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Fighting climate change:
Human solidarity in a divided world

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Energy Development and Climate Change: Decarbonising Growth in South Africa

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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 urbanisation, an economy adjusting to globalisation, 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 mega-projects is unfavourable for mitigation strategies, it may be possible to incorporate sustainable development goals with mitigation.

This paper presents a case study of human development and climate change in South Africa. It starts by outlining the key development challenges that the country faces and the history of recent responses in development policy. Section 2 hones in on the energy sector, providing a brief profile of the sector contributing most to greenhouse gas (GHG) emissions. The implications of South Africa's 'minerals-energy complex'[1] for its GHG emissions profile are examined in section 3. Section 4 discusses the context and development of South African climate change policy, and examines implementation progress to date. The final section of the paper begins with a summary analysis of key mitigation options in energy efficiency, changes in the fuel mix and structural changes. Section 5 then examines the key constraints facing the implementation of such options, before concluding with possibilities for international co-operation to contribute to sustainable development and mitigation in South Africa.

1. Overview of South African development challenges

1.1 The legacy of apartheid

South Africa has an estimated population of 47.4 million people (July 2006)[2], of which 57.5% live in urban areas. Economic activity (and the urban population) is concentrated around four large urban clusters: in the Western Cape (Cape Town), the Eastern Cape (Port Elizabeth, East London), Kwa-Zulu Natal (Durban), and Gauteng (Johannesburg, Pretoria and others), with the largest proportion of the economy located in Gauteng, the historical centre of the mining industry.

The economy was historically based on mineral extraction and processing and agriculture, particularly gold mining. However, from the 1950s agriculture declined in significance, and mining activities expanded dramatically, initially dominated by gold, but followed by other minerals, notably coal and platinum. From the 1950s industrialization led to the development of a significant manufacturing sector, which began to rival the importance of mining in its contribution to GDP, followed by the rise of a services sector in the 1970s. The development path pursued by the apartheid state from the 1940s to the 1990s was based on the development of mining and heavy industry, and characterized by extremely low energy prices and massive capital-intensive and energy-intensive projects. Changes in sectoral contribution to the economy over time can be seen in Figure 1 below. Two notable features are the decline in the contribution

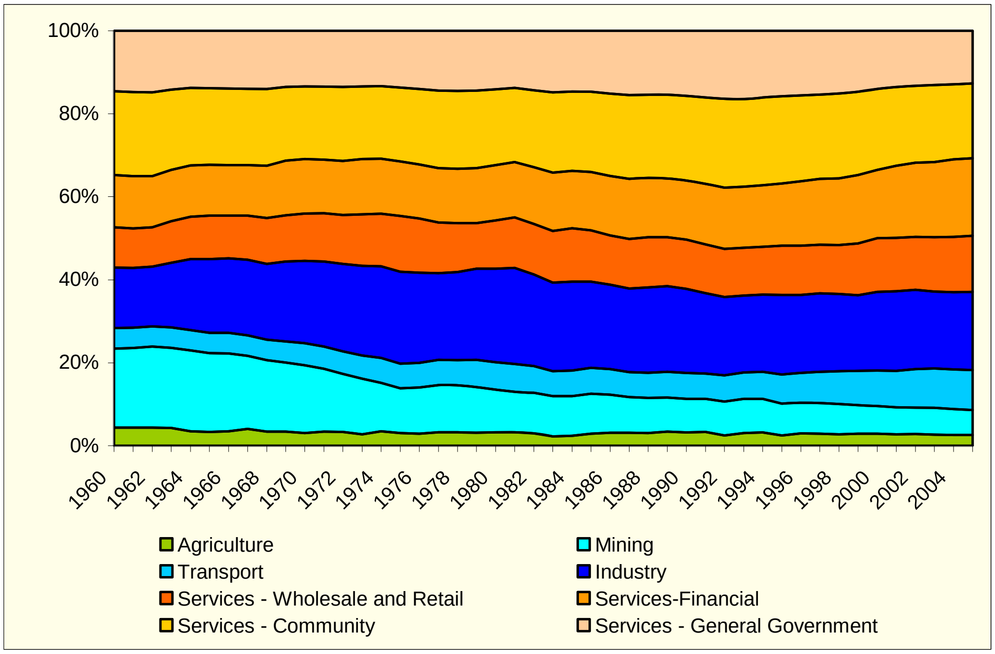
[1] In one of the most insightful analyses of the development of the South African economy, Fine and Rustomjee propose a 'minerals-energy complex', consisting of a tight set of economic interrelationships between the mining, energy and minerals processing sectors. Their central thesis argues that the complex dominates the South African economy despite the relative decline of the mining sector, and has had (and will have) a profound effect on past and future growth patterns (Fine & Rustomjee 1996).

[2] Population estimate from (SSA 2006); 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).

to mining to GDP, and the relatively stable contribution to the economy over the period of the energy-intensive sectors of the economy (mining, transport and industry) – unlike other economies, these sectors were not eclipsed by the services sector as the economy developed, and although industry' contribution to GDP declined from 1980 to 1990, this decline halted at the beginning of the 1990s. Both the country's imports and exports are dominated by the minerals production and processing and energy sectors – the country's most significant exports are gold, platinum and coal, and the most significant import is crude oil.

Figure 1: Sectoral contribution to economy, 1946-2005

Source: South African Reserve Bank Quarterly Bulletin



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 (2006), South Africa's Gini coefficient ranked the country 116th 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 (most developed=1), whereas in GDP per capita (PPP) terms, South Africa is ranked 52nd (UNDP 2006), indicating the significant disparity between economic wealth and development in South Africa (UNDP 2006). 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. The post-apartheid government's attempts to address these were complicated by a number of factors. By the end of apartheid, the economy was in crisis, and economic growth had dropped to low levels, partly as an outcome of structural economic problems due to apartheid, and partly due to sanctions and other forms of international pressure brought to bear on the country during the 1980s. In addition to these problems, globalization posed further challenges, since much of the South African economy was not internationally competitive.

1.2 Development policy frameworks

The post-1994 government's broad policy framework has been based on two sets of principles: first, resolving the macro-economic 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 macro-economic policy framework has been quite conservative, with a strong emphasis on macro-economic 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 marginalisation 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. For instance, the RDP proposed to address the housing backlog of some 2-3 million houses by aiming to build 300 000 units each year for the first five years. In the same period, 30% 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 RDP target of connecting 2.4 million unelectrified households to the grid between 1994 and 1999 (an average of over 400 000 households per year) is one of the few that was exceeded (Borchers *et al.* 2001). Since 2000, electrification has continued under the National Electrification Programme at a slower pace (around 250 000 households per year),with the aim of achieving universal access to electricity by 2012; the RDP target-based approach has been replaced by a broader approach aimed at ensuring the technical, economic and social sustainability of the programme (Tinto 2003).

Two years later, the focus of GEAR shifted to macro-economic 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 could be met through macro-economic reforms. While relatively successful in addressing macro-economic 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 was assumed. By the end of the 1990s, the government saw the state playing a much more significant role in development. Plans to privatise 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, which, 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 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' (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’, but these sectors represent one of the key areas of international competitiveness of the South African economy, and still form the basis for a large proportion of the economy, an even more important share of exports, and 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 policymakers 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. We thus now turn to a discussion of the South African energy sector.

2. The South African energy sector

2.1 Profile of the South African energy system

The basis of South Africa’s current energy system is coal, which constitutes an extremely high proportion of South Africa’ primarily 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%[3] (DME 2004). As for electricity generation, an even greater share, 92%, came from coal-fired power stations in 2004 (NER 2004a).

Unlike many other countries, South Africa did not go through a transition to oil in the 1950s and 1960s, and the limited switch to oil products which did occur in industry was reversed in the 1970s, primarily because of the development of a massive coal-based synthetic fuels programme. As a result of the low cost of coal (see below), there has never been any significant use of liquid fuels in electricity generation.[4] Almost all crude oil is imported, due to the lack of significant local reserves, and the country possesses no significant gas reserves, except a few small fields off the south coast of the Western Cape (currently used as feedstock for synthetic fuels), and a field of similar size off the west coast (not exploited yet). A small amount of natural gas is imported from Mozambique.

South Africa possessed 5.4% of the world’s coal reserves, mines 4.9% of the world’s annual coal production, and uses 3.5% of annually world coal consumption, the remainder being exported (www.cslforum.org/safrica.htm). Other significant energy resources are very small oil and gas reserves, significant reserves of uranium (which is largely a by-product of gold mining), some wind resources around the coast, and very high quality solar insolation over most of the country.

