment and Redistribution Strategy (GEAR,), and the most recent 2006 Accelerated and Shared Growth Initiative AsgiSA (see ANC, 1994; DTI, 1996; AsgiSA, 2006).

Published in the year of transition, the RDP was primarily aimed at overcoming the economic and social marginalization of the majority of the South African population under apartheid and outlined a programme of 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 in housing, water and electrification, and programmes were launched in specific sectors. Two years later, GEAR shifted the focus to macroeconomic stability and economic growth, and was based on a policy of opening the economy and encouraging investment. It was thought at the time that many RDP goals, such as job creation and poverty alleviation, could be met through macroeconomic reforms. While relatively successful in addressing macroeconomic problems, the policies did not create employment or address poverty at the required rate, and the government acknowledged that the role of the market in addressing problems such as unemployment was more limited than had been assumed.

By the end of the 1990s, the government saw the state playing a much more significant role in development. Plans to privatize parastatals were shelved, and these came to be seen as vehicles for infrastructure development and service delivery. In 2006, the government announced a new development policy framework, AsgiSA, responding 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 adequately addressed by the earlier frameworks. These included threats to exports from a strong currency, backlogs and bottlenecks in national infrastructure development 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' (i.e. 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', yet these are 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 (DEAT, 2008). 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.

3. Greenhouse gas emissions overview

The most comprehensive survey to date of South African GHG emissions was the inventory for 1990 and 1994 compiled as part of South Africa's Initial National Communication (INC) to the United Nations Framework Convention on Climate Change (UNFCCC) (RSA, 2004), for the three major GHGs: CO_2, CH_4 and N_2O (RSA, 2004, p. 14). Further work in terms of an inventory for the year 2000 is currently being compiled and includes a component of knowledge management to facilitate conducting future inventories. More up-to-date estimates are available from the World Resources Institute's Climate Analysis Indicators Tool (WRI, 2003, 2005), The CAIT data provides a useful interface for international comparisons. Aggregate estimate of emissions for a 2003 base year[2] were compiled for South Africa's Long-Term Mitigation Scenarios, as well as baseline projections until 2050 (SBT, 2007; Winkler, 2007).

Internationally, South Africa's GHG emissions are relatively high – in 2000, South Africa ranked 57th (all six Kyoto gases plus land use, land-use change and forestry (LULUCF)), 43rd (all six Kyoto gases without LULUCF), or 37th (CO_2 only) in terms of per capita GHG emissions (WRI, 2005)[3]: South Africa's 2000 emissions with LULUCF were 10.1 t CO_2-eq per person; by comparison, those of the EU (25 countries) were 10.5, those of the USA were 22.9, China's were 3.8 and India's were 1.5. Figure 2 plots the UNDP's Human Development Index against per capita emissions (CO_2 only) for 171 countries for which data was available; while there is an exponential trend towards an HDI value of 1, South Africa and a handful of other countries are clearly outliers.

The coal dependency of South Africa's energy system shapes the composition of its GHG emissions. Energy use accounts for the vast majority of emissions of CO_2, CH_4 and N_2O: in 2007, it is estimated that 78% of emissions resulted from

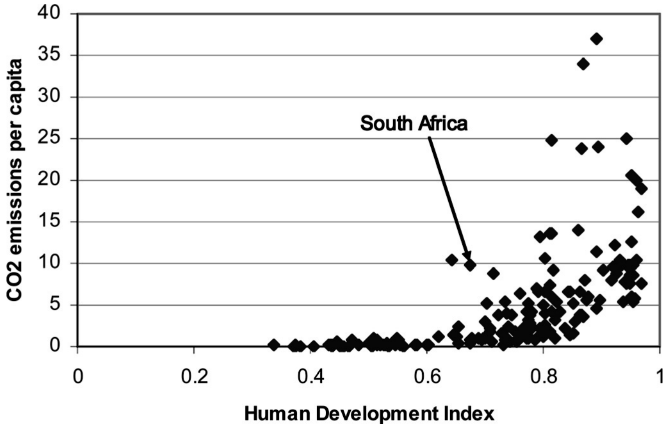

FIGURE 2 Per capita emissions compared to Human Development Index

Source: UNDP (2008).

fuel combustion, 15% from industrial process emissions and 7% from other processes. The energy system's emissions as a whole are much higher on account of an unusual feature of the South African system: large-scale production of synthetic fuels. With process emissions from synfuels, energy emissions comprise 84% of emissions. The electricity sector accounts for 47% of emissions, and the coal-to-liquids (CTL) process, which gasifies coal and then liquefies syngas to produce synthetic fuel, accounts for 10% (direct emissions). If one allocates emissions to economic sectors (adding electricity and CTL emissions to sectors which consume electricity and CTL-derived liquid fuels), industry accounts for 66% of the demand for emissions-generating goods and services. The transport sector is second largest with 12%, the residential sector accounts for 9%, agriculture 8% and commerce/services 5%. Modelled projections up to 2050 indicate that emissions may quadruple under a business-as-usual scenario, assuming GDP growth in the target range of 3–6% and relatively flat population with the impacts of HIV/AIDS (see Winkler, 2007, for details of drivers). Most growth occurs in energy and industrial process emissions (Figure 3).

Thus, the core of South Africa's GHG emissions problem resides on the supply side in the energy and industrial sectors, and on the demand side in the industrial sector, with transport the next largest-emitting sector on the demand side. Thus mitigation efforts will necessarily focus on these sectors, which will be discussed in more detail below.

4. The South African energy sector

The basis of South Africa's current energy system is coal, which constitutes an extremely high proportion of South Africa's primary energy consumption – in fact, the highest in the world (excluding non-commercial energy carriers) in 2003, followed closely by China (BP, 2004). In 2004, coal comprised around 70% of South Africa's primary energy, crude oil around 23%, nuclear energy around 3% and renewable energy around 8%[4] (DME, 2004). As for electricity generation, an even greater share, 92%, came from coal-fired power stations in 2004 (NER, 2004a).

