OVERVIEW OF THE SOUTH AFRICAN COAL VALUE CHAIN

PREPARED AS A BASIS FOR THE DEVELOPMENT OF THE SOUTH AFRICAN COAL ROADMAP

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SYNTHESIS

The South African Coal Roadmap (SACRM) process

The need for a Coal Roadmap for South Africa was identified in 2007 by key role players in the industry, under the auspices of the Fossil Fuel Foundation (FFF). The FFF, coal producers, Eskom and the Department of Minerals and Energy (DME) were amongst the originators of the project. A project plan and initial terms of reference were prepared, along with a proposed structure and governance documents. In November 2008, the project was “launched” at a stakeholder meeting in Johannesburg. An “Interim Board” was established in April 2009, but without a representative from the South African Government, due to the impending reorganisation of the DME into two ministries (Energy and Mineral Resources). In March 2010 the Department of Energy (DoE) formally (re) joined and the initiative was formalised - contributions were requested from participants, enquiries issued for the project management role and a project manager appointed in June 2010. The Department of Mineral Resources (DMR) also subsequently provided its support, along with a wide range of other stakeholders. The budget for the initiative was limited to voluntary contributions from a small number of members and although it was inadequate to cover the total cost of the project, it was decided to commence with “Phase I”. This was to comprise a summary or fact base of the current state of the SA coal industry and key issues facing it – and a description of a future “business as usual” scenario. Phase II, still to be funded, was to look at alternative scenarios and develop a “roadmap” to enable the preferred outcome to be realised.

It had been intended that most information for the fact base be provided by participants via questionnaires and facilitated workshops. This process did not, however, yield the desired level of information and it was necessary to supplement this by specific meetings with individual stakeholders. Other constraints included the lack of updated resource and reserve information on coal in South Africa – the Council for Geoscience is simultaneously concluding work in this area. At the same time, the future generation mix in South Africa was under review and following a consultation process, the Integrated Resource Plan (IRP2010) was promulgated in May 2011. This plan and the degree to which it is implemented will have a defining impact on future domestic coal requirements. A proposed carbon tax and a white paper on climate change also changed the outlook for the power generation and coal to liquid (CTL) industries. Given these key uncertainties, it was decided not to produce a “business as usual” outlook for the South African coal industry but rather to propose three divergent scenarios as a basis for further examination in Phase II.

Perhaps because of these challenges and the lack of an organised coal association, a key aspect of the SACRM process has been the degree of participation that the initiative has generated. This can be observed by the extensive list of organisations making up the SACRM membership. For the first time, a forum has been created in South Africa which enables a wide range of stakeholders to discuss the future of the industry. The fact that at this stage in the process Phase I does not provide any clarity on the outlook for the South African coal industry is offset by the constructive process which has been initiated, which augurs well for the successful development of a South African Coal Roadmap in Phase II.

Aim of the South African Coal Roadmap study

The South African Coal Roadmap study was initiated with the following aims:

- To understand the value of coal to the South African economy;
- To provide independent and impartial analyses and comment on the various national and international drivers that may impact on the supply and utilisation of coal going into the future;
- To understand the primary factors required for the successful development of various future coal related opportunities, including economic enablers and skills development;
- To provide guidance on issues of governance, enabling policy framework, research and development, private sector and infrastructural investments and opportunities for social investment.

The South African Coal Roadmap Study consists of two phases: Phase I develops a status quo assessment and identification of possible future scenarios, and Phase II will include a detailed scenario analysis to define the roadmap. The outcomes of Phase I are presented in two parts. One document presents a comprehensive status quo assessment of all the elements of the South African coal value chain. A second document identifies three scenarios which are being explored as part of the overall study. In Phase II the scenarios will be analysed in more detail, to provide a semi-quantitative assessment of their implications for the coal value chain and South Africa more broadly. The outcome of Phase II will be a “roadmap” of a preferred path for the coal industry in South Africa.

The role of coal in the South African economy

Coal is the major primary energy source for South Africa. More than 90% of the country’s electricity, approximately 30% of the liquid fuel, and approximately 70% of its total energy needs are produced from coal. Coal also plays a significant role in supply to the South African chemicals industry, is an essential component of its steelmaking industry and provided R 35.4 billion in export revenues. Coal and platinum have exchanged the top positions by sales value of South Africa’s resources for the last two years (coal R 69.5 billion in 2010).

South Africa produced 244.6 Mt of marketable coal in 2010, which is expected to have increased to around 255 Mt in 2011. South Africa’s total coal exports were 67.6 Mt in 2010 with 63.4 Mt through Richards Bay Coal Terminal (RBCT), 1.8 Mt through Matola Coal Terminal in Mozambique and...
small amounts through Richards Bay and Durban harbours. Domestically, coal is used primarily to produce electricity by Eskom and liquid fuels and chemicals by Sasol. Other smaller users include the iron and steel, ferroalloys, industrial and manufacturing sectors.

The South African coal mining sector directly employed 73,618 people and paid R 14.1 billion in wages in 2010, which constituted 14.4% of total wage income (2009) in the mining industry as a whole (Chamber of Mines, 2011a). Employment down the value chain is also significant: at the end of the 2009/10 financial year Eskom reported that it had 36,547 direct employees (Eskom, 2010a) and Sasol directly employed 28,978 people in its South African operations at the end of the 2010 financial year (Sasol, 2010a). Both of these enterprises depend on coal for the bulk of their primary inputs. Direct employment by coal mining, Eskom and Sasol is therefore more than 139,000, with many more indirect employment numbers. In 2009, the coal mining sector accounted for about 1.8% of GDP directly, or 4.5% if indirect multipliers are added (StatsSA, 2010).

South Africa has an estimated 32 billion tonnes of coal reserves¹, with a study being conducted in parallel with this one seeking to update this reserve base. Approximately 70% of these resources are found in the Waterberg, Witbank, Highveld and Ermelo coalfields, with the remainder in the Sasolburg, Free State, Springbok Flats and other smaller fields.

Given existing and planned power generation expansion in the country, domestic coal demand is expected to grow, at least within the short to medium term. In line with the promulgated IRP2010, Eskom’s demand is projected to increase by about 40% to 2020. Analysis of these enterprises and new projects indicates potential increase in South African coal production to 319 Mt by 2015, and 359 Mt by 2020 (Wood Mackenzie, 2011a).

Global coal trade is also set to grow significantly during the next two decades. Absolute growth in coal consumption continues to substantially exceed all other energy sources. Coal accounted for nearly 30% of world energy consumption in 2010, its highest share since 1970, while its share is now over 70% in China and nearly 53% in India. According to IEA figures, coal consumption has grown over 4.8% per annum on average over the last ten years (7.6% in 2010, while both China and India increased coal consumption by over 10%). Current forecasts are of energy demand growth of around 50% and electricity demand growth of around 85% to 2035 (IEA, 2010a; US EIA, 2011). Reflecting these increases, over the last 10 years, seaborne thermal coal trade has increased by 75%, showing average growth of 26 Mt a year. Nevertheless, over this period, South Africa’s coal exports have stagnated (RBCT exports in 2000 were 66.9 Mt, vs 63.4 Mt in 2010). Seaborne coal demand is expected to grow at a 5.8% compound annual growth rate (CAGR) over the next twenty years reaching 2.1 billion tonnes by 2030. This represents an increase of 1.4 billion tonnes over 2011’s expected 728 Mt (Wood Mackenzie, 2011b).

South Africa’s potential for increased export is dependent on having sufficient production capacity for coal, the necessary transport infrastructure becoming available, and encouraging foreign investment into coal mining through provision of a suitable policy and financial environment. If South Africa does not take the required measures, it may miss out on the potential economic benefits of this boom in much the same way that it missed out on the commodity and energy booms of 2000 to 2009. In South Africa, there is synergy in the degree of beneficiation undertaken to provide export quality coal on the one hand and the lower grade coal suitable for domestic use in existing power stations and in Sasol’s Fischer-Tropsch process on the other. It is expected that a number of planned new mines could not be viable if producing only one of the two products. Therefore, to some extent, the export market is required to create the product for Eskom consumption and vice versa.

Certain developments in 2011 have been very relevant for the coal industry in South Africa. The electricity plan for the country to 2030 (the IRP2010) was recently promulgated in the absence of any master energy plan for the country. The National Climate Change response strategy green paper has given a clear indication of government’s commitment to reduce carbon emissions from industry. Significantly, the National Planning Commission (NPC) expressed the following view on coal:

“While most of South Africa’s energy comes from coal, it is striking that government has no integrated coal policy. South Africa ranks fifth internationally as a coal producer and exporter, yet government has no clear export strategy. There is also no integrated development of mining, rail and port infrastructure to facilitate either exports or anticipated increases in local production and consumption, within acceptable environmental constraints. The private shareholders of the Richards Bay Coal Terminal have expanded export capacity to 91 million tons per year. However, Transnet has barely been able to transport 60 million tons per year from the central coal fields to the coast. Government urgently needs to bring together all relevant players (mining companies, Transnet, Richards Bay Coal Terminal, relevant government departments, banks and others) to forge an agreed investment strategy and plan to accelerate coal exports, which could have beneficial balance of payment and current account impacts. An expanded export drive would need to be framed within a national policy on the optimal use of depleted coal reserves, including secure supplies for legacy power stations, and the opening of the Waterberg with the required rail links. The private sector has initiated work on a Coal Road Map. Government needs to be an active partner” (NPC, 2011:18)

It is thus important that South Africa maximises the value to society from the production and use of coal while at the same time minimising any negative impacts.

While the current contribution of the coal value chain to the South African economy in terms of employment, income, energy supply and contribution to GDP, coupled with South Africa’s significant coal resource, demonstrates a strong potential for continued economic benefit and energy security, there are a number of challenges to the value chain which will shape its future. Not the least of these is the climate change agenda which is increasingly shaping the global energy space. Other challenges include water, infrastructure, investment and institutional constraints.