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 industrialisation during the twentieth 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 developed for the white population during and before apartheid, and the rest of the population was largely excluded.

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[3] 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 economic is ver small (see below).

[4] This is about to change: the state utility Eskom is in the process of constructing two large open-cycle gas turbine peaking plants in the Western Cape, which will initially run off diesel.

The modern South African energy economy developed in a number of investment cycles. The initial coal and electricity nexus developed from the 1900s to World War 2, based primarily on the expansion of gold mining around what is now called Gauteng, as well as the (less significant) development of municipal power infrastructure. The post-war era saw a boom in energy investment: a significant expansion in electricity generating capacity, driven by massive expansion of gold mining and the expansion of the mining sector out of its traditional focus on gold and coal. This was accompanied by the development of a significant manufacturing sector, including the establishment of an indigenous refining industry from the mid 1950s to the mid-1960s, by which time South Africa had no need to import liquid fuels. The development of a minerals processing industry from the 1960s led to significant expansion in the electricity system. Electricity demand quadrupled between 1950 and 1970, and quadrupled again between 1970 and 2000, growing significantly faster than the economy until the mid-1980s. The 1970s was probably the most significant decade in the twentieth century for energy sector investment, for several reasons.

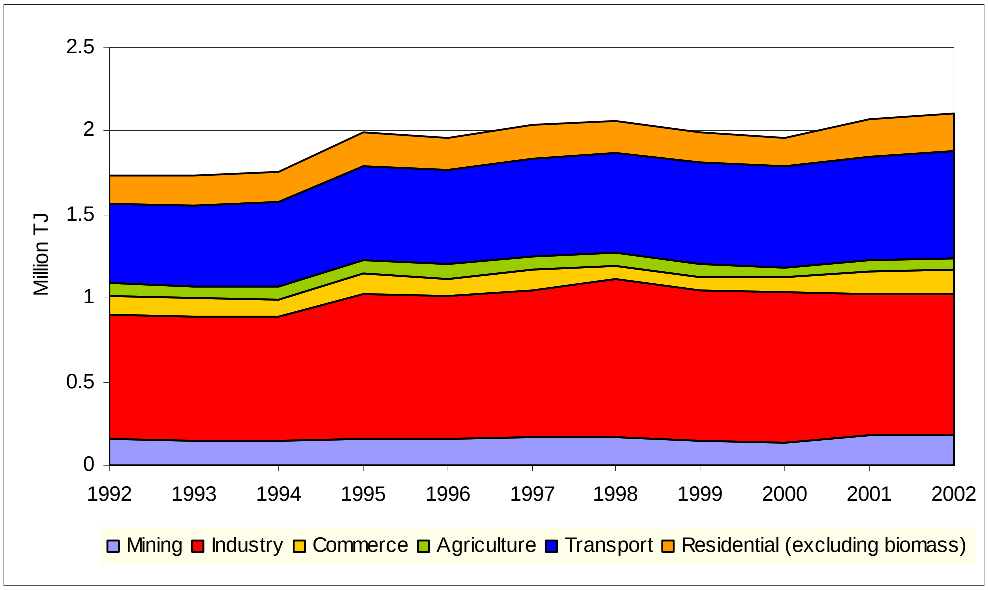
- First, electricity demand was not slowed by the 1973 oil crisis. At the same time, the national grid was completed, which led to the development of a new technological model based on large power plants (average size around 3600MW) located on major coalfields.
- Secondly, in order to provide the coal for all these plants, a massive investment in new coal mines was made, largely by the private sector, driven in part by an export boom bought about by changes in coal policy.
- Thirdly, concerns by the apartheid state about the looming oil embargo led to the development of a massive strategic petroleum reserve, an inland refinery, and a massive synthetic fuels programme based on coal, which also increased electricity demand.
- Fourthly, the state also invested heavily in a nuclear power and weapons programme, including an indigenous fuel cycle (shut down in the 1990s), which was also very electricity-intensive(Marquard 2006).

By contrast, the 1980s saw a stagnation in the economy and in energy demand growth, leaving significant overcapacity in refining/synfuels and electricity generation, and plant in both industries was mothballed. Eskom’s capacity expansion programme was stretched out until the late 1990s, and no new capacity was added until 2006. In order to use this excess capacity, Eskom restructured its tariffs in the late 1980s, and a new round of investments in energy-intensive industries followed in the 1990s.

The South African economy is extremely energy-intensive by international standards, and only a handful of countries have higher intensities Energy intensity is not however equally distributed in the economy, but concentrated in specific sectors. Figures 1 and 2 below indicate energy consumption and contribution to GDP. Manufacturing and transport dominate energy demand 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).

Figure 2: Energy demand, 1992-2000

Source: Based on data in energy balances (DME 2002b)



The development of a ‘civil energy’ infrastructure was based primarily on municipal electrification in its first phase. Early electrification was premised on the spatial and socio-economic characteristics of the colonial and apartheid states. Access to modern energy services was developed along racial lines, with fairly rapid electrification of ‘white’ households in the first part of the twentieth century, followed by a programme of subsidised electrification of rural ‘white’ farms and isolated settlements from the 1940s to the 1980s by the state utility Eskom. Non-white urban and rural areas suffered from a virtual absence of electricity infrastructure development before and during apartheid, and both households and businesses were deprived of electricity. Households, particularly in rural areas, had to rely on unsafe and unhealthy fuels such as wood, paraffin and coal, which caused a range of illnesses (primarily respiratory), as well as a set of paraffin-related maladies (including death), including frequent fires and burns (caused by unsafe stoves) and paraffin poisoning caused by accidental ingestion by children. The obvious alternative which characterises most middle-income countries, LPG, was not widely distributed due collusion by oil companies and the distorted regulatory system. In response, the political transition in the 1990s led to a massive and very rapid electrification programme advanced and financed largely by Eskom (and politically driven and enthusiastically backed by the post-1994 government), which saw residential electrification rates grow from an estimated 30% in 1990 to a current estimated rate of 75%, 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 bases 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 three million new (primarily low-income) residential customers between 1990 and 2004 only increased Eskom’s sales by around 4% (Eskom 1990; NER 2002), whereas growth in Eskom’s industrial sales in the same period added 17% to the 1990 total.

2.2 Key actors and institutions[5]

As indicated above, the three energy supply sectors in the country are coal, liquid fuels and electricity. The production of coal is dominated by several large multinationals, which produce coal for the international and internal markets, and also under long-term contracts for electricity production. Synfuels are an exception – the coal resource is owned by Sasol, but mined under contact by an independent company. The coal market was heavily regulated until the late 1980s when all forms of regulation were removed, but is now only monitored by the Department of Minerals and Energy (DME), which plays a facilitating role in boosting coal exports.

The liquid fuels industry consists of several crude refiners, which own three refineries along the coast and one inland refinery, the previously state-owned Sasol, which owns and operates a massive synthetic fuels plant at Secunda in Mpunalanga, and the state oil company PetroSA, which owns and operates a small synfuels plant fed by natural gas in Mossel Bay. Pipeline infrastructure is owned by the state pipeline company Petronet (part of the larger state-owned transport conglomerate Transnet), and the rest of the industry is vertically integrated. Refiners also own distribution infrastructure, and a significant share of the retail market, although refiners are barred from operating retail outlets themselves. The regulatory regime is complex and labyrinthine, dating mostly from the apartheid era. Pipeline tariffs are set by the National Energy Regulator, but all other aspects of the industry are regulated by the DME. Prices are set for each stage of the value chain, based on an import parity price, and importing of liquid fuels is controlled by the issuing of permits – in practice, only refining companies are granted permits. Wholesale prices of liquid fuels are relatively high by international standards, but taxes are relatively low, leading to modest prices to end-users. Gas pipelines are regulated by the National Energy Regulator.

The electricity sector is dominated by the state-owned national utility Eskom, which owns and operates more than 90% of generation assets, the whole transmission grid, and a significant portion of the distribution industry, especially in rural areas. The remaining generation assets are owned by private producers and local authorities, who were officially discouraged from building additional plant from the 1960s onwards. Local authorities have a right of supply in their areas of jurisdiction, although for a number of historical reasons Eskom distributes electricity in many local authorities. Eskom is most cases also sells electricity directly to large industrial customers. Electricity is regulated by the National Energy Regulator of South Africa (NERSA), which licenses all operators and approves tariffs.