The development of the South African energy system can be divided into two related aspects. The development of an energy–industry complex, designed to drive South Africa's industrialization during the 20th century, and the development of what might be termed 'civil energy', or the provision of energy for households, commerce and services. The former was structured by the development of a 'minerals–energy complex', whereas the latter was largely influenced by, and subject to, the former, as well as to the dictates of apartheid social and economic policy. Energy services were largely

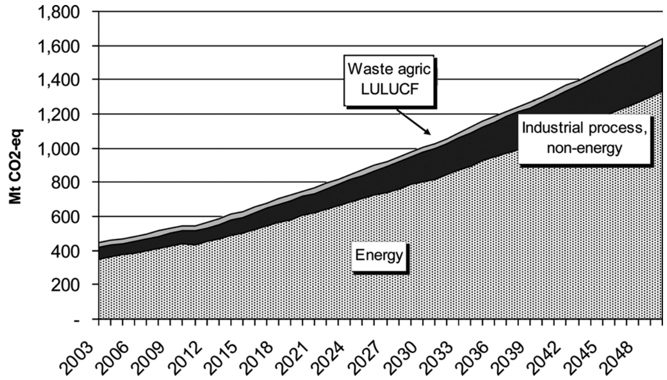

FIGURE 3 Energy and non-energy emissions in Growth without Constraints

Source: Winkler (2007).

developed for the white population during and before apartheid, and the rest of the population was largely excluded. Apartheid era concerns with energy security, overestimates of continued growth in demand and long lead times led to 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)

The South African economy is extremely energy intensive by international standards; only a handful of countries have higher intensities. Energy intensity is not, however, equally distributed in the economy, but concentrated in specific sectors. Manufacturing and transport dominate energy demand, as shown in Figure 4, and are the most energy-intensive sectors. The reasons for the high energy intensity of the South African economy lies in the high use of coal and electricity and the large number of energy-intensive enterprises, which are linked to the low prices of electricity and coal, which have consistently been around 40% of US average prices for the last four decades (calculated using price data from Eskom annual reports and US EIA). While this has provided South Africa with a significant competitive advantage in minerals processing, it has also deterred investment in alternative energy supply, and more importantly, in energy efficiency; South African industrial energy efficiency is on average significantly lower than in other countries (Hughes et al., 2002).

The development of a 'civil energy' infrastructure accelerated after the political transition in the 1990s. A massive and very rapid electrification programme advanced and financed largely by Eskom (and politically driven and enthusiastically backed by the post-1994 government), saw residential electrification rates grow from an estimated 30% in 1990 to 73% in 2006 (DME, 2006) including an innovative off-grid solar PV programme in isolated rural areas. The programme has not been accompanied by reforms in other energy markets, and although paraffin appliances have been made safer (primarily through new standards), fuels such as LPG are not available on the same basis as in other middle-income developing countries, and poor households (even several years after electrification) still use significant amounts of fuelwood and paraffin.

Because of the energy intensity of the economy and the extreme income differential in South Africa, residential energy use is a far smaller fraction of final energy demand than in other countries, and demand from poor households is even smaller. The impact of providing electrification to most of the rest of the population since 1990 has had relatively little impact on electricity consumption. The result of gaining around 3,000,000 new (primarily low-income) residential customers between 1990 and 2004 only increased Eskom's sales by around 4% (Eskom, 1990; NER, 2002a), whereas growth in Eskom's industrial sales in the same period added 17% to the 1990 total.

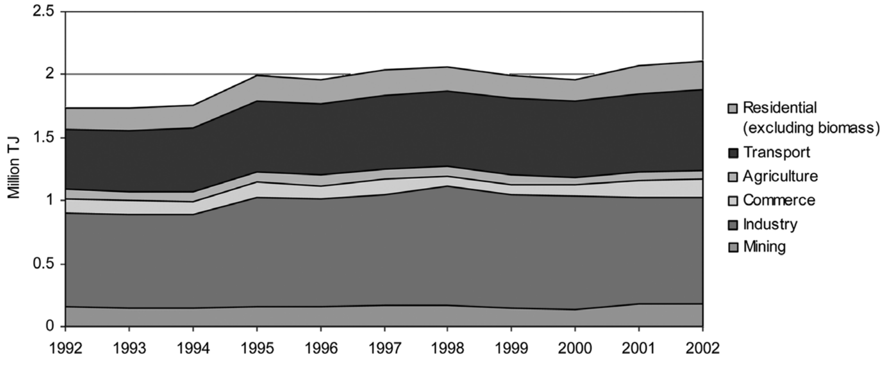

FIGURE 4 Energy demand, 1992–2000

Source: Based on data in energy balances (DME, 2006).

5. South African energy and climate change policy and actions

5.1. Climate change integrated into other policy domains

The climate change policy domain is complex, and is structured around the Department of Environment and Tourism (DEAT), which depends on two other departments for the development of specific mitigation policies. First, international negotiations (see below) are conducted in partnership with the Department of Foreign Affairs (DFA) in the context of South African foreign policy, the relevant principles of which are a focus on Africa, South–South co-operation (specifically Brazil–India–South African co-operation and more broadly through the G77 and China), and a commitment to rule-based multilateralism. Second, energy policy is the domain of the Department of Minerals and Energy (DME). In addition to the DME's line functions, other departments that are closely involved with energy policy are the Department of Trade and Industry (DTI), the National Treasury (NT), and the Department of Public Enterprises (DPE). These three departments play a key, policy-determining role in the 'Economic cluster' in the Executive. Climate change policy in South Africa has been informed since the mid-1990s by a stakeholder body, the National Committee on Climate Change (NCCC), which consists of government departments, major emitters such as Sasol and Eskom, and civil society representatives.

5.2. Development of international and national climate policy

In the international context, South Africa has been an active participant in multilateral negotiations. The country signed the UNFCCC in 1993, and ratified it as a non-Annex 1 country in 1997, acceding to the Kyoto Protocol in 2002.

National policy responses to climate change have been structured by South Africa's international commitments to the UNFCCC, as well as by participation by key stakeholders in the NCCC including Eskom, which has played a key role, and NGOs. Business associations representing businesses in the energy-intensive industries have also been closely involved in policy processes, including the Chemical and Allied Industries Association, the Energy-Intensive Users Group, and the Chamber of Mines.

In the late 1990s, the NCCC commissioned a Country Study as a basis for an INC, which included a GHG emissions inventory and a range of studies on vulnerability, mitigation and adaptation. The INC was submitted to the UNFCCC at COP 9 in 2003.

The INC served as a basis for the key statement of South African climate change policy – the 2004 *National Climate Change Response Strategy for South Africa*, which outlined a framework for action. The response strategy provides a framework, with detailed implementation plans still being required in many sectors.