Critical challenges for the coal value chain

A number of critical challenges to the value chain were highlighted during the course of compiling this status quo assessment. Some of these are as follows:

A unified, overarching country vision for the coal value chain is required to support the development of individual components of the coal industry
- The coal industry already contributes significantly to South Africa’s economic base. South Africa needs to balance and synergise its objectives of societal transformation, economic growth and development, and environmental protection. The purpose of the South African Coal Roadmap study is to begin to develop a strategy and vision for the coal value chain that contributes to the country meeting these objectives.
- The extent to which coal is exported or used domestically is dependent on many factors and requires consistency across policy areas.
- Without a unified government vision for the cleaner and more efficient exploitation of coal, the need to mitigate climate change is in conflict with the continued exploitation of South Africa’s coal resources in its current form.
- The development of the Waterberg coalfield, which is targeted for large-scale development due to declining resources in the Mpumalanga basin, faces various challenges in the form of water availability, lack of transport infrastructure, the need for a large capital base to mine technically difficult resources, the requirement of a market for a multi-product offering, and the requirement for putting effective measures in place to minimise unavoidable environmental damage and ensure the sustainability of communities.
- Similar infrastructural challenges are faced in other basins such as the Limpopo/Tuli and Soutpansberg – and in further exploitation of the Mpumalanga basin.

South Africa has strong policy and legislation in many areas, but coordination of policies and implementation is needed
- There are conflicting views on the success of the Mineral and Petroleum Resources Development Act (MPRDA).
- Environmental legislation is world class and forward looking, but implementation, monitoring and enforcement could be improved. Streamlining requirements for compliance, and reducing timeframes associated with approval processes, would be beneficial to development projects.
- There is a need for increased coordination and clarification of responsibilities between government departments in developing policy which impacts the coal value chain. These include the Departments of Mineral Resources, Energy, Water, Environmental Affairs, Transport, Public Enterprises and Treasury.

Infrastructure is critical to the future of the coal sector
- Transport infrastructure, particularly land-based transport, is a key determinant of the evolution of the coal sector. This is particularly important if the Mpumalanga, Waterberg and other coalfields are to be further exploited. The New Growth Path priorities (among other things) infrastructure development and increased mineral extraction and beneficiation within the overarching goal of creating inclusive and high job rich growth (New Growth Path: Executive Summary 2010). The NPC diagnostic has also identified infrastructure investment as one of nine key priorities.
- Available rail capacity, reliability and coverage need to improve. Sustaining existing capacity and related maintenance is a major cost to Transnet, and can be up to three times as high as the original investment costs.
- Export markets are currently limited by the capacity of the rail link to Richards Bay Coal Terminal.
- Transnet is unable to allocate capacity or build new infrastructure without guaranteed uptake of the capacity. Transnet currently funds expansionary and sustaining investment off its balance sheet and therefore requires certainty of future revenue streams to ensure the appropriate Return on Investment.
- However, development of new mines is sometimes hampered by lack of infrastructure. This “chicken and egg” situation needs to be resolved.
- Road infrastructure is used for transport where rail capacity is lacking or inefficient. One of the big issues with road transport is that externalities (pollution, social impacts, cost of infrastructure) are not accounted for in determining the trade-offs between different modes of transport. Enforcement of road legislation is also of concern.
- Given the structural impediments within the rail market, a market-based approach to costing the externalities inherent in the road transport of coal is likely to have limited success if not supported by a broader range of policy interventions.
• Some of the more remote resources, for example the Waterberg, could be stranded if suitable transport infrastructure is not in place to provide access to markets further afield. This could be mitigated to some degree if a clear vision for the export coal sector is in place.
• Water supply across South Africa is highly dependent on inter-basin transfers. The development of the Waterberg in the medium to long term will be dependent on new transfer streams.
• Carbon capture and storage (CCS) readiness is required for new coal to liquids plants and power stations. The pilot work must address costs of reservoir characterisation and the distances involved in piping of the gas to storage locations in order to achieve full implementation, as well as regulatory and funding frameworks.

A complex trade-off exists between exports and local use, in ensuring energy security and economic viability of the coal mining industry
• Government has raised concerns about exports of coal threatening South Africa’s long term energy security.
• South Africa (Council for Geoscience) is currently compiling an updated inventory of resources in the country, which should assist in quantifying resources available to export and domestic markets.
• Stockpiled coal discards represent a potential affordable fuel resource for new power generation, if new circulating fluidised bed power stations are established by Eskom or the private sector.
• It has historically been too expensive to transport lower grade coals long distances. The accelerating economic growth of India and China and consistent increases in international coal prices has changed this. India as a major buyer could change buying patterns and structure of the local coal export industry.
• The emergence of export markets for lower grade coal are now beginning to impact on the availability of coal which has historically been supplied to Eskom.
• Given the large contribution exports make to the profits of coal mining firms (despite constituting a relatively small percentage of output), a change in export volumes in the future could affect the financial performance of individual mines, as well as the investment models of coal mining groups.

There has been mixed success in transformation of the coal mining sector
• Broad-based black economic empowerment (B-BBEE) has led to a thriving Junior Mining Sector, and all major coal producers have had to move to a minimum of 26% BEE shareholding. More than 30% of South African coal production is attributed to companies controlled by previously disadvantaged South Africans.
• Having said this, smaller scale miners are challenged by the high costs associated with coal mining and low margins obtained on domestic sales.
• Junior miners are also suggested to be limited in their ability to export coal due to access restrictions to transport.
• Further opportunities exist for B-BBEE upstream and downstream in the value chain. Given the particular circumstances in the coal mining industry, where large players are more easily able to be financially viable, a debate seems to be warranted regarding where in the coal value chain B-BBEE should be most strongly promoted in order to maximise its social benefit.
• There is currently some debate on nationalisation in the mining sector, which needs to be resolved.

Climate change mitigation activities will impact on the coal industry, and South Africa more broadly
• Government has expressed a commitment to reducing emissions. All elements of the economy are likely to be affected, with the coal value chain being particularly vulnerable due to its significant contribution to emissions.
• In the longer term, unless the carbon intensity of the economy is reduced, international competitiveness could be impacted, if export markets seek out products with a lower carbon footprint, and/or impose border adjustment taxes on products to account for embodied carbon.
• It is likely that financing of emissions intensive projects is likely to be restricted by those countries that do have legally-binding emissions reduction commitments or where their stakeholders are more environmentally conscious.
• The impact of climate change policies on international demand for coal is suggested to be low in the medium term, since most of the fast-growing Asian economies are locked into significant coal requirements. This is likely to more than offset a decline in demand for coal from Europe as a result of climate change policies in the short to medium term.
• The industry is focussing on geological carbon capture and storage for providing a solution for mitigation of at least some of its emissions. However, the uncertainty and timescales associated with technology development; the remote location of storage sites in relation to coal resources in South Africa; and the costs associated with CCS all represent significant challenges. Test injections planned for later in the decade will hopefully shed light on some of these issues.
Energy and process efficiency have a significant role to play in mitigation of climate change impacts, and should be prioritised over the installation of more extensive low carbon supply-side interventions.

Other mitigation solutions that will play a role in carbon emissions reductions include renewables and nuclear, but given South Africa’s developmental challenges, energy security should remain as the highest priority.

Climate change impacts are likely to be felt along the coal value chain and adaptation measures and strategies are necessary

- The physical impacts of climate change are projected to include average temperature increases, water availability, extreme weather events, lightning, fires, flooding and health impacts. All of these issues could potentially impact the coal value chain in one way or another.
- Selected elements of the coal value chain have focussed their efforts on climate change mitigation, and little effort has been placed on exploring how the value chain needs to adapt to the physical and societal impacts of climate change. Early action is critical to reduce the cost and impacts of climate change. The failure to recognise the need for adaptation in this sector is also reflected in government policies.

Environmental and public perception issues continue to affect the industry’s license to operate

- The industry will need to maintain ongoing engagement to address public perceptions on the impacts associated with coal mining and utilisation, including those relating to the potential impacts of mining in the Waterberg.
- Rehabilitation of post closure mine sites remains a critical challenge.
- Issues raised concerning the long term sustainability of mining communities need to be considered.