The key government institution in the energy sector is the DME, which formulates and implements energy policy, and oversees a group of associated institutions, including the NER, the National Nuclear Regulator (which oversees nuclear safety), the Nuclear Energy Corporation of South Africa (which undertakes nuclear research) and the Central Energy Fund, which is the holding company for the national oil company PetroSA, as well as owning the recently-established South African National Energy Research Institute and the Energy Development Corporation (formed to promote renewable energy). Energy policy is also closely monitored, and at times influenced, by a group of industry stakeholders, including the South Africa Petroleum Industries Association (SAPIA) representing oil companies (including Sasol), the Chamber of Mines representing mining companies (including coal mines), the Energy-Intensive Users Group whose 25 members consume 40% of the country's electricity, and the Chemicals and Allied Industries Association representing chemicals industries. Other stakeholders include NGOs (particularly environmental NGOs), unions, and the South African Local Government Association (SALGA). Historically, the energy supply industry (specifically mining companies, Eskom and the oil companies) have been very closely involved in making energy policy in South Africa. After 1994, the process broadened somewhat to include a wider range of stakeholders, but lack of state capacity in energy policymaking has meant that industry continues to play a significant role.

[5] Material for this section has been sourced from (Marquard 2006).

3. Greenhouse gas emissions overview

The most comprehensive survey to date of South African greenhouse gas (GHG) emissions was the inventory for 1990 and 1994 compiled as part of South Africa's Initial National Communication (INC) to the UNFCCC (RSA 2004). Most of the data below, except where noted, is extracted from the inventory contained in the INC. An updated inventory is currently being planned by the Department of Environment and Tourism (DEAT). South Africa has relatively high emissions per capita, given its level of human and economic development: at 7.8 tons CO_2 annually (including non-energy emissions). This is the 37th-highest CO_2 emissions per capita, higher than many OECD countries such as Italy, France, Sweden and Portugal. However, South Africa's level of economic and social development lag far behind its carbon emissions: as outlined above, its per capita GDP is only the 52nd-highest, and the country only ranks 121st in the UNDP's Human Development Index. This relatively high level of GHG emissions by comparison to the country's level of socio-economic development is largely due to the high energy intensity of the economy (see above), but it does render the problem of reconciling development goals and GHG mitigation more difficult. The Inventory for 1994 was compiled, according to IPCC guidelines (IPCC 1996), for the three major GHGs: CO_2, CH_4, and N_20 (RSA 2004b, p14). There are some significant characteristics of South African GHG emissions:

a) CO_2 is the most significant GHG, comprising over 80% of GHG emissions.

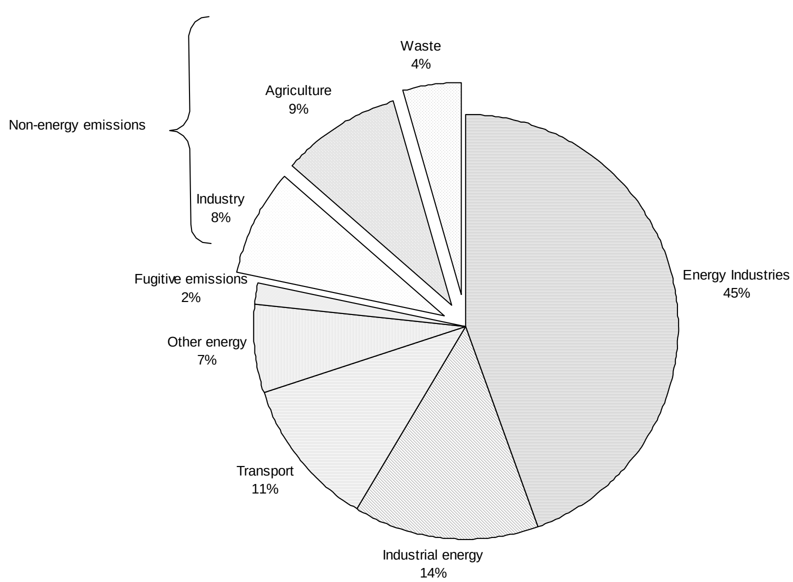
b) Energy-related activities are the dominant cause of GHG emissions, totalling more than 78%, and

c) the energy supply industry (electricity, refineries/synfuel plants) around 56% of these (RSA 2002b: 15-16).

Most of the CO_2 is generated by the energy sector (around 91% in 1994).[6] The pie chart below portrays energy and non-energy emissions for the three gases (CO_2-equivalents).

Figure 3: South Africa's inventory for three greenhouse gases by sector, 1994

Source: (RSA 2004)



[6] The share of carbon dioxide from the energy sector is higher at 91% than for the three GHGs shown in Figure 3, where it is 79%.

3.1 Energy emissions

The energy sector is the key source of South Africa's emissions (see Figure 3), which include a number of critical energy-related activities including energy industries (45% of total gross emissions), energy used in manufacturing industries (14%), energy used in transport (11%), fugitive emissions from fuels (2%), and other energy-related activities (6.6%), which include commercial (0.2%), residential (2.0%) and agricultural (4.4%) use of energy (calculated from RSA 2004). The heavy reliance of the South African energy system on coal, the high level of electricity use, and the energy-intensive synthetic fuels programme are the main drivers of GHG emissions in the energy sector.

There is some question regarding the emissions from the synthetic fuels process. While annual CO_2 emissions were reported at 10.7 Mt (Van der Merwe & Scholes 1998) in the initial Inventory, Sasol's own data indicate that these are more likely to be around 50 Mt per annum. A figure in this vicinity was reported by a number of analysts for years from 2002 to 2004, (Lloyd 2005; Mako & Samuel 1984), and verified with Sasol. Future trends in GHG emissions, according to current government energy plans, indicate a rise from just over 300 Mt CO_2 in 2001 to around 600 Mt in 2025, given an expansion in the energy system based on similar energy resources.

3.2 Non-energy emissions

Non-energy emissions, totalling 21.7% of total CO_2-equivalent emissions, originate from agriculture (43%), industrial processes (37%), and waste (20%). Non-energy agricultural emissions consist mainly of CH_4 emissions from livestock, which in South Africa are mainly kept in open range conditions with relatively low-quality diets, resulting in higher methane emissions (RSA 2004b: 19), and N_2O emissions from agricultural soils due to the use of manure and synthetic fertiliser (RSA 2004b: 21). Industrial processes, which mainly emitted CO_2, comprised cement (14% of non-energy CO_2 emissions), lime (5%), ammonia (7%), calcium carbide (<1%), iron and steel (64%), ferroalloys (9%) and aluminium (1%) production and soda ash use (<1%). Most emissions from waste consisted of CH_4 emissions from landfill sites and wastewater treatment facilities (RSA 2004b: 20).

4. South African energy and climate change policy and actions

4.1 The context of climate change policy in South Africa

The climate change policy domain is complex. While the focal point for climate change in South Africa is the DEAT, energy policy is the line function of the DME. Energy, as we have seen, is the main sector contributing to GHG emissions. A number of other departments are centrally involved in determining areas of policy (such as industrial policy) which will influence mitigation policies. We briefly outline the form which decision-making takes in the South African government, before discussing the broad policy context, and outlining climate and energy policy in more detail.

Governmental institutions in South Africa have undergone significant transformation since 1994. The current Constitution is based on an extensive Bill of Rights, including socio-economic rights (subject to a complicated process of interpretation by the courts) and three elected tiers of government (national, provincial and local). New provinces were created in 1994. Whereas there had previously been four provinces and many 'independent' or 'self-governing' 'homelands', nine provinces were now delineated and corresponding administrations established. Local government, previously organised along racial lines, was consolidated in an interim arrangement until 2000 when new authority boundaries were established. The two significant components of the national government are the executive, organised around the office of the president, and the civil service, consisting of government departments and associated institutions. Increasingly in the post-1994 government, the Presidency has played a dominant role in co-ordinating key policy development across departments through Cabinet 'clusters' (Cabinet subcommittees focused on specific areas of government), which are matched by similar clusters comprising senior civil servants of corresponding departments. Government departments, on the other hand, have maintained the same institutional structure inherited from the apartheid era, based loosely on the post-war UK civil service. However, they have undergone far-ranging changes in leadership, both for political reasons, and under post-apartheid affirmative action programmes (RSA 2001; Marquard 2006).

The climate change policy domain is structured around 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&China), and a commitment to rule-based multilateralism. Second, energy policy is the domain of the DME.

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.