Climate change is, however, becoming a major concern for the executive. In 2005, a large-scale National Climate Change Conference was held, attended by 600 delegates from government, business, academic institutions and civil society, including a wide range of cabinet ministers and the Deputy President, which augmented existing policy by resolving to increase cross-government co-ordination on the issue, use the 2004 Air Quality Act to regulate GHG emissions, establish a South African National Energy Research Institute, develop a technology needs assessment, establish a National Energy Efficiency Agency, compile sectoral plans to augment the National Climate Change Response Strategy, and inaugurate a scenario-building process to examine how best South Africa can meet GHG reduction targets and development goals at the same time (DEAT, 2005).

In 2006, DEAT initiated a Long-Term Mitigation Scenario project, in which various scenarios were developed using energy and macroeconomic models to explore the consequences of various policy interventions aimed at reducing GHG emissions. In July 2008, Cabinet agreed on an ambitious plan, driven by the aim of limiting temperature increase to 2 °C above pre-industrial levels and doing a fair share in the international context. Taking a long-term view, the goal is to make a transition to a low-carbon economy, presenting this as the best option for job creation and development in a carbon-constrained future. Cabinet stated clearly that emissions need to peak (at the latest by 2020–2025), then plateau for a decade or so, and then decline. This strategic direction needs to be given more immediate effect by setting more ambitious domestic targets for energy efficiency, renewables and transport. Increasingly, mandatory action is needed rather than voluntary. In developing formal policy, state-led regulation will play a key role, complemented by getting the economic incentive structure right. An escalating price on carbon is designed to trigger action in many sectors. Greater investment in long-term research and development will be crucial on the road to a low-carbon society (Van Schalkwyk, 2008).

5.3. Energy policies and their implication for mitigating climate change

Developments in the energy sector have the biggest influence on GHG emissions in South Africa. The key policy framework for the energy sector is contained in the 1998 *White Paper on Energy*, and the subsequent 2003 *White Paper on Renewable Energy* (DME, 2003b). The latter set a target of 10,000 GWh of final energy demand to be produced from renewable sources by 2010, which is an average of around 1,000 GWh per year or 0.15% of total final energy demand in 2002.

In 2005, the *Energy Efficiency Strategy* set a target for national improvement in energy efficiency of 12% by 2015 (DME, 2005). A voluntary Energy Efficiency Accord was signed by the Minister of Minerals and Energy and by 31 (later 37) businesses (primarily energy-intensive industries and energy supply industries.

While a policy framework has been developed, there has been relatively little implementation of two key mitigation strategies: the energy efficiency and renewables programmes. A recent development is the government's biomass initiative, although it is not yet clear how this will be implemented, or when. The National Treasury has lowered fuel taxes on biofuels to incentivize their manufacture in the country, and there are a number of very small-scale biofuels projects recycling used cooking oil into biodiesel. The most significant renewable energy project currently underway is the Darling Wind Farm, a 5 MW facility on the West Coast, which became operational in 2008.

In contrast to other parts of the world (specifically Asia), there are relatively few Clean Development Mechanism (CDM) projects in South Africa. By September 2009, 14 CDM projects from South Africa had been registered, covering a wide range of technologies with an estimated 15,000,000 certified emissions reductions by 2013. An innovative initiative in Cape Town, the Kuyasa project, combines GHG mitigation with a number of sustainable development objectives by retrofitting low-income households with energy-efficient technology, including ceiling insulation, low-energy light bulbs and solar water heaters (SSN, 2004).

The project has been implemented on a very limited scale, since CDM funding only covers a fraction of the implementation cost. The project has the potential to mitigate several tons of GHGs per house per year, and could be scaled up on a national basis if funding becomes available. Other small demonstration projects include a number of solar water heater installations for low-income households, and several building efficiency projects in local government.

6. Meeting climate change goals in the context of development

Thus, while there is a relatively broad national consensus on the requirement to do something about climate change in South Africa, there has to date been relatively limited implementation. Below we examine some of the options for GHG mitigation, within the constraints we have outlined above.

6.1. Key areas for mitigation options in South Africa

Mitigation options in South Africa can be divided into three broad categories: energy efficiency (which reduces demand for energy, or uses it more efficiently for the same service); changing the fuel mix (moving to lower- or non-carbon-emitting energy sources); and structural changes to the economy, which lower the energy intensity of the economy as a whole by shifting economic activity and investment to less energy-intensive sectors, or taking other measures to reduce the need for energy services, such as changing urban planning practices to reduce transport requirements. These categories are represented in Figure 5.

The categories also relate broadly to timescale and certainty of outcome.[5] In most cases, energy efficiency strategies can be implemented in the short term and their cost implications are well understood. Changing the fuel mix cannot be accomplished quickly, since power stations and refineries have lifetimes of several decades. Probably the most long-term measures are changes in economic structure. While there is evidence that economies gradually move from primary to tertiary sectors (Schäfer, 2005), it is not clear to what extent this is influenced by policy. As indicated by Figure 1, it is likely that South Africa's low long-term electricity prices have resulted in the energy-intensive sectors of the economy growing at the same pace as the tertiary sectors. However, if the South African economy did shift towards less emissions-intensive sectors, the implications for mitigation would be profound.

The problem which South Africa faces at present is that a limited set of mitigation options has been relatively well explored. Yet science increasingly suggests that GHG emissions need to peak in the next two decades and decline rapidly thereafter (ISSC, 2005; Meinshausen, 2005; Stern Review, 2006). Developed countries will have to act first (UNFCCC, 1992, Article 3), but the problem cannot be solved without mitigation in developing countries as well. The next round of international agreements under the UNFCCC and its Kyoto Protocol are likely to require some action from rapidly developing countries. We will outline options for South Africa according to the categories above, and discuss their potential ramifications. We have considered only energy sector-related measures, since these comprise the majority of current GHG emissions in South Africa.

Several of the demand- and supply-side options below are based on a 2006 study by the Energy Research Centre at the University of Cape Town, which modelled a number of energy policy scenarios over a 25-year period (2000–2025) to explore implications for cost, GHG emissions, and other aspects of sustainable development. The study analysed some of the mitigation options identified earlier in INC (RSA, 2004). The reference case was broadly consistent with government plans, such as the Integrated Energy Plan (whole energy sector) (DME, 2003a) and the National Integrated Resource Plan (electricity) (NER, 2004b). Official expansion plans continue to be based primarily on coal-fired power, with new diesel-drive gas turbines and pumped storage for electricity peaking. Carbon

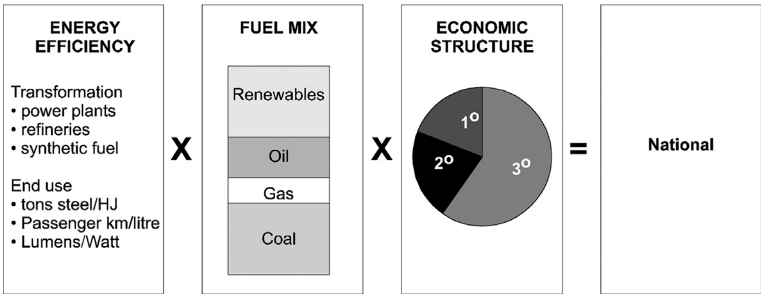

FIGURE 5 Three broad areas for mitigation

emissions for the reference case are 596 Mt of CO_2, 70% higher than the 2001 figure (350 Mt) and 237% higher than the 1990 figure (252 Mt) (Winkler, 2006).