The South African Coal Roadmap study was initiated with the aim of examining these challenges, and charting potential trajectories for the evolution of the coal value chain.
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<td>AMD</td>
<td>Acid Mine Drainage</td>
</tr>
<tr>
<td>CBM</td>
<td>Coal Bed Methane</td>
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<tr>
<td>CCS</td>
<td>Carbon Capture and Storage or Carbon Capture and Sequestration</td>
</tr>
<tr>
<td>CGS</td>
<td>Council for Geoscience</td>
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<tr>
<td>COM</td>
<td>Chamber of Mines</td>
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<tr>
<td>CTL</td>
<td>Coal to Liquids</td>
</tr>
<tr>
<td>DEA</td>
<td>Department of Environmental Affairs</td>
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<tr>
<td>DEAT</td>
<td>Department of Environmental Affairs and Tourism (now separate departments)</td>
</tr>
<tr>
<td>DME</td>
<td>Department of Minerals and Energy (now separate departments)</td>
</tr>
<tr>
<td>DMR</td>
<td>Department of Mineral Resources</td>
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<tr>
<td>DoE</td>
<td>Department of Energy</td>
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<td>DoT</td>
<td>Department of Transport</td>
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<tr>
<td>DPE</td>
<td>Department of Public Enterprises</td>
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<tr>
<td>DST</td>
<td>Department of Science and Technology</td>
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<tr>
<td>DWA</td>
<td>Department of Water Affairs</td>
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<tr>
<td>DWAF</td>
<td>Department of Water Affairs and Forestry (now separate departments)</td>
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<tr>
<td>ECBM</td>
<td>Enhanced Coal Bed Methane</td>
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<tr>
<td>FBC</td>
<td>Fluidised Bed Combustion</td>
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<td>FGD</td>
<td>Flue gas desulphurisation</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GTL</td>
<td>Gas to Liquids</td>
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<tr>
<td>ICMM</td>
<td>International Council on Mining and Metals</td>
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<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IGCC</td>
<td>Integrated Gasification Combined Cycle</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>IPP</td>
<td>Independent Power Producer</td>
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<td>IRP</td>
<td>Integrated Resource Plan</td>
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<tr>
<td>LCOE</td>
<td>Levelised Cost of Electricity</td>
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<tr>
<td>LTMS</td>
<td>Long Term Mitigation Scenarios</td>
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<tr>
<td>MCLI</td>
<td>Maputo Corridor Logistics Initiative</td>
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<tr>
<td>MCWAP</td>
<td>Mokolo and Crocodile (West) Water Augmentation Project</td>
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<tr>
<td>MPRDA</td>
<td>Mineral and Petroleum Resources Development Act</td>
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<tr>
<td>MQA</td>
<td>Mining Qualifications Authority</td>
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<td>NEEA</td>
<td>National Energy Efficiency Agency</td>
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<tr>
<td>NEMA</td>
<td>National Environmental Management Act of 1998</td>
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<td>NWRS</td>
<td>National Water Resource Strategy</td>
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<td>OCGT</td>
<td>Open Cycle Gas Turbine</td>
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<tr>
<td>PCI</td>
<td>Pulverised Coal Injection</td>
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<tr>
<td>PF</td>
<td>Pulverised Fuel</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>RBCT</td>
<td>Richards Bay Coal Terminal</td>
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<tr>
<td>REFIT</td>
<td>Renewable Energy Feed-in Tariff</td>
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<tr>
<td>ROM</td>
<td>Run of Mine</td>
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<tr>
<td>RTS</td>
<td>Return to Service</td>
</tr>
<tr>
<td>SACCCS</td>
<td>South African Centre of Carbon Capture and Storage</td>
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<td>SACRM</td>
<td>South African Coal Roadmap</td>
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<tr>
<td>SAMREC</td>
<td>South African Mineral Resource Committee</td>
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<tr>
<td>SANEDI</td>
<td>South African National Energy Development Institute</td>
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<tr>
<td>SANERI</td>
<td>South African National Energy Research Institute</td>
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<tr>
<td>SAPIA</td>
<td>South African Petroleum Industry Association</td>
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<tr>
<td>SAPP</td>
<td>Southern African Power Pool</td>
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<td>UCG</td>
<td>Underground Coal Gasification</td>
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<tr>
<td>UGCC</td>
<td>Underground Gasification Combined Cycle</td>
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<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<td>WEC</td>
<td>World Energy Council</td>
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<tr>
<td>WMA</td>
<td>Water Management Area</td>
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<td>WRC</td>
<td>Water Research Commission</td>
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**List of Units**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>bbl</td>
<td>Barrel</td>
</tr>
<tr>
<td>GWh</td>
<td>Gigawatt hour</td>
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<tr>
<td>kt</td>
<td>Kilotonne</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
</tr>
<tr>
<td>Mt</td>
<td>Megatonne</td>
</tr>
<tr>
<td>Mtce</td>
<td>Megatonne coal equivalent</td>
</tr>
<tr>
<td>Mtpa</td>
<td>Megatonne per annum</td>
</tr>
<tr>
<td>MWh</td>
<td>Megawatt hour</td>
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OVERVIEW AND REPORT STRUCTURE

1.1 The role of coal in the South African economy

Coal is the major primary energy source for South Africa. More than 90% of the country’s electricity, approximately 30% of the liquid fuel, and approximately 70% of its total energy needs are produced from coal. Coal also plays a significant role in supply to the South African chemicals industry, is an essential component of its steelmaking industry and provided R 35.4 billion in export revenues. Coal and platinum have exchanged the top positions by sales value of South Africa’s resources for the last two years (coal R 69.5 billion in 2010).

South Africa produced 244.6 Mt of marketable coal in 2010, which is expected to have increased to around 255 Mt in 2011. South Africa’s total coal exports were 67.6 Mt in 2010 with 63.4 Mt through Richards Bay Coal Terminal (RBCT), 1.8 Mt through Matola Coal Terminal in Mozambique and small amounts through Richards Bay and Durban harbours. Domestically, coal is used primarily to produce electricity by Eskom and liquid fuels and chemicals by Sasol. Other smaller users include the iron and steel, ferroalloys, industrial and manufacturing sectors.

The South African coal mining sector directly employed 73,618 people and paid R 14.1 billion in wages in 2010, which constituted 14.4% of total wage income (2009) in the mining industry as a whole (Chamber of Mines, 2011a). Employment down the value chain is also significant: at the end of the 2009/10 financial year Eskom reported that it had 36,547 direct employees (Eskom, 2010a) and Sasol directly employed 28,978 people in its South African operations at the end of the 2010 financial year (Sasol, 2010a). Both of these enterprises depend on coal for the bulk of their primary inputs. Direct employment by coal mining, Eskom and Sasol is therefore more than 139,000, with many more indirect employment numbers. In 2009, the coal mining sector accounted for about 1.8% of GDP directly, or 4.5% if indirect multipliers are added (StatsSA, 2010).

South Africa has an estimated 32 billion tonnes of coal reserves2, with a study being conducted in parallel with this one seeking to update this reserve base. Approximately 70% of these resources are found in the Waterberg, Witbank, Highveld and Ermelo coalfields, with the remainder in the Sasolburg, Free State, Springbok Flats and other smaller fields.

Given existing and planned power generation expansion in the country, domestic coal demand is expected to grow, at least within the short to medium term. In line with the promulgated IRP2010, Eskom’s demand is projected to increase by about 40% to 2020. Analysis of existing operations and new projects indicates potential increase in South African coal production to 319 Mt by 2015, and 359 Mt by 2020 (Wood Mackenzie, 2011a).

Global coal trade is also set to grow significantly during the next two decades. Absolute growth in coal consumption continues to substantially exceed all other energy sources. Coal accounted for nearly 30% of world energy consumption in 2010, its highest share since 1970, while its share is now over 70% in China and nearly 53% in India. According to IEA figures, coal consumption has grown over 4.8% per annum on average over the last ten years (7.6% in 2010, while both China and India increased coal consumption by over 10%). Current forecasts are of energy demand growth of around 50% and electricity demand growth of around 85% to 2035 (IEA 2010a; US EIA, 2011). Reflecting these increases, over the last 10 years, seaborne thermal coal trade has increased by 75%, showing average growth of 26 Mt a year. Nevertheless, over this period, South Africa’s coal exports have stagnated (RBCT exports in 2000 were 66.9 Mt, vs 63.4 Mt in 2010). Seaborne coal demand is expected to grow at a 5.8% compound annual growth rate (CAGR) over the next twenty years reaching 2.1 billion tonnes by 2030. This represents an increase of 1.4 billion tonnes over 2011’s expected 728 Mt (Wood Mackenzie, 2011b).

South Africa’s potential for increased export is dependent on having sufficient production capacity for coal, the necessary transport infrastructure becoming available, and encouraging foreign investment into coal mining through provision of a suitable policy and financial environment. If South Africa does not take the required measures, it may miss out on the potential economic benefits of this boom in much the same way that it missed out on the commodity and energy booms of 2000 to 2009. In South Africa, there is synergy in the degree of beneficiation undertaken to provide export quality coal on the one hand and the lower grade coal suitable for domestic use in existing power stations and in Sasol’s Fischer-Tropsch process on the other. It is expected that a number of planned new mines could not be viable if producing only one of the two products. Therefore, to some extent, the export market is required to create the product for Eskom consumption and vice versa.

Certain developments in 2011 have been very relevant for the coal industry in South Africa. The electricity plan for the country to 2030 (the IRP2010) was recently promulgated. The National Climate Change response strategy green paper has given a clear indication of government’s commitment to reduce carbon emissions from industry. Significantly, the National Planning Commission (NPC) expressed the following view on coal:

“While most of South Africa’s energy comes from coal, it is striking that government has no integrated coal policy. South Africa ranks fifth internationally as a coal producer and exporter, yet government has no clear export strategy. There is also no integrated development of mining, rail and port infrastructure to facilitate either exports or anticipated increases in local production and consumption, within acceptable environmental constraints. The private shareholders of the Richards Bay Coal Terminal have expanded export capacity to 91 million tons per

year. However, Transnet has barely been able to transport 60 million tons per year from the central coal fields to the coast. Government urgently needs to bring together all relevant players (mining companies, Transnet, Richards Bay Coal Terminal, relevant government departments, banks and others) to forge an agreed investment strategy and plan to accelerate coal exports, which could have beneficial balance of payment and current account impacts. An expanded export drive would need to be framed within a national policy on the optimal use of depleting coal reserves, including secure supplies for legacy power stations, and the opening of the Waterberg with the required rail links. The private sector has initiated work on a Coal Road Map. Government needs to be an active partner” (NPC, 2011:18)

It is thus important that South Africa maximises the value to society from the production and use of coal while at the same time minimising any negative impacts.

While the current contribution of the coal value chain to the South African economy in terms of employment, income, energy supply and contribution to GDP, coupled with South Africa’s significant coal resource, demonstrates a strong potential for continued economic benefit and energy security, there are a number of challenges to the value chain which will shape its future. Not the least of these is the climate change agenda which is increasingly shaping the global energy space. Other challenges include water, infrastructure, investment and institutional constraints.

1.2 Objectives and report description

The South African Coal Road Map study was initiated with the overarching objectives being to:

- Understand the primary factors required for the successful development of various future coal related opportunities, including economic enablers and skills development;
- Identify technologies, coal and coal-derived products that meet current, new and emerging future market needs and demands;
- Provide guidance on technology acquisition and implementation for South Africa in key areas, including, inter alia, external partnerships, policies and structures, and centres of global excellence;
- Provide guidance on issues of governance, research and development, private sector and infrastructural investments and opportunities for social investment.