Sustainable development policy is currently the subject of a consultation process. DEAT released a *Draft Strategy for Sustainable Development* at the end of 2006 for public comment. Coordination of this policy domain was allocated to the 'International Relations, Peace and Security' cabinet cluster in 2004, but this seems to have been mostly outward-focused (in relation to NEPAD) (IISD 2004). For instance, the recent decision announced by the Minister of Public Enterprise to proceed with the construction of a new nuclear power plant by Eskom was made outside the framework of the DME's first Integrated Energy Plan (DME 2003) (in which further nuclear power was not a viable option in the short term), and before the second Integrated Energy Plan was completed.

4.2 Links to energy and industrial policy

The government's 2004 *National Climate Change Response Strategy* prefaces its detailed list of measures with the proviso that '..it should be noted that, although DEAT may support the suggested measures in principle, much of the work comes under the jurisdiction of other national government departments, and within other spheres of government..' (DEAT 2004, p.22). This is possibly most true with respect to energy policy. Most mitigation options rest on the success of two energy policy initiatives. While the DME is the official custodian of energy policy in the country, in many instances the policymaking activities of other departments and spheres of government have a determinate effect. Three of these are particularly important: the Department of Trade and Industry (DTI), the National Treasury (NT), and the Department of Public Enterprises (DPE) have a significant impact on the formulation and implementation of energy policies. These three departments play a key, policy-determining role in the 'Economic cluster'.

While the DPE's infrastructure development programme (which includes ports, railways, power plants, transmission and distribution strengthening, and telecommunications) is premised on considerable expansion of the industrial base, the development of industrial policy itself provides a crucial context for energy policy and mitigation. Since industrial policy has been historically premised on energy-intensive industries, and the demand for electricity in particular, as well as bulk transport, is largely predicated on the number and size of energy-intensive industries in the economy. This context has framed the potential range of mitigation measures considered by policymakers.

The core goals of industrial policy since 1994 have been to meet key development goals by accelerating economic growth, largely through diversifying the economy (in structure, ownership and participation), and mitigating the impact of 'the apartheid government's support for large-scale capital-intensive industries, which, together with protection, led to poor productivity and competitiveness' (Roberts 2005, p.3). The apartheid government focused a co-ordinated effort on developing capital-intensive, usually resource-based and often strategic sectors such as mining, liquid fuels, beneficiation, defence and a cluster of related secondary industries, through a combination of protectionism, market regulation and direct state support and investment. The post-1994 government has promoted trade liberalisation (removal of tariff barriers), skills development, technological development, the development of small business, and more recently the provision of a range of incentives through financing by the state-owned Industrial Development Corporation[7] (IDC), and an Integrated Manufacturing Strategy (Roberts 2005). While the aim of the broad industrial and economy policy frameworks have been to diversify from the minerals-energy complex, the combined effect of non-targeted industrial policies, opening the economy, and the effectiveness of state agencies associated with the minerals processing sector in promoting new programmes has favoured the further expansion of the energy-intensive parts of the economy.

While the small business programmes have been relatively successful, however, the incentive programmes, coupled with the efforts of other state agencies connected to the minerals, energy and heavy industry sectors such as the IDC, Mintek[8] (which has promoted beneficiation), as well as the new openness of the economy, have promoted very significant developments in traditional energy-intensive, resource-based industries, who were best able to thrive in the globalised economy of the 1990s. State incentives have mainly been taken up by these industries. For instance, Sasol, the most energy-intensive liquid fuels producer in the world, alone accounted for four projects under the Strategic Industrial Projects incentive, which amounted to 24% of the available tax allowances (Roberts 2005). While other more employment-intensive industries such as textiles contracted as a result of the lowing of tariff barriers, energy-intensive industries were able to compete globally on account of low South African energy prices.

This trend was reinforced by IDC lending, which was largely allocated to the same kinds of projects, and by industrial development incentives such as the Coega port development in the Eastern Cape, which has managed to attract a number of energy-intensive projects, including a new aluminium smelter, subject to a long-term power supply agreement with Eskom. Trade liberalisation and economic openness also led to the 'internationalisation' of the South African minerals and beneficiation sector, which was inward-looking during apartheid. Large conglomerates such as Anglo American have diversified globally, and South African mineral assets (and processing) have been incorporated into multinational resource companies such as BHP-Billiton.

The current cycle of state-driven infrastructure development, specifically in electricity and transport infrastructure, is based on an expectation of more resource- and energy-intensive investments, which are further encouraged by two further factors. First, the DTI recently introduced a 'Developmental Electricity Pricing Programme', under which below-price electricity tariffs are negotiated with potential international investors in new energy-intensive projects. The aim of the incentive is to encourage investors who 'would in the absence of DEPP not invest in the Republic', by guaranteeing them (through lower electricity prices) 'an IRR that will ensure that the applicant will invest in South Africa' (DTI 2005). Second, the state is encouraging the development of beneficiation industries under its new mining policies, to add value to South African-produced raw materials, and is currently exploring ways to link beneficiation to mining licenses.

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[7] The Industrial Development Corporation is a state-owned enterprise which invests in key areas of the economy which that state regards as key development areas, later withdrawing when the enterprises concerned (or the sector as a whole) are regarded as competitive. Investments in the past have been mainly concentrated in the minerals processing and energy sectors, a trend which continues through the IDC's heavy investment in Eskom's nuclear reactor development programme.

[8] Mintek is a state institution associated with the Department of Minerals and Energy which researches and disseminates minerals processing technology.

4.3 The development of climate change policy

South Africa signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, and ratified it as a non-Annex 1 country in 1997, acceding to the Kyoto Protocol in 2002. Climate change-related policymaking began in earnest in the mid-1990s with the establishment of the Government Committee on Climate Change (GCCC), an interdepartmental committee consisting of representatives from key government departments (Agriculture; Science and Technology; Foreign Affairs, Health, Housing, Local and Provincial Government, Minerals and Energy, Trade and Industry; Transport), and a stakeholder group, the National Committee on Climate Change (NCCC), including the above government departments, some provincial and local government representatives, civil society organisations, labour and business, and major emitters of GHGs (particularly Eskom and Sasol). The NCCC was given a mandate by government to both 'express the concerns of key stakeholders' and 'to design and participate in a process leading to the formulation of a national climate change policy' (www.environment.gov.za).

In the late 1990s, the NCCC commissioned a Country Study as a basis for an Initial National Communication, which included a GHG emissions inventory and a range of studies on vulnerability, mitigation and adaptation. The Initial National Communication 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 main principle of the strategy was based on attempting a harmonisation between development challenges and climate change by integrating both into a sustainable development programme:

> The South African Government's national priorities include, inter alia, the creation of employment, the alleviation of poverty and the provision of housing, which implies a commitment to the process of sustainable development and advancement. Thus South Africa's position is to view climate change response as an opportunity for achieving these aims. (DEAT 2004, p.8)

The Strategy cites twelve 'key interventions', a mix of process-oriented measures (accessing funds, promoting education, training and awareness, maintaining presence at UNFCCC and related meetings, and setting a 'timeframe for action' for implementation of specific policies and measures), adaptation and mitigation policies and measures (DEAT 2004, p.vii). The former were aimed at the areas of South African society which were assessed by the Country Study to be most vulnerable, which were climate change-related threats to health, negative impacts on maize production, threats to plant and animal biodiversity, diminishing water resources and negative impacts on rangelands, and the latter was mainly based on implementation of the Government's 2003 *White Paper on Renewable Energy* and 2005 *Energy Efficiency Strategy*, as well as the protracted establishment of a CDM Designated National Authority in the DME. Seven of the 12 'key actions' are entirely dependent on other government departments and agencies for implementation (DME, DST, DTI, DWAF, DA, IDC, etc), which would require these departments to develop a specific capacity, estimated to cost around R5 million (DEAT 2004, p.6), which emphasises the critical role of co-ordination within the government, and particularly co-ordination with the Treasury, as a central requirement for implementation.

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 are being developed using energy and macroeconomic models to explore the consequences of various policy interventions aimed at reducing GHG emissions. The scenario process aims to inform a long-term climate policy.

4.4 Energy policies for sustainable development 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* and 2005 *Energy Efficiency Strategy*, which have been made key pillars of South Africa's climate change mitigation strategy. The 1998 White Paper focused on improving energy governance, the furthering of programmes to provide affordable energy to the poor, improving energy sector governance (including the introduction of integrated energy planning), addressing the environmental impacts of energy production and use, reform of energy markets, and emphasis on a demand-side approach to energy policymaking (DME 1998). However, the framework was weak on the details of specific measures. Lack of capacity in the DME, combined with changing priorities of the new government, have led to uneven implementation of the policy framework (Marquard 2006).