6.1.1. Energy efficiency mitigation options

The least-cost energy efficiency option, and probably the quickest of the scenarios analysed, involves a set of energy efficiency improvements in industry, which would save around 770 Mt of CO_2 over the 25-year period, and save a net R18 billion (2000 Rands). The energy efficiency programme would aim at a reduction of 12% from the reference case by 2014.[6] Because of rising electricity prices (due to construction of new plants) during the period, energy efficiency investments become more attractive later in the period. Commercial energy efficiency (also with a target of 12% by 2014) is also a significant option, with a net saving of around R13 billion, and a reduction in CO_2 emissions in 2025 of 12 Mt of CO_2. Interventions consist primarily of improved building design and improved HVAC efficiency (Winkler, 2006, pp. 161–163, 176).

A ‘cleaner and more efficient residential energy scenario’, involves energy-efficient housing shells, efficiency interventions such as deployment of CFLs and geyser insulation blankets (the latter particularly relevant in poor households in South African townships), and a number of fuel-switching options, including installing solar water heating, replacing other fuels with LPG for cooking, replacing paraffin with electricity for lighting, linked to substantial increases in the residential electrification rate. These combined measures would save around R1 billion, and reduce CO_2 emissions in 2025 by 4 Mt. Implementation of these scenarios would require ‘significant policy intervention’ (Winkler, 2006). Higher energy efficiency targets have not been modelled, but would be achievable if energy prices rose significantly.

Another category of energy efficiency interventions would involve improving the efficiency of energy supply technologies. Examples of supply-side efficiency include ultra-supercritical (all new coal to be super-critical) and improving the efficiency of converting coal into liquid fuels, e.g. by providing more gas to CTL plant. In the latter case, small-scale interventions become viable if the improvements are registered as CDM projects, indicating that there would be significant incentives if energy prices rose or funding was available from another source. Finally, there are significant efficiency gains to be made in the transport sector in South Africa, through motor efficiency improvements, mode-switching (particularly road and air to rail) and the development of integrated urban transport networks, which are currently extremely underdeveloped in South Africa. These options have not been well explored on a national level and the rebound effect for efficiency gains must be taken into account. Since there is a significant unmet demand for transport (especially from poor South Africans), the development of efficient urban and regional transport networks is also an important national development goal.

Energy efficiency has great potential, but widespread implementation requires effort. Theoretical gains are not always realized in practice, which requires consideration of barriers (Winkler and Van Es, 2007). Removing key barriers is critical – informational, institutional, social, financial and market, and technical (EDRC, 2003). Important success factors to implement efficiency measures include government policy (standards, incentives, recovery of programme costs), electricity pricing mechanisms that do not penalize efficiency, and the effectiveness of demand-side management delivery agencies (NER, 2002b).

6.1.2. Options to lower the carbon content of the fuel mix

The key supply-side measures are aimed at reducing the use of coal in the energy system. Major options involve measures to reduce or replace coal-fired power in the electricity sector, to displace coal use in synfuels manufacture, and to switch from coal to lower-carbon fuels in industry. Several options for electricity supply (other than coal, which is the reference case) were modelled in the scenario exercise – imported gas, important hydroelectricity, generating electricity domestically from pebble bed modular nuclear reactors, and introducing more renewable energy technologies. A sustained move towards greater diversity requires more than a single policy (Winkler, 2006).

The first of these involves the increased use of imported gas (either from Mozambique, Namibia or in the form of LNG), primarily as fuel for combined-cycle turbines for electricity generation. This would cost a little more than the reference case (around R95 million), but save around 200 Mt CO_2 over the study period, with a reduction of 12 Mt in 2025. A major constraint on this scenario is the limited size of gas reserves available in southern Africa, although there is some potential to build gas-fired power plants in Namibia and export the electricity to South Africa.

The second option considered would involve importing hydroelectricity. There are two sources potentially available. The first is Mozambique, from which South Africa already imports hydroelectricity (from the Cahora Bassa plant). However, there is the potential to construct a new plant downstream (at the Mepanda Uncua site) of around 1300 MW. The second source is the Inga Falls on the Congo River in the Democratic Republic of Congo (DRC), which could potentially provide 40,000 – 100,000 MW of capacity, but would require significant strengthening of the regional electricity grid, as well as posing fairly significant security of supply risks, given the political instability of the region. The option which was modelled only involved importing electricity from Mozambique (assuming completion of Mepanda Uncua). This would save R11 billion, and also save 167 Mt of CO_2 emissions, as well as 17 Mt in 2025. If the security of supply risks could be successfully mitigated, importing hydroelectricity from the DRC could be one of the most important ways of changing the electricity supply profile, and could reduce CO_2 emissions drastically without significantly reducing the energy intensity of the South African economy.

The third option involved the deployment of Eskom's indigenous nuclear reactor concept, the PBMR. Assuming that the technological challenges are successfully met, the scenario assumed that around 4,500 MW of baseload nuclear capacity is added to the electricity system during the period, which would add R4.6 billion to the costs for the reference scenario, and would avoid 246 Mt of CO_2 including avoiding 32 Mt CO_2 emissions in 2025, subject to the usual complications and constraints of nuclear power.

Renewable energy options in South Africa, the fourth and fifth options, were modelled for both electricity-generating renewable technologies (a combination of biomass, solar thermal technologies and wind energy), which added R4.5 billion to the reference case, avoided 180 Mt of CO_2 emissions, and would cut CO_2 emissions in 2025 by 15 Mt, and for a biofuels scenario, which would provide around 8% of liquid fuels by 2025, cost R2 billion more than the reference case, and would save 31 Mt of CO_2 over the period, and around 5 Mt in 2025. The extent of renewable energy deployment in these scenarios is relatively modest. The electricity target is in line with the state's target of achieving 10,000 GWh of generated electricity by 2014 (see above), but current thinking in government is that three-quarters of this target will now be met through biofuels. Investing in more labour-intensive technologies such as renewables (AGAMA, 2003) would create more 'green jobs'.