A detailed description of the current status of the coal value chain provides the basis for this analysis. In this report, each element of the coal value chain is analysed in detail – a background understanding of the value chain element is provided, key metrics and technologies are described where relevant, and the current activities and players in South Africa are outlined. Significant attention is placed on the environmental, economic and social implications of each value chain element. Where relevant, commentary is offered on the likely evolution of that element of the value chain. Detailed quantitative information is provided where available.

In addition to the descriptors of individual value chain elements, a number of cross-cutting themes are explored. An analysis of global coal markets and regional energy considerations sets the context for the analysis. Alternatives to coal are described. Considerations relating to water supply and demand are presented, as is a comprehensive review of the climate change related issues for the coal industry – including impacts, mitigation and adaptation. A detailed analysis of the policy, legislative and institutional context is presented, followed by a summary of ongoing research activities relating to the entire value chain.
1.3 Scope of this report

A schematic showing the scope of this report is presented in Figure 1.

Figure 1: Scope of this report

Context

Value Chain

Impact

1. The Value of Coal
2. Global context
3. Regional context
4. Exploration
5. Resources & reserves
6. Mining
7. Coal preparation
8. Coal exports
9. Transport
10. Electricity
11. CTL
12. Metallurgical use
13. Industrial use
14. Residential use
15. Alternatives to coal
16. Social impacts
17. Environmental impacts
18. Water
19. Climate Change
COAL IN THE GLOBAL CONTEXT

Globally, coal represents a significant energy carrier, with 27% of world primary energy demand being supplied by coal in 2008. Coal is of particular importance in the electricity generation market, and coal-fired electricity comprised 41% of generation (IEA, 2010a).

2.1 Global coal reserves

Coal is the most abundant of the fossil fuels, with proven reserves estimated at 1,000 billion tonnes, which is equivalent to almost 150 years’ supply at current rates of consumption (BGR, 2009, in IEA, 2010a). Coal deposits are widely distributed geographically, and many countries are involved in its extraction. Figure 2 shows the distribution of coal reserves by world region, while Figure 3 shows the coal reserves of the 10 countries with the largest reserves and their reserve-to-production ratios.

What does Mtce mean?

Because of the differences in qualities of coal produced across the globe, it is common practice to express quantities of coal in terms of a “reference fuel” with a set energy content in order to make comparisons. One Megatonne of “coal equivalent” (Mtce) has a calorific value of 29.3 MJ/kg. Quantities of different coals can be expressed in Mtce by multiplying by 29.3 and dividing by their actual calorific value.

Figure 2: Proved recoverable coal reserve distribution by region, 2008

Figure 2 shows that coal deposits are spread out between regions, with the Middle East being the only region with no meaningful coal reserves. Figure 3 shows that the top 10 countries in terms of coal reserves all have sufficient reserves to last them a number of decades at current production levels, with only China and Poland’s reserves being insufficient to last for at least a century (reserve-to-production ratios for Brazil and the Russian Federation were not available).

(Source: WEC, 2010)

3 The reserves-to-production (R/P) ratio indicates the length of time a country’s proved coal reserves would last if production remained at its current level and no new reserves were proved (BP, 2010).
2.2 Coal production

Total global demand for coal was estimated at 4,736 Mtce in 2008 (IEA, 2010a). In absolute terms this is approximately 6,795 Mt (BP, 2010). South Africa is currently the sixth largest coal producer in the world, with total South African production being equivalent to approximately 4% of world production (Table 1).

Table 1: Top ten hard coal producers, 2009

<table>
<thead>
<tr>
<th>Country</th>
<th>Output</th>
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<tr>
<td>PR China</td>
<td>2,971 Mt</td>
<td>South Africa</td>
<td>247 Mt</td>
</tr>
<tr>
<td>USA</td>
<td>919 Mt</td>
<td>Russia</td>
<td>229 Mt</td>
</tr>
<tr>
<td>India</td>
<td>526 Mt</td>
<td>Kazakhstan</td>
<td>96 Mt</td>
</tr>
<tr>
<td>Australia</td>
<td>335 Mt</td>
<td>Poland</td>
<td>78 Mt</td>
</tr>
<tr>
<td>Indonesia</td>
<td>263 Mt</td>
<td>Colombia</td>
<td>73 Mt</td>
</tr>
</tbody>
</table>

(Source: World Coal Association, 2011a)

Under the “New Policies” Scenario of the IEA World Energy Outlook 2010, the demand for coal is expected to increase to just over 5,600 Mtce by 2035, with most of the demand growth before 2020 (IEA, 2010a). Most of the additional production is likely to occur in non-OECD countries, and nearly all the additional growth in coal production is envisaged to come in the form of an increase in steam coal production (IEA, 2010a). Coking coal production is likely to only increase by 5% up to 2035, and brown coal production is expected to decline by 20 Mtce by 2035 (IEA, 2010a).

In order to meet its energy needs, China is scheduled to increase its annual coal production by 200 – 300 Mt of coal per annum under some scenarios. This is roughly equal to the current EU consumption of hard coal (IEA, 2010a). Provided that transport bottlenecks can be addressed and the necessary industrial investment take place, more than three times the planned increase in coal production could materialise in the Xinjiang region to feed into electricity generation, chemical production and synthetic fuel manufacturing (IEA, 2010a).

The demand for coal in India is expected to grow significantly over the next 2 decades. Although India has significant coal reserves as shown in Figure 3, concerns exist regarding how easy it will be to extract these reserves. The reason for this is that, in addition to inadequate railway infrastructure to transport any new coal production, much of India’s coal reserves are located either in environmentally protected areas or in areas that have been dedicated to indigenous peoples (Economist, 2010).

2.3 Global demand for coal

Global patterns of coal consumption have changed dramatically in recent years, as rapid economic growth in Asia has increased demand in that region (Table 2). Whereas China constituted only 17% of primary coal demand in 1980, its
share had risen to 43% by 2008 and it has now emerged as the dominant consumer of coal internationally. Over the period 2000 – 2008 China’s coal demand increased by 1,120 Mtce and accounted for three quarters of the total increase in coal demand over this period (IEA, 2010a).

Table 2: Global primary coal demand (Mtce)

<table>
<thead>
<tr>
<th>Region</th>
<th>1980</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>2,560</td>
<td>4,736</td>
</tr>
<tr>
<td><strong>Selected Regional Estimates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OECD North America</td>
<td>22%</td>
<td>17%</td>
</tr>
<tr>
<td>OECD Europe</td>
<td>26%</td>
<td>9%</td>
</tr>
<tr>
<td>OECD Pacific</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>China</td>
<td>17%</td>
<td>43%</td>
</tr>
<tr>
<td>India</td>
<td>3%</td>
<td>8%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Africa</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

(Source: DNA Economics calculations based on IEA, 2010a)

While Chinese consumption of coal increased significantly, primary coal demand in European OECD countries fell significantly as coal was increasingly displaced by less carbon-intensive energy sources, such as gas, nuclear and renewable (World Coal Association, 2011a).

The IEA’s World Energy Outlook 2010 scenarios for the coal market to 2035 suggest that government policies, and particularly those related to climate change, are expected to play a critical role in shaping the global coal market in years to come. Three scenarios are modelled (IEA, 2010a):

- The “Current Policies” Scenario assumes no change in government policies, strong global economic growth and near tripling of electricity demand in non-OECD countries. It leads to an increase in global coal demand to over 7,500 Mtce by 2035, which is nearly 60% higher than coal demand in 2008.
- The “New Policies” Scenario takes into account planned reforms of fossil-fuel subsidies, implementation of measures to meet climate change targets and other announced energy-related policies. It leads to a world coal demand that is roughly 25%, or 1,925 Mtce, lower in 2035 than the Current Policies scenario (which is equal to about 40% of total coal demand in 2008 – or China’s current coal demand)
- The “450” Scenario assumes more decisive implementation of climate and energy policy plans and a ratcheting up of climate change mitigation policies after 2020 in order to try and limit man-made climate change to a 2°C increase in the long-term rise in the global average temperature. It leads to a global primary demand for coal of about 3,565 Mtce in 2035 (a quarter lower than the level in 2008 and close to levels seen in the 1990s and early 2000s)

The impact of the different scenarios on global coal demand is shown in Figure 4 below and the impact on primary coal demand in key regions is shown in Figure 5.

Figure 4: Global primary coal demand according to IEA 2010 scenarios

(Source: IEA, 2010a)

5 Primary coal demand includes hard coal (steam and coking coal), brown coal (ignite) and peat (IEA, 2010a).
Coal use in OECD countries decreases significantly between 2008 and 2035 in all three scenarios and never returns to the peaks seen before the global financial crisis of 2007/2008 as countries continue to reduce the average carbon-intensity of electricity generation (IEA, 2010a). As a result, all future increases in global coal demand are found to come from non-OECD countries. China and other Asian countries with large populations and fast-growing economies will have a particularly important impact on the global coal market in future, not just in terms of demand, but also with respect to production and trade. In the New Policies Scenario, which is reported most often in the World Energy Outlook 2010, 90% of total growth in coal demand is seen to originate from China, India and Indonesia (IEA, 2010a). By 2035, China constitutes about half of global coal demand.

Demand for coal in China is driven by a strong demand for coking coal to ensure a sufficient supply of iron and steel to support China’s fast growth, as well as a significant increase in coal-fired power generation over the period in question (Economist, 2010; IEA, 2010a). China is planning to add 600 GW of coal-fired electricity generation capacity over the period 2010 - 2035, which is equivalent to the installed coal-fired generation capacity of the European Union, the United States and Japan together (IEA, 2010a).

Under the “New Policies” Scenario, India is expected to represent the second largest demand for coal by 2035, and is expected to double its coal consumption from 370 Mtce currently to 780 Mtce by the end of the period – of which 500 Mtce would be produced locally. More than half of the additional coal demand is expected to be linked to electricity generation (as the country embarks on a large-scale rural electrification drive) and about a third of new demand is expected to come from the industrial sector (IEA, 2010a).