While the 1998 White Paper advocated a highly integrated, demand-side approach to energy policy making and implementation, emphasising transparency and public participation by contrast to the apartheid-era's legacy of secrecy and almost exclusive emphasis on the supply side, a number of factors have led to a narrowing of energy policy objectives between 1998 and the present. Priorities have focused more on post-1994 national development goals, including service delivery to poor households (primarily through the electrification programme), development of national infrastructure, security of supply, formalisation of regulatory regimes in supply sectors (rather than deregulation), and black economic empowerment.

The major demand-side initiative in the DME consists of the development of an Energy Efficiency Strategy in 2005, which set a target for national improvement in energy efficiency of 12% by 2015 (DME 2005). The target was based on reducing final energy demand against a baseline figure derived from a energy model constructed for the DME's 2003 Integrated Energy Plan. The target will be implemented according to a series of sectoral strategies. In the wake of the launch of the Strategy, a voluntary Energy Efficiency Accord was signed by the Minister of Minerals and Energy and 31 (later 37) businesses (primarily energy intensive industries and energy supply industries, but also a bank, a retail chain and the cement industry association), whereby the businesses committed to meeting the targets set out in the Strategy, with a higher target of 15% adopted by mining and industrial signatories. Accord signatories have established a Technical Committee to develop a detailed programme (NBI & DME 2005). The state has also established an Energy Efficiency Agency under the auspices of the Central Energy Fund, the state-owned company overseen by the DME which holds the state's energy sector assets.

Another focus of the DME's activity (and the best-resourced) is the electrification programme. The programme has been highly successful, and aims to electrify all households in South Africa by 2012. The programme is, however, not well integrated with policy initiatives for other household fuels, which are mainly handled by a different section of the department, and required reforms in the LPG industry have not taken place. The electrification programme includes a small off-grid programme based on PV technology. In order to encourage the use of electricity (in place of more dangerous and unhealthy fuels such as paraffin), the government has introduced Free Basic Electricity, whereby qualifying households receive 50kWh free per month; the programme has been successful in increasing very low consumption levels of poor households, and partially successful in displacing other energy carriers in households..

On the supply side, coal policy remains unchanged from its last significant reform in the late 1980s. The state actively promotes coal export and beneficiation, and the domestic coal market is not regulated. Most domestic coal is sold through long-term contracts to large users (of Eskom is the largest).

Ambitious plans for reform in the electricity sector include supply-side reform (breaking up Eskom into competing generation companies and a state-owned transmission company, introducing a market in generation), and restructuring the country's distribution assets into six Regional Electricity Distributors. Both supply and distribution reform have stalled, for a number of reasons. Supply industry restructuring lacked natural supporters and was opposed by Eskom and powerful national ministries, and was finally cancelled in 2004. The distribution industry restructuring has stalled under pressure from local authorities and the National Treasury, concerned about local authorities losing their ability to tax electricity.

However, an important post-apartheid development was the establishment of a national electricity regulator (in 1994), now merged with the Gas Regulator and the Petroleum Pipelines Regulator into a single National Energy Regulator. The plans for deregulation of the liquid fuels sector in South Africa were initially made contingent on the achievement of black economic empowerment targets, but these have largely been achieved, and there are no plans to deregulate the industry soon. The nuclear sector, contrary to its fortunes in the 1990s, when the new government regarded the whole nuclear programme as a legacy of apartheid, has undergone a renaissance. Eskom is developing an indigenous Pebble-Bed Modular Reactor (completion of prototype due in 2013) and also recently announced plans to build another nuclear plant in the interim, probably a similar plant to the two existing reactors at Koeberg in the Cape (French PWRs). Thus, energy supply sectors in South Africa are highly regulated, and renewable energy promotion policies and initiatives need to propose mechanisms to operate within these constraints. As a result, most of the current large-scale proposals are either directly promoted by the state or by an incumbent public or private enterprise.

The development of renewable energy (currently negligible) was the focus of a White Paper in 2003, the goals of which are modest: 10 000GWh of final energy demand to be produced from renewable sources by 2010, which is an average of around 1000GWh per year, which is 0.15% of total final energy demand in 2002. In order to achieve this modest aim, a number of 'strategic, goals, objectives and deliverables' was set out, which included financial and fiscal instruments, legal instruments, technology development, and 'awareness raising, capacity-building and education' (DME 1998, p.49-52). So far three concrete actions have been taken: 1) the establishment of a DNA in the DME; 2) the establishment of a modest capital subsidy programme for renewable energy projects (tens of millions of rands annually) in the DME; and 3) the establishment in the Central Energy Fund of the Energy Development Corporation in 2004, which invests in renewable energy projects.

4.5 Implementation of policy to date

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 incentivise 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 5MW facility on the West Coast, which is expected to be operational in June 2007. The project recently signed a power purchase agreement with the City of Cape Town. There are no other large-scale renewable energy initiatives under consideration for execution in the medium term, with two exceptions.

The first is a by-law proposed by the City of Cape Town, which should be enacted this year, to make solar water heaters compulsory on new residential properties over a certain value (to exclude poor households, which will continue to use electricity or other fuels for water heating).

The second is the DME's off-grid concession programme, under which private concessionaires install solar PV systems on households in isolated rural areas remote from the grid. The motivation for this programme is not climate change mitigation, however, and its impact on emissions is limited. Energy efficiency measures are largely being investigated through the voluntary National Energy Efficiency Accord between business and government; while promising, the initiative has not yet delivered measurable efficiency gains.

By contrast to other parts of the world (specifically Asia), there are relatively few CDM projects in South Africa. From inception in 2005, 37 proposals are pending, and six small projects have been registered, which together will reduce CO_2-equivalent emissions by 0.27 MT per year. Three are fuel-switching projects in industrial plants, switching from coal to natural gas or biomass; one plans to utilise landfill gas, and one is a small biofuels project. The last project is an innovative initiative in Cape Town, the Kuyasa project, which combines GHG mitigation with a number of sustainable development objectives by retrofitting low-income households with energy-efficient technology, including ceiling insulation, low-energy lightbulbs and solar water heaters (SSN 2004). The project has been implemented (with great success) on a very limited scale, since CDM funding only covers a fraction 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.

4.6 Public and private enterprise responses and actions

Publicly and privately owned companies are undertaking several initiatives with mitigation outcomes. These can be divided into several categories: energy supply measures, energy demand measures, and innovations such as green energy trading.

The two main actors involved in developing or deploying energy supply measures are Sasol and Eskom, the plants of which emit the largest portion of energy sector emissions. Eskom is currently conducting research on improving the GHG efficiency of coal-fired power plants, including exploring new coal-fired plant technology such as fluidised-bed combustion (Eskom 2000b). The utility also runs a research programme on large-scale renewable energy generation, the South African Bulk Renewable Generation project (SABRE-GEN), and has medium- to long-term plans for a 100MW wind facility and a solar-thermal power plant in the Northern Cape. As mentioned above, Eskom is also developing the PMBR and has recently announced plans to build another conventional nuclear power plant.

Both Sasol and Eskom are investigating carbon capture and storage potential in South Africa. In terms of emission sources, South Africa has significant potential for capture, in particular in the pure CO_2 streams (90-98%) already produced at Sasol. The largest volumes of CO_2 come from coal-fired power stations, but these are much lower in CO_2 content (10-15%) and require separation of CO_2 at significant additional cost (Engelbrecht *et al.* 2004). Storage poses more of a problem, since suitable geological formation in the area are of low permeability and porosity. Other options are being investigated, including exporting CO_2 to neighbouring countries with more favourable geology, ocean storage, and the use of CO_2 for coalbed methane recovery (Engelbrecht *et al.* 2004). If feasible, carbon storage could provide a transition to other energy resources. Sasol is also investigating various efficiency improvements to its plant, four of which are in the process of being registered as CDM projects. Various long-term possibilities are also being researched to replace some coal feedstock with natural gas or biomass.

There are three areas in which business is promoting energy efficiency initiatives. The first is the voluntary Energy Efficiency Accord (outlined above). The second is Eskom's Efficient Lighting Initiative (jointly funded by Eskom and the GEF), which promoted the use of energy-efficient lightbulbs, aims to install 18 million CFLs over 20 years, and was the largest energy efficiency programme in South Africa to date (Bredenkamp 2000; Eskom 1999), which translates into an estimated GHG emissions reduction of approximately 0.3 Mt tons of CO_2 over the period. The third is Eskom's national Demand-Side Management Programme, modelled on a highly-successful programme conducted in the Western Cape to avoid blackouts caused by regional constraints on electricity supply in the winter of 2006. The programme, involving a number of measures including distribution of free geyser insulation blankets, replacement of incandescent bulbs with CFLs, demand shifting and load shedding, and a publicity campaign, achieved load reduction of around 600MW a fraction of the cost of other supply-side alternatives. The national programme aims to reduce peak demand by several GW. The significance of the Western Cape programme was that it starkly demonstrated the speed, effectiveness and affordability of energy efficiency measures.