Other, more ambitious renewable energy interventions are possible, particularly involving a massive effort to develop solar energy technologies, since South Africa has excellent solar resources, but this depends again on the electricity price. Current evidence indicates that solar water heating (for domestic, commercial and potentially industrial applications) is economically viable, even given current low prices. Developing the potential of solar energy in South Africa would probably require a massive state-driven research and an investment programme similar to the synthetic fuels programme in the 1960s and 1970s.

Other supply-side options which require further investigation are new coal technologies, unconventional coal technologies such as fluidised-bed combustion and others, as well as carbon capture and storage combined with coal gasification (many of which are being researched by Sasol and Eskom). There are currently no reliable estimates for the cost of these programmes, especially given the lack of oil or gas wells in South Africa, which adds significant technical complications to CO_2 storage. Another option would be to convert Sasol's synfuels plant to a natural gas feedstock, which would reduce CO_2 emissions by around 30 Mt. However, gas reserves in Mozambique (from which gas is currently piped to Sasol's plant) are currently too limited to convert more than 15% of feedstock to gas. Other efficiency improvements, plus the potential use of biomass as a partial feedstock, might reduce CO_2 emissions by 10–20%, but Sasol also plans (with government backing) to build another similar plant, which (with efficiency improvements) will increase CO_2 emissions by around 40 Mt per annum, unless the CO_2 is captured and stored, which is being investigated by Sasol. There are also plans to develop a biofuels industry in South Africa, but on a relatively small scale, only replacing around 8% of conventional liquid fuels, which represents a limit based on price and on available arable land and water resources.

Mitigation options in energy supply are particularly sensitive to changing energy prices. Sensitivity to higher oil prices was included in the LTMS study (Winkler, 2007). Prices of \$100 or \$150 a barrel seem much more likely in 2008 than at the time, 2006. Modelling these higher oil prices, reflective of a post-peak oil world, showed clearly that the increases in system costs dwarf the costs of even very costly mitigation options. The corollary is that mitigation options that displace oil products (e.g. vehicle efficiency or biofuels) are more attractive. In the South African context, one must remember that the emissions-intensive CTL process also becomes more attractive.

6.1.3. Structural changes to the economy

The modelled options outlined above, if they were all implemented, would reduce CO_2 emissions from the reference case by 143 Mt (24%), but these would still be 30% higher than the 2000 level. All these scenarios have been modelled with the assumption that the structure of the energy system (and thus the economy) remains essentially the same. Another more complex set of options exists for GHG mitigation which involves significant changes to the *structure* of the energy system; in particular, options which would lower the energy intensity of the economy. At present, industrial energy use is the main driver for the high energy intensity of the economy, whereas projections indicate that transport will become a major factor in the next few decades in terms of both its contribution to GHG emissions and its contribution to the energy intensity of the economy.

Historically, low electricity prices have been seen as central to South Africa's competitiveness. 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 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).[7]

The risk of the current approach is that, while they may promote industrial development in the short run, they carry 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 either the energy efficiency or the production process. Recent investments in steel and aluminium bear this out – while the processes may be optimized for that technology, the wholesale switch to a more efficient technology is very costly after construction (Visser et al., 1999).

While growth trends in the economy in the last two decades have resulted in higher growth in the advanced manufacturing and services sectors (as part of an orthodox development path), significant investment in energy-intensive industries in the 1990s has limited this diversification, and several new mega-projects (including a new aluminium smelter) are now in the planning stage.

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 and Padayachee, 1998, p. 634). This would represent a major shift in industrial policy and would take decades to complete, given large investments in infrastructure. 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 and Marquard, 2007), but are summarized 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[8] 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 and Marquard, 2007). The fourth strategy might be economics instruments, such as a carbon tax or domestic emissions trading, which would be expected to affect the energy-intensive sectors most strongly. 'Putting a price on carbon' now has political support (ANC, 2007). The Treasury, having conducted a discussion of options for environmental fiscal reform (National Treasury, 2006), announced this year that four options would come 'under scrutiny for implementation include[ing] the use of emission charges and tradable permits, tax incentives for cleaner production technologies and reform of the existing vehicle taxes to encourage fuel efficiency' (Manuel, 2008). While policy design will be elaborated further, an initial levy of 2 c/kWh on the sale of non-renewable electricity is to be collected at source from the electricity generator (Manuel, 2008). To put this into context, this is a single-digit increase in the electricity tariffs (which vary), while the utility Eskom applied for 60% increases for other reasons, notably to fund a build programme (NERSA, 2008). 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.

6.2. Key constraints

One can group the constraints to implementation of an aggressive mitigation programme in South Africa into three types: markets, institutions and lack of policy co-ordination. Unlike many other developing countries, South Africa does not suffer greatly from lack of technological capacity or inability to raise finance, as has been demonstrated by large-scale and innovative projects developed in the past in the energy sector (for instance, the development of a large-scale synfuels programme in the 1970s, or the electrification programme in the 1990s). However, not all projects are pursued with equal political will or find a conducive economic environment.

The key barriers to the deployment of energy efficiency programmes, and particularly large-scale renewable energy technologies, are low energy prices. These are ultimately based on ultra-low coal prices; as outlined above, South African coal prices are amongst the lowest in the world. Unlike export-grade coal (about one-third of South Africa's production), the price of low-grade coal used for power generation and synfuels in South Africa is not significantly influenced by international energy prices since it cannot be economically exported. Furthermore, overcapacity in the 1980s led to electricity prices dropping in real terms from the early 1990s to the early 2000s to below long-run marginal cost, a trend enforced by a new regulator (established in 1994) which was keen to pursue government's traditional policy of low energy prices. This trend ended abruptly in 2008 as Eskom applied successfully for two price reviews which pushed up electricity prices by almost 30% to cope with sharply rising fuel costs, triggered by a supply crisis which saw coal shortages and the intensive use of diesel. Government has indicated the need to raise prices sharply at around the same rate annually for the next few years, which will create added incentives for energy efficiency, and make investment in renewable energy technologies more attractive, as well as curbing demand for electricity.