### Coal trade

Coal usage is centred in six key markets, namely China, the United States, the European Union, India, Russia and Japan, which together accounted for 83% of coal consumption in 2008 (IEA, 2010a). Of these key markets, only Japan does not also feature in the list of the world’s top ten coal producers. Partly for this reason, and partly because transport costs add significantly to the price of coal, a relatively small proportion of total global coal production is exported. International trade accounts for only around 16% of coal consumed (World Coal Association, 2011a).

#### Table 3: Top coal exporting/importing countries, 2009 estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Steam</strong></td>
<td><strong>Steam</strong></td>
</tr>
<tr>
<td><strong>Coking</strong></td>
<td><strong>Coking</strong></td>
</tr>
<tr>
<td>Australia</td>
<td>Japan</td>
</tr>
<tr>
<td>259 Mt</td>
<td>165 Mt</td>
</tr>
<tr>
<td>134 Mt</td>
<td>113 Mt</td>
</tr>
<tr>
<td>125 Mt</td>
<td>52 Mt</td>
</tr>
<tr>
<td>Indonesia</td>
<td>PR China</td>
</tr>
<tr>
<td>230 Mt</td>
<td>137 Mt</td>
</tr>
<tr>
<td>200 Mt</td>
<td>102 Mt</td>
</tr>
<tr>
<td>30 Mt</td>
<td>35 Mt</td>
</tr>
<tr>
<td>Russia</td>
<td>South Korea</td>
</tr>
<tr>
<td>116 Mt</td>
<td>103 Mt</td>
</tr>
<tr>
<td>105 Mt</td>
<td>82 Mt</td>
</tr>
<tr>
<td>11 Mt</td>
<td>21 Mt</td>
</tr>
<tr>
<td>Colombia</td>
<td>India</td>
</tr>
<tr>
<td>69 Mt</td>
<td>67 Mt</td>
</tr>
<tr>
<td>69 Mt</td>
<td>44 Mt</td>
</tr>
<tr>
<td>-</td>
<td>23 Mt</td>
</tr>
<tr>
<td>South Africa</td>
<td>Chinese Taipei</td>
</tr>
<tr>
<td>67 Mt</td>
<td>60 Mt</td>
</tr>
<tr>
<td>66 Mt</td>
<td>57 Mt</td>
</tr>
<tr>
<td>1 Mt</td>
<td>3 Mt</td>
</tr>
<tr>
<td>USA</td>
<td>Germany</td>
</tr>
<tr>
<td>53 Mt</td>
<td>38 Mt</td>
</tr>
<tr>
<td>20 Mt</td>
<td>32 Mt</td>
</tr>
<tr>
<td>33 Mt</td>
<td>6 Mt</td>
</tr>
<tr>
<td>Canada</td>
<td>UK</td>
</tr>
<tr>
<td>28 Mt</td>
<td>38 Mt</td>
</tr>
<tr>
<td>7 Mt</td>
<td>33 Mt</td>
</tr>
<tr>
<td>21 Mt</td>
<td>5 Mt</td>
</tr>
</tbody>
</table>

(Source: World Coal Association, 2011a)
Because of the relatively high cost of transporting coal, the global coal market has historically been divided into two relatively separate markets (Eberhard, 2011; World Coal Association, 2011a), namely:

- the Atlantic market, consisting of importing countries in Western Europe, notably the UK, Germany and Spain and mainly served by Russia, South Africa, Colombia, the USA and Canada; and

- the Pacific market (accounting for 57% of seaborne steam coal trade), which consists of developing and OECD Asian importers, notably Japan, Korea and Chinese Taipei, China, India, Japan, Korea and is largely served by Australia and Indonesia.

When price differentials and profit margins in the different markets become sufficiently large, however, and sufficient coal supplies are available, the two markets tend to overlap (World Coal Institute, 2005). South Africa is a natural point of convergence between the Atlantic and Pacific coal markets as a result of its geographic location, and thus serves as a swing producer between these two markets (Eberhard, 2011; World Coal Institute, 2005). A combination of increasing prices in Asian markets as a result of strong demand and a reduction in prices in the Atlantic market due to weak electricity demand as a result of the recession in the aftermath of the global financial crisis in 2009 led to South African export prices increasing above European import prices, with the effect that South African coal exports were partially diverted from their traditional destination of Europe to Asian markets (IEA, 2010a). This was a continuation of a longer term trend of South African coal exporters to increasingly focus on the growing Asian market rather than the declining European markets, as shown in Figure 6 below (Eberhard, 2011). South African coal exports to India have increased in recent years while exports to Europe have fallen from roughly three-quarters of South African exports in 2005 to less than half in 2009 (Eberhard, 2011).

Figure 6: Destination of South African coal exports over time

(Source: Eberhard, 2011)

South Africa’s current and expected future production and exports, based on current and planned operations, is shown in Figure 7.

Figure 7: South Africa’s current and expected production and export split

(Source: Wood Mackenzie, 2010a)
2.5 Coal use by sector

Close to two-thirds of global coal demand in 2008 was from the electricity sector, and another 20% was from the industrial sector. Since 1990, the relative share of coal in the electricity sector has grown by 10%, balanced by declines observed in the agriculture and buildings sectors (which together accounted for about 10% of total coal demand in 1990) and marginal declines in industrial energy applications (IEA, 2010a).

The relative demand of each sector utilising coal is expected to remain roughly similar over the period up to 2035, but global coal demand increases by 0.6% per annum according to the “New Policies” Scenario. Demand from electricity generation accounts for close to 60% of the total increase in global coal demand over this period of 885 Mtce, while the industrial sector accounts for another 30% of growth in demand. Coal-to-liquids (CTL) is expected to become a moderate source of coal demand in the “New Policies” Scenario, with demand increasing by around 125 Mtce (accounting for 45% of the growth in global industrial coal use). CTL is expected to generate over 1 million barrels per day or 1% of global oil demand by 2035 under this scenario (IEA, 2010a).

The change in global primary coal demand by sector and country/region for the period 2008 – 2035 under the “New Policies Scenario” is shown in Figure 8 below.

2.6 International policy perspectives

The international discussion on coal policy is dominated by a number of issues. Of these, climate change is acknowledged as a critical issue for the sector (CIAB, 2010), and is receiving most of the sector’s attention through its publications and reports. The challenge is framed as achieving a balance between “adequate coal supply” for socio-economic objectives, and reduction of greenhouse gases (CIAB, 2010). Whilst economic drivers are still held to be stronger than social and environmental drivers, particularly in developing countries where the demand for coal will be strongest going forward, climate change is already influencing investment patterns, and the uncertainty relating to international climate policy is being felt and is damaging for the industry (CIAB, 2009).

The international coal sector identifies best practice (including energy efficiency), CCS and “other new developments” as enabling emission reductions from the sector. It is supportive of sectoral approaches and benchmarks in international climate change policy, and access to support for “cleaner coal” through the Clean Development Mechanism. Delay to the commercialisation of CCS is identified as an issue, large-scale pilots are required but these have been slow to emerge. The sector argues that CCS is a step change technology that will require public support for the initial demonstration project.

Coal is identified by the sector as being affordable, reliable and secure, and therefore valuable amongst fossil fuels (CIAB, 2010), and important for global energy security. Adequate investment in infrastructure, including mines, rail, ports and power stations is required for coal to deliver energy, and ensuring this investment going forward is an important role for international policy.

The coal sector needs to adapt to increasingly liberalised international energy markets, and a transition in focus from purely economic development to sustainable development. The achievement and maintenance of a social licence to operate is becoming a requirement in a greater number of countries, together with the use and management of land and interaction with local communities. Transparency of information in the mining sector is also becoming more and more important.

Sector governance is an important current topic, with a focus on roles, responsibilities and policy instruments. These issues are being framed within an integrated approach to the use of minerals. In the Southern African region, there has been a move to modernise mining policies to reflect the more liberal mining policy environment internationally (MMSD, 2001).
Box 1: A perspective of South African coal policy
Coal policy and regulation in South Africa is restricted to that pertaining to the individual parts of the coal value chain, with no overarching policy or national strategic direction for coal. This is especially true for the past twenty years, where government has had a “hands-off” approach, allowing the sector to respond to market opportunities with no price or export controls. Prior to this, coal policy was very linked to industrial policy, with the coal sector expanding on the back of the expansion of Eskom’s fleet of coal fired power plants, and Sasol’s coal to liquids plant.

South Africa’s mining, energy, transport and environmental policies, in line with its Constitution, are amongst the best in the world and aligned with a 21st century agenda. The White Papers and Strategies developed since 1994 are forward looking and inclusive, and inspire optimism and confidence. However, the country falls short in terms of implementation, of these policies.

Government is showing signs of becoming interested in coal, appropriately from a national resource perspective. Policy questions which are beginning to emerge include: how much coal remains? How economically viable is it to mine this coal? How much atmospheric carbon space does South Africa have to burn coal? How much atmospheric carbon space is there internationally for the use of South Africa’s coal exports? How best to beneficiate the coal in the most environmentally friendly manner? What are the implications for our water resources of mining and burning coal? And essentially, what is the best use of the remaining national coal asset? Coal is a strategic asset for South Africa, important in providing energy and for use by the key sectors of mining and industry. But it is also subject to significant resource constraints, particularly those of the coal resource itself, but also of water, climate change and capital for investment.

South Africa has policy objectives that include economic growth, sustainable development and social transformation. These have not always necessarily combined synergistically within the coal value chain, and are likely to continue to cause tension going forward. Whilst the policy governing these aspects is largely clear and supportive of synergies in general, a greater focus on, and understanding of the characteristics of the coal value chain, along with improved policy implementation, will help to realise this opportunity.

As with many aspects of South Africa, the sector could be described as being at a critical juncture. There are a number of paths it could take forward, and all involve trade-offs and compromise. However, it is clear that without a strategic and co-ordinated policy approach, it is unlikely that any of those possible paths will arrive at a future that is better than the present and the impact on energy security in the country would still need to be contextualised.