Another promising, but limited development of the last five years in South Africa has been the establishment of a fledgling market in 'Green Electricity': A company trading 'tradeable renewable energy certificates' (TRECs) was established in 2003 (see www.greenxenergy.com/). TRECs could be used to meet companies' renewable energy targets, and demonstrates a commitment to minimizing environmental impact and develop labour-intensive energy sources. Green electricity is generated with technology that minimises the impact on the environment and which uses primary energy sources (fuel) that are renewable. The TRECs constitute trade in 'green electricity', *not* in carbon credits per se. 845 MWh of 'green electricity' were supplied to the World Summit on Sustainable Development in Johannesburg. Beyond WSSD, NERSA has indicated a commitment to regulating the development of a green electricity market. Several companies and government agencies have already listed on NERSA's web-site (see www.ner.org.za/gwatts/green_watts_certificates.htm), although the abortion of the introduction of an electricity market probably requires a new institutional framework, since under the current framework Eskom is not obliged to 'wheel' power.

4.7 Civil society initiatives on energy and climate change

The involvement of civil society organisations in climate change policy processes and mitigation has mainly consisted of participation in national policy forums, advocacy and research, and implementing small-scale demonstration projects. Whereas trade unions have been involved in national forums (mainly to express concerns over potential job losses), environmental organisations have been consistently involved in national debates and in policy advocacy and research, and have also developed links with international networks such as the Climate Action Network to lobby for faster mitigation action and higher targets for renewable energy. Civil society representatives have also formed part of the country's negotiating team at international climate meetings since 2003.

5. 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.

5.1 Key areas for mitigation options in South Africa

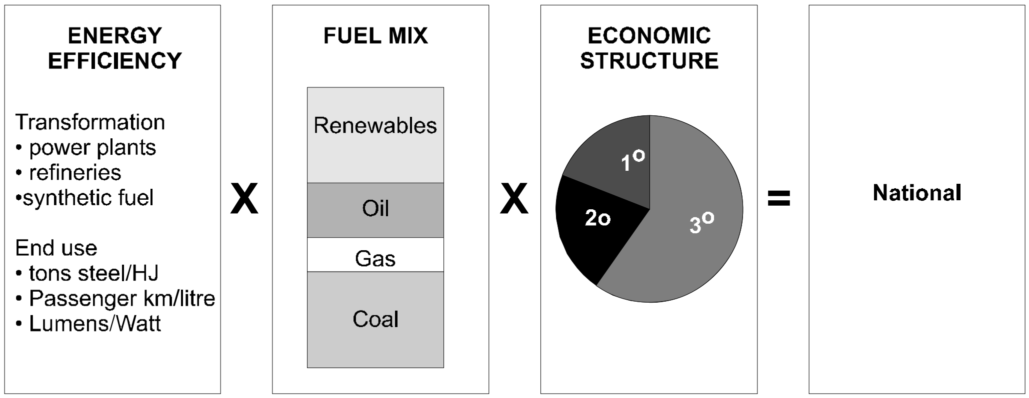
Mitigation options in South Africa can be divided into three broad categories: energy efficiency (which reduces demand for energy, or uses it more efficiently for the same service); changing the fuel mix (moving to lower or non carbon-emitting energy sources); and structural changes to the economy, which 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 4 below.

The categories also relate broadly to timescale and certainty of outcome.[9] 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 life-times 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

[9] 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.

tertiary sectors (Schäfer 2005), it is not clear to what extent this is influenced by policy. As indicated by Figure 1 above, 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 SA economy did shift towards less emissions-intensive sectors , the implications for mitigation would be profound.

Figure 4: Three broad areas for mitigation



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 (Meinshausen 2005; ISSC 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 to 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 Initial National Communication (RSA 2004). The reference case was broadly consistent with government plans, such as the Integrated Energy Plan (whole energy sector) (DME 2003) and the National Integrated Resource Plan (electricity) (NER 2004b). Officials expansion plans continue to be based primarily on coal-fired power, with new diesel-drive gas turbines and pumped storage for electricity peaking. Carbon 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).

5.1.1 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, reduce emissions by 44 Mt, 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.[10] Because of rising electricity prices (due to construction of new plants) during the period, energy efficiency investments become more attractive later in the period.

[10] 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.

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, p.161-163, 176).

A 'cleaner and more efficient residential energy scenario', involving energy-efficient housing shells, efficiency interventions such as deployment of CFLs and geyser insulation blankets, 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 transformation technologies (the efficiency of converting coal into electricity or liquid fuels), in particular in the synthetic fuels plants. In the latter case, small-scale interventions have 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. 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.

5.1.2 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 1300MW. The second source is the Inga Falls on the Congo River in the Democratic Republic of Congo, which could potentially provide from 40 000 to 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 4500MW 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 ¾ of this target will now be met through biofuels.

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 30Mt. 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 improvement, 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 40Mt 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.

5.1.3 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 involve 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.

Measures aimed at lowering the energy intensity of the industrial sector, other than through improving efficiency of existing processes, would involve addressing the problem of the large proportion of energy-intensive industries in the composition of the country's industrial sector (over 45% in 1991 in South Africa's case (DME 2002a)). Most of these industries were established as a result of investment decisions (often with considerable incentives from government) made in the last 40 years, primarily on the basis of low energy prices, which is the basis of South Africa's international competitiveness in the minerals beneficiation and processing sector. In addition to this, the mining sector is inherently energy-intensive, especially deep-level gold mining. While some minerals processing operations beneficiate locally-mined minerals and provide local inputs (for example iron and steel, coal, ferrochrome etc), others are based in South Africa primarily because of the country's low electricity prices. The best example of this is the aluminium processing industry, which imports all its feedstock from elsewhere, and exports most of the final product; aluminium smelting in South Africa is thus really another form of coal beneficiation or electricity export.

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. Furthermore, future mitigation-linked energy price rises in other (particularly industrialised) countries will enhance this competitive advantage, especially given the growing demand for commodities from the Asian economies. In addition to this, current minerals and industrial policies encourage foreign investment in energy-intensive minerals processing industries, usually under long-term price compacts, but also under industrial development incentives linked to spatial development initiatives such as the Coega[11] project. However, investments in these industries do not occur incrementally, but tend to be based on mega-projects involving a handful of investors. Thus, decisions to invest are usually based on lengthy negotiations with government and Eskom, and thus tend to be directly related to industrial policy initiatives, and the state's willingness, usually on a case-by-case basis, to facilitate the projects through its agencies, and provide the necessary incentives and infrastructure. Since these investments (made in plant which has a 20-40 year lifespan) are made on the basis of low and very stable energy prices, and since most of the output is traded in the international market, there is a very high sensitivity to energy price rises.

What interventions might shift the South African economy to less emissions-intensive sectors? Making policy proposals in this area is very difficult due to the complexity of the question under consideration, but we propose that the strategies which follow might form a useful part of a more ambitious mitigation programme for South Africa. 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. At the same time, the strategies would aim to identify parts of the economy which are not as sensitive to energy price rises, and pursue more aggressive mitigation options in these.

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. While this coincides with the broad tenor of current industrial policy (but not necessarily of public investment), it would require adjustments in the way policies are implemented, and the inclusion of GHG mitigation criteria in incentive programmes.

The second strategy would involve the application of a much more rigorous mitigation programme to the non-energy-intensive[12] section of the economy, since the international competitiveness of this part of the economy would not be significantly affected by higher energy prices, which would be ameliorated by energy efficiency improvements in the medium term. The costs of switching to low-carbon fuels could be allocated disproportionately to this section of the economy, which would also boost investments in energy efficiency. The aim of this strategy would be to insulate the non-energy intensive section of the economy from the

[11] Government agencies are developing a new deep-water port in the Easter Cape province, and set out to attract large industrial anchor tenants. So far, they have succeeded in attracting a new aluminium smelter, which will add several hundred MW of electricity demand, and require strengthening of the local power grid.

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

long-term effect of low energy prices, and thus encourage a significantly higher investment in energy efficient technology and design. An exception would be low-income households – policy would have to ensure that safe and adequate energy services were delivered at an affordable cost, which might include state (or other agency) subsidised energy efficiency measures.