Coupled with these developments has been considerable uncertainty about the institutional structure of the electricity sector. In 2004 government announced that a 1998 policy of introducing competition in the generation sector would be scrapped, and since then there has been considerable uncertainty about the conditions under which Independent Power Projects (IPPs) would participate in the sector. While government has expressed a desire for large-scale participation by private investors in the electricity sector, it is not currently clear on what terms they would participate. There is also uncertainly about Eskom's role and the role of the regulator in planning the expansion of the grid. Although there is a national integrated resource planning process situated in the regulator, Eskom's own (non-public) process is more influential in decision-making on new capacity. The liquid fuels sector is also tightly regulated, and dominated by traditional refining companies and Sasol, and it is not clear on what basis biofuels would enter the market.

These problems point to a third and more pressing problem: that of policy co-ordination. In the time since the end of apartheid, a new demand-side energy policy was developed which required government's traditional rather narrow engagement with the energy sector to be put on a much broader footing. The new approach was to embrace policies requiring a much broader co-ordination of different areas of government (for instance, energy efficiency and household energy policies). By and large this has not been achieved, and even in the face of the current electricity crisis, there is little sign that much-needed energy efficiency programmes (on which the country now depends to avoid wide-ranging black-outs in the next few years) are being implemented.

Climate change mitigation policies require even more cross-government co-ordination, and ideally need to be co-ordinated at a very high level. In order to pursue least-cost options with the most co-benefits, trade-offs and synergies will have to be achieved between a wide range of policy domains, including industrial policy, energy policy, environmental policy, social policy and other domains such as housing, agriculture and transport policy. The discourse of development is the only context for this unprecedented scale of co-ordination of policymaking. Without fusing climate change mitigation and development, mitigation is unlikely to be politically or institutionally achievable.

6.3. Potential for international co-operation to assist with mitigation and removal of constraints

In the Bali Action Plan, the international community framed part of the mitigation challenge as 'nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner' (UNFCCC, 2007, para 1.b(ii)). This points to three areas in which international co-operation would enhance the implementation of mitigation policies in South Africa: finance, technology and capacity building.

At the Rio Earth Summit already, Annex II Parties to the UNFCCC undertook to 'meet the agreed full incremental costs' of a range of measures undertaken by developing countries (UNFCCC, 1992, article 4.3). A key component of the future of the climate regime after 2012 will be scaled-up finance. This may require a significant increase in the capacity of the financial mechanism. In our view, South Africa should put its own resources into a range of mitigation options, particularly negative-cost ones. But assistance on the more expensive options will be needed if the country is to make a greater contribution to mitigation, and achieve 'deviation from baseline' emissions (UNFCCC, 2007). International support on finance, technology and capacity will be important. Innovative means are needed to address the 'price gap', the cost difference between renewable energy options and existing fossil-fuel-based power. There are a number of innovative financing instruments which could be applied, including the CDM, which would lower the risk of these investments for local investors (primarily Eskom). Other options would be to 'green' Official Development Assistance and export credit policies in OECD countries.

A Multilateral Technology Acquisition Fund may be needed to 'buy down' the costs of existing low-carbon technology. Concessionary finance might be sufficient in middle-income countries like South Africa, whereas poorer countries might require direct funding. To bring emerging technologies to market, greater investment by venture capital will be critical. For the long term, new technologies will be important, requiring increased investment in research and development.

The second component involves technical co-operation. Technology cooperation is not transfer, but should build on existing technical capacity in South Africa, matching it with international finance and technological assistance in agreed areas. Technology is central to addressing the challenge of climate change. Massive new investments required in the energy sectors over the next 30 years – both in South Africa and globally – provide a window of opportunity for technological change (without premature retirement of existing capital stock). A multilateral technology transfer facility might set out to do several things to promote the 'development and climate agenda', including addressing intellectual property rights barriers, accessing multilateral funding for technology development in developing countries, joint technology development. and developing international technology standards and research and development protocols.

The third area where international co-operation could be decisive is capacity building in, and support for, climate change-related policymaking, which could include training officials and the seconding of experts to key strategic points in government. Another two areas where such a facility might be useful is capacity building in state and non-state entities where technology choices are made and implemented, and the development of demonstration projects. Whereas South Africa has significant technology capacity, there is currently little incentive to investigate or implement certain types of mitigation projects (for instance, super-efficient buildings), and there is thus little technological capacity to do so. Funding specialized agencies or posts, as well as the facilitation of South–South exchanges on innovative policies and measures, would assist the country's effort to take ambitious, nationally appropriate mitigation actions.

7. Conclusion

South Africa has urgent socio-economic development priorities. To undo the legacy of apartheid, millions of people require housing, clean water, sewage, land, energy and other basic services. Cabinet agreed that emissions will have to peak, plateau and decline as part of its climate policy, making a transition to a low-carbon economy. Such a transition faces particular challenges in the context of South Africa's particular historical path of development.

The existing development path is energy and carbon intensive. The use of cheap and abundant coal in the primary energy mix has provided relatively low-cost electricity, and little incentive for greater energy efficiency. Industrial development has to a significant extent been built around energy-intensive sectors. These sectors are sensitive to changes in energy prices, so that particular attention needs to be given to them in the move to a low-carbon economy. While current government policy has embraced sustainable development goals, the country continues to provide significant incentives for investment in energy-intensive industries. These industries are still an important source of employment, investment and income for the country.

South Africa has made a start on policy to bend the curve of rising GHG emissions downwards, while making development more sustainable. Following an intensive scenario process, Cabinet has agreed that emissions must peak, plateau and decline. This will be pursued using both regulatory and economic instruments. The vision of a low-carbon economy has been outlined as one that can promote employment and development, while reducing emissions. Initially, these emissions will be relative, that is lower than business-as-usual but still increasing, but the recognition that they need to be declining by 2030–2035 at the latest has dawned on South African policymakers.

The challenge of climate change is a long-term challenge, requiring immediate action. So near-term actions must be part of tackling mitigation in South Africa. The most effective and affordable short-term strategy to reduce GHG emissions is an energy efficiency programme. Multiple studies demonstrate that significant savings can be made at no overall cost to the economy and provide often significant benefits. The next strategy would be to change the fuel mix, notably to reduce the three-quarter share of coal in the total primary energy supply. In the medium term, reduced-carbon and non-carbon energy supplies, such as natural gas, hydroelectricity (imported from the region) and solar thermal technologies can be introduced into the energy system. These measures together can achieve significant reductions in GHG emissions in relation to business-as-usual development. They would probably help to slow the rate of emissions growth, but GHG emissions are likely to continue increasing in absolute terms. Further action will be required to reduce emissions, in the form of pursuing the above programmes more aggressively, possibly with the help of international funding.