2.7 Other countries’ approaches to coal and climate change challenges

There are essentially two broad approaches to reducing emissions from coal:

1. Using coal in a more efficient way e.g. by increasing combustion efficiency in power generation (see section 10.1 for more details of the technology), or by using Underground Coal Gasification (UCG) to gas for synthesis or power generation (see section 6.1.3 for more details).

2. Capturing and storing emissions from process that use coal with Carbon Capture & Storage (CCS) (see section 19.5.6).

A survey of world practice leaves an impression that countries are looking more to CCS than to combustion efficiency to decarbonise their economies in the future.

2.7.1 Using coal more efficiently

Little is published in the way of general overviews of country efforts to use coal more efficiently. What is published reveals that combustion technologies such as supercritical and ultra-supercritical pulverised fuel, and gasification technologies such as underground coal gasification, are being pursued in places.

China has emerged in the past two years as the world’s leading builder of more efficient, less polluting coal power plants, mastering the technology and driving down the cost (Bradsher, 2009).

India recently commissioned its first supercritical plant (The Economic Times, 2010), and is planning an ultra-supercritical 800 MW coal-fired power plant (Krar, 2011).

Other countries currently using or proposing to adopt SC/USC include Canada, Czech Republic, Denmark, Germany, Italy, Japan, Mexico, Poland, Russia, South Africa, South Korea, Chinese Taipei and the UK. Research and development is under way for ultra-supercritical units operating at even higher efficiencies, potentially up to around 50%. The introduction of ultra-supercritical technology has been driven over recent years in countries such as Denmark, Germany and Japan, in order to achieve improved plant efficiencies and reduce fuel costs. Research is focusing on the development of new steels for boiler tubes and on high alloy steels that minimise corrosion. These developments are expected to result in a dramatic increase in the number of SC plants and USC units installed over coming years (World Coal Institute, 2007).

The interest in UCG has grown significantly in recent years. UCG is now being recognised globally as a viable and economic method for accessing deep otherwise unrecoverable coal reserves, on and offshore. Most coal rich nations are developing UCG programmes.

Projects underway include (Figure 9):
- Australia - BloodwoodCreek, Chinchilla, Pekira Basin,
2.7.2 Carbon capture and storage

A survey of world practice revealed that many countries are counting on the success of CCS to decarbonise their economies – including South Africa, those in the European Union, Australia and the United States.

In 2010, the Global Carbon Capture and Storage Institute identified 234 active or planned CCS projects across a range of technologies, project types and sectors. Seventy-seven of these projects were large-scale integrated CCS projects (LSIPs). Of these 77 LSIPs, there were eight operating projects and a further four projects in the execution stage, although all were linked to the oil and gas sector.

North America accounts for 39 of the 77 LSIPs (31 in the United States and 8 in Canada). The allocation of government funding grants to projects is most advanced in this region. Europe has 21 LSIPs, though projects appear to be moving at a slightly slower pace than in North America. European projects face significant challenges surrounding the use of potential onshore storage sites, underscoring the need to gain public endorsement for CCS projects. The most advanced CCS activity in Europe is in Norway (which has two operational LSIPs) and in the United Kingdom and the Netherlands, with 11 LSIPs under development between them.

Most of the significant CCS projects in China, where five LSIPs were identified, are driven by major state-owned enterprises. China’s LSIPs span a range of industries from power generation through coal to chemical to oil and gas.

Australia has six LSIPs split between the petroleum sector (CO₂ injection projects associated mainly with offshore gas field developments) and projects associated with the capture of CO₂ from power stations and industrial facilities. There are currently no LSIPs identified in key emitter countries such as Japan, India and Russia. LSIPs are spread across a number of industries, but of those in development planning the majority (42 projects) are in power generation, reflecting the large allocation of government funding support to that sector. Projects in the cement, iron and steel and alumina industries have low representation. Little detail is given on coal projects within these listings (GCCSI, 2010).

Various other sources refer to coal-based projects including Italy (Porto Tolle), Poland (Belchatow) (lignite), the USA (Texas, Illinois (CTL), Ohio River, Natchez and Wyoming), the UK (Renfrew and NE England), and Germany (Spremberg). While Japan may not have any LSIPs of its own, it is involved in several demonstration projects around the world, with the aim of generating CDM carbon credits (Stefanova, 2011).

A contradictory report by the Climate Group on China’s current 5 year plan states that there is no provision for carbon capture and storage in the 5 year plan although it remains a development priority in energy R&D (The Climate Group, 2011).
THE REGIONAL CONTEXT WITH RESPECT TO COAL AND ENERGY

To put the South African coal and energy analysis into context, a review is presented on the energy resources, energy demand and coal-related activities in the Southern African region. The Southern African Power Pool (SAPP) is also discussed.

Table 4 gives a breakdown of economic activity for selected countries in the region.

Table 4: GDP and contribution by sector for a selection of Southern African countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Agriculture</th>
<th>Industry</th>
<th>Services</th>
<th>GDP [billion USD PPP]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>9.6%</td>
<td>65.8%</td>
<td>24.6%</td>
<td>114.1</td>
</tr>
<tr>
<td>Botswana</td>
<td>2.3%</td>
<td>45.8%</td>
<td>51.9%</td>
<td>26.6</td>
</tr>
<tr>
<td>Mozambique</td>
<td>28.8%</td>
<td>26.0%</td>
<td>45.2%</td>
<td>22.2</td>
</tr>
<tr>
<td>Namibia</td>
<td>9.0%</td>
<td>32.7%</td>
<td>58.2%</td>
<td>14.6</td>
</tr>
<tr>
<td>South Africa</td>
<td>3.0%</td>
<td>31.2%</td>
<td>65.8%</td>
<td>527.5</td>
</tr>
<tr>
<td>Zambia</td>
<td>19.7%</td>
<td>33.7%</td>
<td>46.6%</td>
<td>20.0</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>19.5%</td>
<td>24.0%</td>
<td>56.5%</td>
<td>4.4</td>
</tr>
</tbody>
</table>

South Africa makes up over 70% of the region’s GDP on a USD PPP basis, followed by Angola with a further 15%.

3.1 Energy resources in Southern Africa

Southern Africa is host to substantial energy resources, both fossil and renewable, much of which have not been developed to their full potential (Mbirimi, 2010). Table 5 and Table 6 provide an overview of these. Particularly noteworthy from the Southern African perspective are the coal deposits of South Africa, Botswana, Zimbabwe and Mozambique; the oil reserves of Angola; the hydroelectric potential of the Democratic Republic of Congo (DRC) and Mozambique; and South Africa’s wind resources. Solar power has significant potential in several locations throughout the region. To put solar energy in context, South Africa receives solar insolation equivalent to approximately ten thousand times Eskom’s output.

Table 5: Fossil fuel resources and reserves in the Southern African region

<table>
<thead>
<tr>
<th>Country</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>10 billion bbl proven reserves</td>
<td>161 billion m³ reserves</td>
<td>No reserves</td>
</tr>
<tr>
<td>Botswana</td>
<td>212 Gt of resource, 40 Mt reserve</td>
<td>No reserves</td>
<td>354 billion m³ of gas from coal bed methane</td>
</tr>
<tr>
<td>DRC</td>
<td>180 million barrels proven*</td>
<td>990 billion m³ resource estimated, 990 million m³ reserve</td>
<td>No reserves</td>
</tr>
</tbody>
</table>

*The DRC additionally has substantial shale oil resources, estimated at 100 billion bbl (WEC, 2010).

It is recognised that the DRC is not in “Southern” Africa. Nevertheless, the hydro potential is relevant for South Africa and the Southern African Power Pool.
Table 6: Renewable energy resources in the Southern African region

<table>
<thead>
<tr>
<th>Country</th>
<th>Hydro Description</th>
<th>Biomass consumption and potential description</th>
<th>Wind Potential</th>
<th>Solar insolation [kWh/m2-day]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>Potential for economic development 152 TWh/year, 140 MW mini hydro potential for rural electrification</td>
<td>Pot.: Fuelwood (510 - 1,020 million cubic m/year)</td>
<td>Poor-average</td>
<td>4 – 7</td>
</tr>
<tr>
<td>Botswana</td>
<td>no hydropower</td>
<td>Fuelwood, current harvesting practices are not sustainable</td>
<td>Poor</td>
<td>5 – 7</td>
</tr>
<tr>
<td>DRC</td>
<td>100 GW potential</td>
<td>Pot.: 122 million ha of forest</td>
<td>Poor</td>
<td>3 – 6</td>
</tr>
<tr>
<td>Lesotho</td>
<td>450 MW</td>
<td>Pot.: Fuelwood (39 kha)</td>
<td>20 MW potential</td>
<td>Average 5.5</td>
</tr>
<tr>
<td>Madagascar</td>
<td>Economic potential of small-hydro of 49 TWh/year</td>
<td>Forest area of 13 kha</td>
<td>Good along the coast</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Malawi</td>
<td>Estimated potential of 900 MW</td>
<td>Con.: Ethanol (7% of liquid fuel, 12 million litres per annum) locally produces and blended with petrol,</td>
<td>Poor</td>
<td>4 – 6, Average 5.8</td>
</tr>
<tr>
<td>Mauritius</td>
<td>59 MW existing, potential almost fully tapped</td>
<td>Bagasse, fuelwood and charcoal</td>
<td>Good</td>
<td>Average 6</td>
</tr>
<tr>
<td>Mozambique</td>
<td>14 GW potential (2.5 GW developed)</td>
<td>3.5 – 4 billion tonnes</td>
<td>Average</td>
<td>4 – 6, Average 5.2</td>
</tr>
<tr>
<td>Namibia</td>
<td>Hydro potential along the lower Kunene, Okavango and Orange Rivers</td>
<td>abundant in north, scarce in south</td>
<td>Good along the coast</td>
<td>5 – 8, Average 6</td>
</tr>
<tr>
<td>South Africa</td>
<td>668 MW installed capacity</td>
<td>Bagasse, fuelwood</td>
<td>Good (32 GW/67.8TWh from sites with capacity factor&gt;25%)</td>
<td>4 – 8</td>
</tr>
<tr>
<td>Swaziland</td>
<td>0.3 TWh/year potential of which about a third has already been tapped</td>
<td>1.5 Mt of bagasse, 625 kha of forest (162 kha is commercial plantations)</td>
<td>Poor</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Potential for 4.7 GW of which 12% is currently developed</td>
<td>Fuelwood and charcoal from natural forests and plantations, bagasse</td>
<td>Good along the coast</td>
<td>4 – 7</td>
</tr>
<tr>
<td>Zambia</td>
<td>Possible hydro projects: 1.6 GW at Batoka Gorge, 1.2 GW at Devils Gorge</td>
<td>Fuelwood and charcoal</td>
<td>Poor</td>
<td>4 – 7</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Possible 37 TWh on Zambezi, 10 TWh harnessed</td>
<td>13 million tonnes fuelwood yield per annum</td>
<td>Poor</td>
<td>5 – 7</td>
</tr>
</tbody>
</table>

(Source: Merven et al., 2010)

In addition to the fossil and renewable resources detailed above, both South Africa and Namibia have substantial uranium reserves, although the cost of recovery in Namibia is relatively high (Table 7). This table presents the resources economically available at a given acceptable recovery cost.