The third strategy would be to encourage a shift to another area of competitive advantage with low-carbon characteristics, which makes use of local resources. One of the best prospects is a solar thermal energy industry, since South Africa has some of the best solar resources in the world. In the same way that Demark became a world leader in wind technology, South Africa could become a world leader in solar thermal technology, with the right supporting measures. These would be a combination of measures, including the creation of a local market (commitment by Eskom and IPPs to commission a certain number of plants), state incentives and support (including technology support and public investment), and risk-sharing with international partners, either from the private sector, or through multilateral agencies. The South African state has a long history of supporting and developing new energy technologies to meet national goals, the most recent example of which is the PBMR. A similar level of public funding for solar thermal technology could establish a significant programme.

The fourth strategy would aim to reform the energy-intensive sector itself, by gradually reducing its energy intensity while protecting employment and existing investment. There are four parts to the strategy:

- The first would reconsider the current beneficiation-promotion strategies in terms of energy intensity: while further beneficiation increases the value of primary minerals production (and thus cuts imports and boosts exports), sometimes quite dramatically, it also leads to further energy costs; furthermore, higher levels of beneficiation also tend to create opportunities for less capital-intensive employment generation. While beneficiation often leads to increased energy intensity, in some cases the added value of the beneficiated products outweighs the additional energy use, and the energy intensity of the economy would decrease. Thus, by targeting beneficiation policies accordingly, the economy could be moved to a lower energy intensity, and more employment would result.
- The second would consist of higher energy efficiency targets negotiated with specific energy-intensive industries, to lower energy intensity faster in the short and medium term.
- The third would consist of an initiative in international climate change forums to explore the future of energy-intensive industries, which might include a short- or medium-term international carbon tax, or a long-term global strategy for locating these industries.
- The fourth strategy would examine the possibilities of resource companies shifting from an emphasis on resource extraction to materials provision, which would include a shift to recycling, producing biomaterials, and investigating new material-related technological possibilities.

A final economy-wide strategy might include a tax on energy use: a tax equivalent to R50/ton of coal would mitigate 28 Mt of CO_2 over a 20-year period and add a mere R23 million cost to the reference case (Winkler 2006). An alternative cap-and-trade system (fixed quantities) (Weitzman 1974) might be difficult to implement in developing countries like South Africa, which have large opportunity costs to spending money on climate change – notably spending it on development. Yet it might be possible to introduce cap-and-trade systems that mix the regulation of quantities of GHG emission with using economic instruments (tradeable permits) to meet that objective cost-effectively. One early assessment of domestic emissions trading was conducted for South Africa (Blignaut 2001), but has thus far not been pursued in policy circles.

5.2 Key constraints

Unlike many developing countries, South Africa does not suffer 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, in both the development of a large-scale synfuels programme in the 1960s and 1970s, and the massive electrification programme of the 1990s, technological innovation was rapid and effective, and the programmes were financed in a number of innovative ways. Instead, constraints lie elsewhere. We have considered three types of constraints in this section: first, constraints created by low energy prices, which are probably the most fundamental constraints to more extensive renewable energy and energy efficiency programmes; second, technological capacity; and third, constraints arising from current structures of institutions and policy domains.

5.2.1 Prices, markets and regulation

As we have pointed out above, low energy prices, and particularly low electricity and coal prices, are a major barrier to investment in renewable energy and energy efficiency. While coal prices are low primarily because of the favourable geology of coal deposits, electricity prices are currently below marginal cost, since current capacity was effectively paid for by electricity consumers in the 1970s and 1980s. Moreover, as a parastatal for most of its existence, Eskom did not have to pay tax and dividends, and was the recipient of other indirect subsidies, such as insurance by the country's Reserve Bank against currency depreciation in the 1980s and early 1990s; (the estimated benefit to Eskom was R22 579 million between 1986 and 1998 (Steyn 2000: 7)); in combination these contributed to significant allocative inefficiency (Roberts 2005). Even with this windfall, Eskom's debt burden was high in the 1980s, but since the early 1990s, Eskom has been able to reduce its debt-equity ratio[13] (due to very few demands for further capital expenditure) and price electricity at a very low marginal cost (Van Horen & Simmonds 1998; Davis & Steyn 1998; Eberhard 2000). Eskom's high debt-equity ratio in 1986 at 2.93 declined to 0.85 in 1998 (Steyn 2000), and was reduced further by 11.5% per year to 0.63 in 2000 (Eskom 2000a). In a commercial firm, lower debt repayments would have been replaced by higher payments of dividends to shareholders, but this did not happen in the case of Eskom until after 2001. With the capital costs of power plants having been paid off by consumers and others in the 1970s and 1980s, consumers are currently paying only for coal and distribution costs. 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, nor are externalities priced.[14] While electricity prices will rise in the near future due to new plant construction, consumers will only pay the average cost of electricity production, and thus pricing below marginal cost will persist for a number of years, deterring investments in energy efficiency, and leading to a significant price gap between existing coal-fired power and alternative options, such as renewable energy and energy efficiency options.

While mechanisms such as the CDM can make an important contribution by overcoming this price gap in certain cases, other more creative measures are required, possibly including multilateral financing. Positive incentives need to be put in place to promote the deployment of climate-friendly technology in countries like South Africa. This could take the form of development assistance, but larger flows are likely to be in foreign direct investment. South African enterprises, such as Eskom and Sasol, are capable of raising significant capital at very low cost (Eskom has its own treasury, and issues bonds which have a higher rating than those of the South African government), but might look for risk-sharing agreements to invest in unfamiliar technologies. This might be relevant in South Africa particularly for technologies proven at large scale, but not yet fully commercialised.

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[13] 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 finances from retained earnings.

[14] South African power plants are not equipped with scrubbers to remove SOx and NOx gases.

Another constraint to investment in renewable energy is a lack of clear rules for market access by independent power producers interested in entering the renewables market (including industrial users interested in investing in cogeneration plants). Whereas in many other countries there are regulations which specify the conditions under which independent producers can sell power to the incumbent utility (and the price they might receive for it), or wheel it through the transmission grid to a third party, no such regulations or obligations exist in South Africa yet, thus creating significant uncertainty for potential investors.

5.2.2 Technology support and development

While South Africa has an impressive array of technological resources, it lacks specific technological capacity in many areas of energy efficiency and renewable energy technologies. A Technology Needs Assessment for mitigation measures is currently being carried out for the Department of Science and Technology. It is also possible that technology transfer could be facilitated through a multilateral technology transfer facility. While many technologies are successfully transferred by private companies through the market, there are certain types of market failure which such a facility could help overcome.

5.2.3 Institutions and policy frameworks

The main constraint in this section is the problem of policy co-ordination. While the climate change policy process so far has been very open, involving a wide range of government departments and stakeholders, it has developed very slowly, and there are many problems in reconciling climate change policies with policies in other sectors of government. Seeing climate change policies as part of a broader programme in sustainable development does help to address this problem. Yet there is still a significant gap between development and sustainable development. There is a surprisingly large area of common ground between the government's general development framework (AsgiSA) and the type of sustainable development measures which would contribute to GHG mitigation. Currently, most expertise in government on climate change is located in the DEAT, but it also needs to shift into the line-function department most affected, the DME. To effectively address development, climate policy needs to move onto the agendas of the economic cluster of departments. (the National Treasury, the Department of Trade and Industry, and the Department of Public Enterprises). As heads of state become involved in climate negotiations, this shift needs to continue into the President's Office. One of the ways in which this constraint could be addressed would be to use international funding to fund the appointment of dedicated climate change policy personnel in the Presidency. Given the important role that the Presidency plays in co-ordinating national policy, this would be a stepping stone to addressing institutional and policy constraints in other areas (such as energy market structure) in more detail.

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

There are three areas in which international co-operation would enhance the implementation of mitigation policies in South Africa: finance, technology and capacity-building. Since Annex II Parties to the UNFCCC undertook in Article 4.3 to 'meet the agreed full incremental costs' of a range of measures undertaken by developing countries (UNFCCC 1992), including activities in these three areas, a range of creative options could be developed to marry these obligations with international co-operation in these areas. The first addresses the problem of 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, as well as establishing a Multilateral Technology Acquisition Fund. Mobilizing funds for low-carbon technology in long-life infrastructure investments is central to the question of who will 'buy down' the costs of low-carbon technology. If it were structured to leverage private investment as well, funding could be channeled through a Multilateral Technology Acquisition Fund or similar instrument. Concessionary finance might be sufficient in middle-income countries like South Africa, whereas poorer countries might require direct funding.