The most fundamental changes are to economic structure. The envisaged changes are large, and it will take time to shift big systems. Changing development paths does not happen overnight, if they happen by design at all. This paper has suggested that this enormous challenge could be addressed through five means: incentive programmes for energy-intensive industries; pricing energy to reflect external costs for non-energy-intensive sectors of the economy; investment (both public and private, national and international) in climate-friendly technologies where the country has a resource, e.g. solar thermal technology; a raft of measures to lower the energy intensity of key industries, including selective beneficiation, accelerated energy efficiency programmes, and other options such as a shift from resource extract to materials provision; and finally economy-wide measures such as carbon taxes or emissions trading systems.

Notes

1. Population estimate (SSA, 2007b); the estimate for urbanization is based on the 2001 Census, since no more recent estimates are available. The next census will be conducted in 2011. The definition of 'urban' changed between 1996 and 2001. The

figure above for 1996 was rebased using the new definition (SSA, 2003).
2. The 2003 base year was used in the LTMS process to align with the base year that had been chosen for the compilation second Integrated Energy Plan, which was subsequently put on hold.
3. These rankings could differ if other data sets are used. The WRI compiles a good data set, in particular for energy emissions which predominate in South Africa.
4. This figure represents mainly biomass used for residential heating and cooking, and has never been accurately determined and is therefore probably unreliable. The contribution of 'modern' renewable energy to the South African energy economy is very small.
5. The category 'fuel mix' has the attractiveness of simplicity, but does not easily accommodate all available forms of energy supply (especially renewable energy). However, here we mean it to signify any energy input into the economy.
6. A target of 12% by 2014 was used for the scenario modelling. These figures are very close to the government's 2005 National Energy Efficiency Strategy targets (12% by 2015), and those additionally specified in the National Energy Efficiency Accord (15% by 2015 for mining and industry), but not identical.
7. 'There are sufficient electricity and water resources to meet the future demands within the Industrial Development Zone. These utilities are available in bulk at very favourable rates' (CDC, 2004).
8. Energy-intensive industries could be identified by the percentage of their costs spent on energy.

References

AGAMA, 2003. Employment potential of renewable energy in South Africa. A study commissioned by Sustainable Energy and Climate Change Partnership, a project of Earthlife Africa Johannesburg, in partnership with WWF, Denmark. Johannesburg, SECCP.

ANC (African National Congress), 1994. *The Reconstruction and Development Programme: A Policy Framework*. Umanyano, Johannesburg.

ANC (African National Congress), 2007. Resolution on climate change. *ANC 52nd National Conference*, Polokwane, Limpopo, SA. [http://www.anc.org.za/show.php?doc=ancdocs/history/jan8-08.html].

AsgiSA (Republic of South Africa), 2006. *Accelerated and Shared Growth Initiative for South Africa*. AsgiSA, Pretoria. [http://www.info.gov.za/asgisa/asgisa.htm, accessed December 2006].

Bond, P., 2000. Economic growth, ecological modernization or environmental justice? Conflicting discourses in South Africa today. Municipal Services Project, Johannesburg.

BP, 2004. *BP Statistical Review of World Energy*. British Petroleum, London, June. [www.bp.com/centres/energy/].

CDC, 2004. *Investment Opportunity*. [www.coega.co.za].

DEAT (Department of Environment Tourism), 2005. Action for Climate Change Conference Statement, Bojanala. DEAT, Pretoria.

DEAT (Department of Environmental Affairs and Tourism), 2008. *People–Planet–Prosperity: A National Framework for Sustainable Development in South Africa. July 2008*. Pretoria. [www.environment.gov.za, accessed 17 July 2008].

DME (Department of Minerals and Energy), 2003a. *Integrated Energy Plan for the Republic of South Africa*. DME, Pretoria. [www.dme.gov.za].

DME (Department of Minerals and Energy), 2003b. *White Paper on Renewable Energy*. DME, Pretoria. [http://www.dme.gov.za/pdfs/energy/renewable/white_paper_renewable_energy.pdf, accessed 7 May 2008].

DME (Department of Minerals and Energy), 2004. *South Africa National Energy Balance*. DME, Pretoria. [http://www.dme.gov.za/energy/documents/stm, accessed 29 January 2009].

DME (Department of Minerals and Energy), 2005. *Energy Efficiency Strategy of the Republic of South Africa*. March 2005. Pretoria. [http://www.dme.gov.za/pdfs/energy/efficiency/ee_strategy_05.pdf].

DME (Department of Minerals & Energy), 2006. *Digest of South African Energy Statistics*. DME, Pretoria. [http://www.dme.gov.za/pdfs/energy/planning/2006%20Digest.pdf, accessed 30 July 2008].

DTI (Department of Trade and Industry), 1996. *Growth, Employment and Redistribution: A Macro-economic Strategy*. DTI, Pretoria.

Eberhard, A., 2003. The political, economic, institutional and legal dimensions of Electricity Supply Industry reform in South Africa. *Political Economy of Power Market Reform conference*, 19–20 February, Stanford University, Palo Alto, CA.

EDRC (Energy & Development Research Centre), 2003. *Policies and Measures for Renewable Energy and Energy Efficiency in South Africa*. Prepared for the Sustainable Energy & Climate Change Partnership. EDRC, University of Cape Town, Cape Town,

Eskom, 1990. *Annual Report 1990*. Eskom, Sandton, Johanesburg.

Fine, B. and Rustomjee, Z. 1996. *The Political Economy of South Africa: From Minerals–Energy Complex to Industrialization*. C. Hurst, London.

Hughes, A, Howells, M. and Kenny, A. 2002. *Energy Efficiency Baseline Study. Capacity Building in Energy Efficiency and Renewable Energy (CABEERE). Report No. 2.3.4*. Report No. P-54126. Department of Minerals & Energy, Pretoria. [http://www.dme.gov.za/energy/efficiency_projects.stm].

ISSC (International Scientific Steering Committee), 2005. Avoiding dangerous climate change: executive summary. Scientific Symposium on Stabilisation of Greenhouse Gases, 1–3 February, Exeter. Department of Environment Food and Rural Affairs, Exeter, UK. [www.stabilisation2005.com/steering_committee_Report.pdf, accessed 29 January 2009].

Manuel, T., 2008. *Budget Speech, 20 February*. Parliament, Cape Town. [http://www.treasury.gov.za/documents/national%20budget/2008/speech/speech.pdf, accessed 22 February 2008].

Meinshausen, M., 2005. On the risk of overshooting 2°C. *Avoiding Dangerous Climate Change*. MetOffice, Exeter, UK, 1–3 February.