Table 7: Reasonable assured uranium resources in South Africa and Namibia, at a given cost of recovery.

<table>
<thead>
<tr>
<th>Cost of recovery</th>
<th>South Africa</th>
<th>Namibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;USD 80/kg U</td>
<td>142</td>
<td>2</td>
</tr>
<tr>
<td>&lt;USD 130/kg U</td>
<td>195.2</td>
<td>157</td>
</tr>
</tbody>
</table>

(Source: WEC, 2010)
3.2 Energy demand in Southern Africa

Many Southern African countries have very low GDP per capita in comparison with countries of the developed world, as well as low per capita energy consumption. It is well understood that the region faces significant developmental challenges, with some 45% of the population surviving on one USD per day (SADC, 2008). It has been estimated that only 25% of the population has access to electricity (Merven et al., 2010).

At present the major energy source for many countries is biomass, principally fuelwood used for domestic heating and cooking purposes. South Africa, with a more developed industrial sector, has much higher per capita energy consumption than other countries in the region, with coal dominating the energy mix (Merven et al., 2010; Mbirimi, 2010). Figure 10 presents the energy mix of a selection of Southern African countries. Table 8 gives the fuel sources used for electricity generation in the region.

Figure 10: Energy mix by source in selected Southern African countries

Table 8: Proportion of installed capacity in MW for selected Southern African countries*

<table>
<thead>
<tr>
<th>Country</th>
<th>Hydro</th>
<th>Coal</th>
<th>Nuclear</th>
<th>Gas</th>
<th>Liquid fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>76%</td>
<td>8%</td>
<td>0%</td>
<td>16%</td>
<td>0%</td>
</tr>
<tr>
<td>Botswana</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>DRC</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Lesotho</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Mozambique</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>&lt;1%</td>
<td>0%</td>
</tr>
<tr>
<td>Namibia</td>
<td>61%</td>
<td>33%</td>
<td>0%</td>
<td>&lt;1%</td>
<td>6%</td>
</tr>
<tr>
<td>South Africa</td>
<td>1%</td>
<td>85%</td>
<td>4%</td>
<td>0%</td>
<td>6%</td>
</tr>
<tr>
<td>Zambia</td>
<td>99%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>39%</td>
<td>61%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

(Source: SAPP, 2009; EDM, 2009; Eskom, 2010a)

*Note that, due to different patterns of usage, the proportions of electricity sent out can vary significantly from the proportions of installed generation capacity.
3.3 Coal activity in Southern Africa

Coal production figures for various Southern African countries are shown in Table 9. Production in South Africa clearly dwarfs production in any of the other countries.

Table 9: Estimated 2008 coal production in Southern Africa

<table>
<thead>
<tr>
<th></th>
<th>Thermal [Mt]</th>
<th>Coking [Mt]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana</td>
<td>0.86</td>
<td>0</td>
</tr>
<tr>
<td>DRC</td>
<td>0.13</td>
<td>0</td>
</tr>
<tr>
<td>Mozambique</td>
<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>South Africa</td>
<td>250.6</td>
<td>1.64</td>
</tr>
<tr>
<td>Tanzania</td>
<td>0.09</td>
<td>0</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>2.5</td>
<td>0.58</td>
</tr>
</tbody>
</table>

(Source: IEA, 2011)

Despite the current limited levels of coal production and demand in the rest of Southern Africa, a number of coal-related activities are identifiable in the region. These are presented in Box 2. Current interest appears to be focussed on the largely undeveloped Mozambique coalfields, which have the potential to become a source of export coal, including metallurgical coal, as well as supplying local power generation. Development of new mines in Botswana could also occur in the future, including in the Mmamabula coalfield near the South African border.

Box 2: Coal-related activities in Southern Africa

Mozambique:

- Riversdale Mining is an Australian coal company which operates in Mozambique’s Tete province. Their Benga project has coal reserves of 502 Mt from a resource of 4 billion tonnes, and is planned to run at ROM 5.3 Mtpa (Riversdale Mining, 2010). Development of a mine-mouth power station has received environmental approval from the Mozambican authorities (Swanepoel, 2010). Riversdale is also developing the adjacent Zambezi project with a resource of 9 billion tonnes (Riversdale Mining, 2010).

- Vale's Moatize project, also in the Tete province of Mozambique, is planned to produce 8.5 Mtpa of hard coking coal and 2.5 Mtpa of thermal coal, with production beginning in 2011 (Vale, 2011).

- The Sena railway line connecting the Tete coalfields to the port of Beira is being rehabilitated to carry 5 Mtpa of coal (Venter, 2010a), although this is expected to be insufficient to provide for all producers in the area (Thomaz, 2009a). There is also a possibility of coal export through the more northerly Mozambican port of Nacala (Mangwiro, 2011).

Botswana:

- The Morupule Colliery (owned principally by Anglo American) operates in Botswana, with an output capacity of ROM 1 Mtpa, and in the process of upgrading to 3.2 Mtpa. The colliery’s principle client is Botswana Power Corporation’s Morupule coal fired power station (Morupule Colliery, 2010). This 132 MW station provides 80% of domestically generated electricity (Mawson, 2005) but the majority of the Botswana’s electricity supply is currently imported, mainly from South Africa (BPC, 2009). Plans are underway for Morupule B, a 600 MW station, which is expected to be completed toward the end of 2012 (BPC, 2009).

- Increases to Botswana’s coal capacity are also being planned in the south-east of the country, with a total planned output of ROM 7.3 Mtpa for the Mmamabula Coalfield project of CIC Energy (CIC Energy, 2010). The accompanying Mmamabula Energy Project entails a 1,200 MW power station which would sell electricity onto the South African grid, but this project has been unable to secure purchasing agreements and has been delayed (CIC Energy, 2009; CIC Energy 2010; Mguni, 2010). The Mookane Domestic Power Project, also in the Mmamabula area, is being pursued as a separate project on a different portion of the field, with the intention to install a 300 MW station supplying power to the Botswana grid (CIC Energy, 2010).

- The development of a trans-Kalahari rail line has been proposed, which would link south-eastern Botswana with the Atlantic coast of Namibia. A pre-feasibility study has been completed with positive results, and there appears to be some support for the development (Railways Africa, 2010; Mining MX, 2010a). If developed, this line would be a route for coal export from Botswana, but could potentially play a role for South African coal as well.

Zimbabwe:

- Hwange Colliery operates in Zimbabwe. The mine produced 1.7 Mt in 2009, and its principle customer is the Zimbabwe Power Company (Hwange Colliery, 2010)

Others:

- A number of other smaller initiatives can be identified, including the Maamba colliery in Zambia, the Sonichar mine in Niger, the Mchenga mine in Malawi, and small Swaziland collieries.
Competition from Botswana and Mozambique on world markets is a potential reality. However, both countries suffer from having undeveloped infrastructures and large distances between coal mines and new or existing export terminals.

According to Botswana’s permanent secretary in the Ministry of Minerals, Energy and Water Resources, Botswana recently suspended the issuance of new prospecting licences for coal, coal bed methane and related minerals as it seeks to conclude a new strategy for the sector. The electricity crisis and shortage of coal in Southern Africa was seen to have turned coal into a major growth opportunity and increased economic diversification for Botswana (Nyaungwa, 2011).

African Development Bank (ADB) is reported as saying that in 2020 Mozambique will be Africa’s second-largest coal exporter, with annual sales of close to 110 million tonnes (Macauhub, 2011).

While there is no shortage of optimism reports about Botswana’s and Mozambique’s future in coal, further careful assessment will need to be given to these.

### 3.4 Southern African Power Pool

The Southern African Power Pool was established in 1995 following the signing of an Inter-Government MOU. The aim was to coordinate and facilitate power sharing between the national electricity utilities of continental SADC states (Table 10) as well as to optimise the use of available energy resources in the region and support one another during emergencies (US EIA, 2002). SAPP represents a framework in which generation capacity could be developed regionally rather than nationally, enabling greater use of the variety of energy resources in the region (Mbirimi, 2010). Figure 11 shows the generation and transmission infrastructure of SAPP members.
Electricity is traded between members across the regional transmission grid, largely through long-term bilateral agreements between members but also through a short-term energy market with day-ahead trading (SAPP, 2009; Madakufamba, 2010). South Africa holds by far the greatest generation capacity in the region and, along with Mozambique, is a major seller as well as purchaser of electricity in the pool (Table 10) (Mbirimi, 2010). Some “non-operating” countries do not yet have transmission infrastructure connecting them to the regional grid. The development of a western corridor to connect Angola as well as develop large hydroelectric capacity in the DRC (intended to be located at Inga) has been under discussion for several years, but to date this has not come to fruition and it is no longer a SAPP project (Madakufamba, 2010; SAPP, undated; Wait, 2009).