The second involves technical co-operation. 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, and developing international technology standards and research and development protocols. Inter-governmental agreements could be facilitated to enable access to commercial technologies whilst respecting property rights, and such a facility could act as an exchange facility for information on the development and deployment of viable technological solutions in developing countries, thus promoting South-South technology transfer. 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.

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, seconding of experts to key strategic points in government, and funding specialised agencies or posts, as well as the facilitation of South-South exchanges on innovate policies and measures.

6. 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. Moving to a low-carbon economy in this context poses particular problems: the existing development path is energy-intensive 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 is very price-sensitive, and thus resistant to changes to a low-carbon economy. While current government policy has embraced sustainable development goals, the country is to a large degree locked into an energy-intensive development path and continues to provide significant incentives for investment in energy-intensive industries. These industries are still an important source of employment, investment and wealth for the country.

Some start has been made in developing climate policy and integrating aspects in energy policy. Notably, the country has a target for renewable energy and an energy efficiency accord. Yet emission continue to rise. The challenge is to bend the curve of rising GHG emissions downwards, while making development more sustainable.

The most effective and most 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 often significant benefits. The next strategy would be to change the fuel mix, notably to reduce the three-quarter share of coal in 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.

Perhaps the most long-term challenge is a move towards a low-carbon economy. 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.

References

ANC (African National Congress) 1994. The Reconstruction and Development Programme: A policy framework. Johannesburg, Umanyano.

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.

Blignaut, J 2001. Domestic pollution permit allocation regimes. Study for the ATRIP project on the Clean Development Mechanism and future emissions trading regimes: Economic opportunities for South Africa. Cape Town, Energy & Development Research Centre, University of Cape Town.

Borchers, M, Qase, N, Gaunt, T, Mavhungu, J, Winkler, H, Afrane-Okese, Y & Thom, C 2001. National Electrification Programme evaluation: Summary report. Evaluation commissioned by the Department of Minerals & Energy and the Development Bank of Southern Africa. Cape Town, Energy & Development Research Centre, University of Cape Town.

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

Bredenkamp, B 2000. Lower costs for efficient lighting technologies expected. *Energy Management News* 6 (4): 50-51. December.

Davis, M & Steyn, G 1998. *Electricity in South Africa*. London, Financial Times Energy.

DEAT (Department of Environmental Affairs and Tourism) 2004. A national climate change response strategy. Pretoria.

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

DME (Department of Minerals and Energy) 1998. White Paper on Energy Policy for South Africa. Pretoria, DME. http://www.dme.gov.za.

DME (Department of Minerals and Energy, Energy Research Centre, Eskom) 2002a. Energy Outlook for South Africa: 2002. Pretoria.

DME (Department of Minerals and Energy) 2002b. South Africa National Energy Balance 2000. Pretoria, DME.

DME (Department of Minerals and Energy) 2003. Integrated energy plan for the Republic of South Africa. Pretoria. www.dme.gov.za.

DME (Department of Minerals and Energy) 2004. South Africa National Energy Balance. Pretoria, DME. http://www.dme.gov.za/energy/pdf/Aggregate%20balance%202001.pdf.

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

DTI (Department of Trade and Industry) 1996. Growth, Employment and Redistribution: A macro-economic strategy. Pretoria.

DTI (Department of Trade and Industry) 2005. Developmental Electricity Pricing Programme. Pretoria. http://www.dti.gov.za/publications/2006_11_17_DEPP.pdf.

Eberhard, A 2000. Competition and regulation in the electricity supply industry in South Africa. Paper for the Competition Commission. University of Cape Town.

Engelbrecht, A, Golding, A, Hietkamp, S & Scholes, R J 2004. The potential for sequestration of carbon dioxide in South Africa. Report for the Department of Minerals & Energy. Pretoria, Council for Scientific and Industrial Research.

Eskom 1990. Annual Report 1990. Sandton, Eskom.

Eskom 1999. Business plan for the Efficient Lighting Initiative. Sandton, Eskom.

Eskom 2000a. Annual Report 2000. Sandton, Eskom. www.eskom.co.za.

Eskom 2000b. Environmental report 2000: Towards sustainability. Sandton, Eskom.

Fine, B & Rustomjee, Z 1996. *The political economy of South Africa: from minerals-energy complex to industrialization*. London, C. Hurst.

Hughes, A, Howells, M & 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. Pretoria, Department of Minerals & Energy. http://www.dme.gov.za/energy/efficiency_projects.stm.

IISD (International Institute for Sustainable Development) 2004. South Africa Case Study - Analysis of National Strategies for Sustainable Development. Winnipeg, Canada. http://www.iisd.org/measure/capacity/sdsip.asp.

IPCC (Intergovernmental Panel on Climate Change) 1996. Revised 1996 guidelines for national greenhouse gas inventories. Paris, Organisation for Economic Co-operation and Development.

ISSC (International Scientific Steering Committee) 2005. Avoiding dangerous climate change: Executive Summary. Scientific symposium on stabilisation of greenhouse gases, 1-3 February, Exeter. Exeter, UK, Department of Environment Food and Rural Affairs, UK. http://www.defra.gov.uk/environment/climatechange/internat/dangerous-cc.htm.

Lloyd, P J D 2005. Personal communication. Honorary research fellow, Energy Research Centre.

Mako, P F & Samuel, W A 1984. The Sasol approach to liquid fuels from coal via the Fischer Tropsch reaction. Chapter 2.1. R A Meyers (Ed). *Handbook of Synfuels Technology*. New York, McGraw-Hill.

Marquard, A 2006. The Origins and Development of South African Energy Policy - Unpublished Ph.D Thesis. Energy Research Centre. Cape Town, University of Cape Town.

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

NBI & DME (National Business Initiative & Department of Minerals and Energy) 2005. Energy Efficiency Accord. Pretoria. http://www.nbi.org.za/welcome.php?pg=122.

NER (National Electricity Regulator) 2002. Electricity supply statistics for South Africa 2002. Pretoria, NER. www.ner.org.za/publs.htm.

NER (National Electricity Regulator) 2004a. Electricity supply statistics for South Africa 2004. Pretoria, NER. www.ner.org.za/publs.htm.

NER (National Electricity Regulator) 2004b. National Integrated Resource Plan 2 (NIRP2) 2003/4. Pretoria, National Electricity Regulator. www.ner.org.za.

Roberts, S 2005. Industrial development and industrial policy in South Africa – a ten year review. South African Economic Policy under Democracy: a 10-Year Review, University of Stellenbosch.

RSA (Republic of South Africa) 2001. Democratic Governance - A restructured Presidency at work. Government Communication and Information Services.

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. unfccc.int/resource/docs/natc/zafnc01.pdf.

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

SSA (Statistics South Africa) 2003. Census 2001: Investigation into appropriate definitions of urban and rural areas for South

Africa: Discussion document. Statistics South Africa.

SSA (Statistics South Africa) 2006. Mid-year population estimates, South Africa. Statistical release P0302. Statistics South Africa.

SSN (SouthSouthNorth) 2004. Project design document for the Kuyasa project. Submitted to the Executive Board of the Clean Development Mechanism. http://cdm.unfccc.int. Cape Town, SouthSouthNorth Project. www.southsouthnorth.org.

Stern Review (Stern review team) 2006. What is the economics of climate change? London, Treasury.

Steyn, G 2000. A competitive electricity market for South Africa: The need for change and a strategy for restructuring South Africa's electricity supply industry. Pretoria, for the Department of Minerals & Energy.

Tinto, E 2003. Sustainability issues in the restructured electricity supply Industry. *Journal of Energy in Southern Africa* 14 (1).

UNDP (United Nations Development Programme) 2006. Human Development Report 2006 - Beyond scarcity: power, poverty and the global water crisis. New York.

UNFCCC 1992. United Nations Framework Convention on Climate Change. New York, United Nations. http://unfccc.int/resource/conv/index.html.

Van der Merwe, M R & Scholes, R J 1998. South African Greenhouse Gas Emissions Inventory for the years 1990 and 1994. Pretoria, National Committee on Climate Change.

Van Horen, C & Simmonds, G 1998. Energy efficiency and social equity: seeking convergence. *Energy Policy* 26 (11): 893-903. September.

Weitzman, M 1974. Prices vs Quantity. *The Review of Economic Studies* 41 (4): 477-491.

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. Cape Town, Energy Research Centre. www.erc.uct.ac.za/publications/Energy%20policies%20for%20SD.pdf.