Michie, J. and Padayachee, V., 1998. Three years after apartheid: growth, employment and redistribution? *Cambridge Journal of Economics*, 22. 623–635.

National Treasury, 2006. *A Framework for Considering Market-based Instruments to Support Environmental Fiscal Reform in South Africa*. Draft Policy Paper. National Treasury Tax Policy Chief Directorate, Pretoria. [http://www.treasury.gov.za/Public%20comments/Draft%20Environmental%20Fiscal%20Reform%20Policy%20Paper%206%20April%202006.pdf, accessed 29 January 2009].

NER (National Electricity Regulator), 2002a. *Electricity Supply Statistics for South Africa 2002*. NER, Pretoria.

NER (National Electricity Regulator), 2002b. *An Integrated Electricity Outlook for South Africa*. NER, Pretoria.

NER (National Electricity Regulator), 2004a. *Electricity Supply Statistics for South Africa 2004*. NER, Pretoria.

NER (National Electricity Regulator), 2004b. *National Integrated Resource Plan 2 (NIRP2) 2003/4*. NER, Pretoria. [http://www.nersa.org.za/UploadedFiles/ElectricityDocuments/NIRP2%20compiled%202004.pdf, accessed 12 May 2008].

NERSA (National Energy Regulator of South Africa), 2008. *Inquiry into the National Electricity Supply Shortage and Load Shedding*. Report by the National Energy Regulator, Pretoria. [http://www.nersa.org.za/documents/electricity/LSEnergyRegulatorReportByELS14May2008V3Rev8SSMFinalpdf.pdf, accessed 26 May 2008].

Raskin, P., Gallopin, G., Gutman, P., Hammond, A. and Swart, R., 1998. *Bending the Curve: Toward Global Sustainability*. Report of the Global Scenario Group. Stockholm Environment Institute, Boston, MA.

RSA (Republic of South Africa), 2004. South Africa: Initial National Communication under the United Nations Framework Convention on Climate Change. Submitted at COP-9, Pretoria. [www.unfccc.int/resource/docs/natc/zafnc01.pdf].

SBT (Scenario Building Team), 2007. *Long Term Mitigation Scenarios: Strategic Options for South Africa*. Department of Environment Affairs and Tourism, Pretoria. [http://www.environment.gov.za/HotIssues/2008/LTMS/A%20LTMS%20Scenarios%20for%20SA.pdf, accessed 15 October 2008].

Schäfer, A., 2005. Viewpoint: structural change in energy. *Energy Policy*, 33. 429–437.

Spalding-Fecher, R., 2001. *Energy and Sustainability in South Africa: The 2001 Sustainable Energy Watch Report*. Energy & Development Research Centre, University of Cape Town, Cape Town.

SSA (Statistics South Africa), 2003. *Census 2001: Investigation into Appropriate Definitions of Urban and Rural Areas for South Africa*. Discussion document, SSA.

SSA (Statistics South Africa) 2007a. *General household survey*. Statistical release P0318, SSA, Pretoria.

SSA (Statistics South Africa), 2007b. *Mid-year Population Estimates*. South Africa. Statistical release P0302, SSA, Pretoria.

SSN (SouthSouthNorth), 2004. Project design document for the Kuyasa project. Submitted to the Executive Board of the Clean Development Mechanism. [http://cdm.unfccc.int]. SouthSouthNorth Project, Cape Town. [http://www.southsouthnorth.org/default.asp?/country_home.asp?country_id=11, accessed 29 January 2009].

Stern Review Team, 2006. *What is the Economics of Climate Change?* Treasury, London.

UNDP (United Nations Development Programme), 2007. *Human Development Report 2007/2008: Fighting Climate Change: Human Solidarity in a Divided World*. UNDP, New York.

UNDP (United Nations Development Programme), 2008. *Statistics of the Human Development Report*. UNDP, New York.[http://hdr.undp.org/en/statistics/, accessed 31 July 2008].

UNFCCC, 1992. *United Nations Framework Convention on Climate Change*. United Nations, New York. [http://unfccc.int/resource/docs/convkp/conveng.pdf].

UNFCCC (United Nations Framework Convention on Climate Change), 2007. *Bali Action Plan*. Decision 1/CP.13. Bali, Indonesia.

Van Schalkwyk, M., 2008. *Government Outlines vision, Strategic Direction and Framework for Climate Policy*. Statement by Marthinus van Schalkwyk, Minister of Environmental Affairs and Tourism, 28 July, Cape Town. [www.environment.gov.za, accessed 29 July 2008].

Visser, M., Spalding-Fecher, R. and Leiman, A., 1999. *Manufacturing and Economic Growth*. Paper No. 10: World Wildlife Fund Macroeconomic Reforms and Sustainable Development in Southern Africa Project. Energy & Development Research Centre, University of Cape Town, Cape Town.

Winkler, H. (ed.) 2006. *Energy Policies for Sustainable Development in South Africa: Options for the Future*. ISBN: 0-620-36294-4. Contributors: O. Davidson, H. Winkler, A. Kenny, G. Prasad, D. Sparks, M. Howells, T. Alfstad, S. Mwakasonda, B. Cowan and E. Visagie. Energy Research Centre, Cape Town. [www.erc.uct.ac.za/Research/publications/06Winkler_Energy%20policies%20for%20SD.pdf, accessed 29 January 2009].

Winkler, H. (ed.) 2007. *Long Term Mitigation Scenarios: Technical Report*. Prepared by the Energy Research Centre for Department of Environment Affairs and Tourism, Pretoria, October. [http://www.erc.uct.ac.za/Research/LTMS/LTMS-intro.htm, accessed 30 October 2008].

Winkler, H. and Marquard, A., 2007. *Energy Development and Climate Change in South Africa: Decarbonising Growth in South Africa*. Occassional paper 2007/40, for UNDP's Human Development Report 2007/8: Fighting climate change: Human solidarity in a divided world. Human Development Report Office, New York. [http://hdr.undp.org/en/reports/global/hdr2007-2008/papers/winkler_harald%20and%20-marquard_andrew.pdf, accessed 29 January 2008].

Winkler, H. and Van Es, D., 2007. Energy efficiency and the CDM in South Africa: constraints and opportunities. *Journal of Energy in Southern Africa*, 18 (1). 29–38.

WRI (World Resources Institute), 2003. *Climate Analysis Indicators Tool (CAIT)*. Washington, DC. [http://cait.wri.org].

WRI (World Resources Institute), 2005. *Climate Analysis Indicators Tool (CAIT), Version 3.0*. Washington, DC. [http://cait.wri.org/].