South Africa, as the largest potential market for electricity imports, plays an important role in the development of infrastructure and capacity in SAPP, particularly the viability of exploiting the very large hydroelectric potential of the DRC, Mozambique and Zambia (Mbirimi, 2010). However, the degree to which South Africa can rely on imported power may be limited by regional politics and the desire for energy self-sufficiency.

Table 10: SAPP members and their installed electricity generation capacity.

<table>
<thead>
<tr>
<th>Operating members</th>
<th>Utility</th>
<th>Abbreviation</th>
<th>Installed capacity [MW as at January 2011]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>Empresa Nacional de Electricidade</td>
<td>ENE</td>
<td>1,187</td>
</tr>
<tr>
<td>Botswana</td>
<td>Botswana Power Corporation</td>
<td>BPC</td>
<td>202</td>
</tr>
<tr>
<td>DRC</td>
<td>Societe Nationale d’Electricite</td>
<td>SNEL</td>
<td>2,442</td>
</tr>
<tr>
<td>Lesotho</td>
<td>Lesotho Electricity Corporation</td>
<td>LEC</td>
<td>72</td>
</tr>
<tr>
<td>Malawi</td>
<td>Electricity Supply Corporation of Malawi</td>
<td>ESCOM</td>
<td>287</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Electricidade de Mocambique</td>
<td>EDM</td>
<td>233</td>
</tr>
<tr>
<td></td>
<td>Hidroeléctrica de Cahora Bassa</td>
<td>HCB</td>
<td>2,075</td>
</tr>
<tr>
<td>Namibia</td>
<td>NAMPOWER</td>
<td>NamPower</td>
<td>393</td>
</tr>
<tr>
<td>South Africa</td>
<td>Eskom</td>
<td>Eskom</td>
<td>44,170</td>
</tr>
<tr>
<td>Swaziland</td>
<td>Swaziland Electricity Company</td>
<td>SEC</td>
<td>70</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Tanzania Electricity Supply Company Ltd</td>
<td>TANESCO</td>
<td>1,008</td>
</tr>
<tr>
<td>Zambia</td>
<td>Zesco Ltd</td>
<td>ZESCO</td>
<td>1,812</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>ZESA Holdings Private Limit</td>
<td>ZESA</td>
<td>2,045</td>
</tr>
</tbody>
</table>

(Source: SAPP, 2011)
EXPLORATION

4.1 Coal formation

Coal is a carbon-rich sedimentary rock formed over millennia from peat, the degraded remains of plant matter. The accumulation of sufficient layers of plant material typically occurred under anaerobic (oxygen-free) conditions that limited the extent of bacterial decomposition, a situation provided by static water bodies such as swamps, wetlands and the margins of shallow lakes and glacial valleys. Sufficient geological and climatic stability was required for substantial accumulation of material to occur, aided by steady subsidence of the site to allow further plant growth and accumulation of submerged material (Baruya et al., 2003). Subsequent geological conditions further contributed to coal development, with heat and pressure in particular acting to improve coal rank. Climatic conditions supporting the vegetative source of the material varied, and contributed to the differences in today’s coal characteristics. For example, Carboniferous coals of the northern hemisphere originated as peats from equatorial forests, where rapid vegetative growth balanced the rapid bacterial degradation, whilst the peat deposits of the Permian formed from temperate shrubby growth in the cool climates, matched by slower rates of degradation (Earth Science Australia, 2010; Baruya et al., 2003). Suitable deposits of peat and conditions for coal formation have coincided in a number of locations throughout geological history.

4.1.1 Formation of South African deposits

In late Palaeozoic times, collision of crustal plates caused an area of the Gondwanaland supercontinent to steadily subside. This created the Karoo Basin, where peat swamps developed on the margins of glaciated valleys and lakes (Baruya et al., 2003). The coal deposits were subsequently affected by igneous intrusions associated with the uplift of the Drakensberg (Schmidt, undated), providing the heat and pressure to improve the coal rank. These geological transformations contributed to the variability of coal rank in South Africa and the tendency for rank to increase from the southwest to the northeast (Baruya et al., 2003), with anthracite deposits occurring in eastern Mpumalanga and KwaZulu-Natal (Council for Geoscience, 2010a).

4.2 Exploration activities

Although existing geological knowledge exists on large areas likely to hold significant coal resources, it is necessary to prospect at much smaller scales before selecting sites for establishing mining operations, so as to provide confidence that production will be of suitable quality and economically viable. In other words, coal in the ground is just that, a coal resource and only once an applicable study has been completed to determine economic viability and based on a mine plan, can the coal be classified as a coal reserve. Among relevant considerations are the confident quantification of the amount of coal in place; geological assessment of its mineability over the lifetime of the mine; and determination of the coal’s characteristics, which in turn will determine which markets can be targeted and what level of beneficiation will be required. In addition to mine planning, this information is often of key importance to raising finance for a proposed mining operation.

Prior to selecting a site for the establishment of a mine, a variety of activities are undertaken to investigate the coal geology of the area, determine subsurface features and identify sites for drilling boreholes to obtain bore cores. These activities and related techniques include:

- Mineralogy and petrology: Studying the rocks and minerals of an area to yield insight into the geological history of the region.
- Remote sensing: Use of satellite and aerial imagery to identify geological structures.
- Seismic mapping: Use of special machinery or controlled detonation of explosives to generate sonic waves. These waves travel down from the surface, reflect off the interface of lower rock layers and are captured by receivers on the surface. The recordings from the receivers allow a reconstruction of the layers.
- Magnetic surveying: Sensitive measurement of the magnetic field at the surface to provide insight into the structure and origin of subsurface features.
- Isotopic analysis: Measurement of the isotopic abundance of certain elements to age rocks and minerals, which in turn provides information about their place and time of origin, and clues about the geological history of the area.

Boreholes are then drilled for direct observation of the coal and the rock formations in which the coal is contained to confirm the coal’s presence and character. Core recovery drilling techniques make use of a hollow drill bit to remove a long cylinder of subsurface material, which reflects the order of layers as they occur along the drilling direction. The bore cores that are extracted are logged in detail, frequently photographed at regular depths for record keeping and reference purposes, characterised and samples taken for subsequent analysis according to specified protocols. Once an adequate amount of data is obtained, geological modelling of the deposit is done. The modelling is done to:

- estimate the geometry of the deposit;
- determine spatial distribution of coal characteristics; and
- estimate the coal resource available for exploitation.

Although some data on an area may already be available prior to prospecting, including geological surveys undertaken by governmental bodies and databases of drilling records from previous exploration projects, prospecting to provide sufficient data to justify establishment of a mine can be very expensive. Particularly high costs are associated with
drilling and the analysis of core materials. Skills shortages are also a challenge for prospecting, with a particular shortage of experienced geologists and drillers (SACRM Mining and Exploration Focus Group, 2010).

Prospecting is undertaken by private companies and mining houses.

4.3 Policy and legislation

The 1998 White Paper on a Minerals and Mining Policy for South Africa, building on the principles of the 1955 Freedom Charter, remains the policy reference point for the mining sector. The document made clear government’s long term objective of mineral rights vesting in the state. It introduced a “use it or lose it” approach to minerals rights, and transferred the right to prospect and mine for all minerals to the state. The Paper also proposed principles of black economic empowerment for the mining and minerals sector.


This central piece of legislation pertains to all aspects of mineral, and therefore coal, exploration, reserves and resources, mining, beneficiation and discards. The Act is comprehensive on environmental management of mining activities, taking a cradle to grave approach. Whilst the Act has been described by some as a milestone in the transformation of the mining sector in South Africa (Swartz, 2003), others criticise that it focuses on transformation to the detriment of investment.

The MPRDA had a number of core objectives, including: to ensure equitable access to South Africa’s mineral and petroleum resources; to ensure that historically disadvantaged persons participate meaningfully in the mining industry; to encourage investment in the sector, particularly in beneficiation; and to ensure a proactive social plan accompanies all mining activities (Cawood et al., 2001; Polity, 2010).

Significantly, the MPRDA vested custodianship of all minerals in the South African State, with four authorisations available with respect to minerals.

- Prospecting rights: may be granted for up to five years and may be renewed once for a period not exceeding three years. The holder of a prospecting right has the exclusive right to apply for and be granted a mining right. At present the applications for and granting of prospecting rights is considered confidential, and it not possible to determine where prospecting is being undertaken or by whom.

- Retention permit: this will be considered in cases where the holder of a prospecting right cannot proceed to mining because of unfavourable prevailing market conditions. It is valid for up to three years and may be renewed once for a period not exceeding two years. The holder of a retention permit has the exclusive right to apply for and be granted a mining right over the retention area.

- Mining right: granted for a maximum of 30 years but renewable for an indefinite number of further periods, each of which may not exceed 30 years.

Including prospecting and all permissible extensions, exclusive rights to an area could thus be retained for a maximum period of thirteen years (5 + 3 + 3 + 2) before requiring a mining right. Once a mining right comes into effect, the holder is required to commence mining within one year (DME, 2002; Cawood, 2004).

The Act contains certain transitional measures with regard to mineral rights, prospecting permits, and mining authorisations obtained prior to 1 May 2004. These are termed “old order rights”, and are required to be converted to the authorisations recognised under the MPRDA, termed “new order rights”. In addition, any requests for old order rights not finalised on or before 1 May 2004 are treated as having been made under the MPRDA. A subsequent amendment to the MPRDA (Amendment 49 of 2008) affords statutory protection to certain existing old order rights through technical amendments regarding the transitional period. The amendment also removed ambiguities related to certain definitions, and added functions to the Regional Mining Development and Environmental Committee.

The Act gives the minister rights to inter alia; expropriate property for the purpose of prospecting or mining, intervene where it does not appear that the mineral resources are being optimally mined, further investigate mineral resource occurrence, and to prohibit or restrict prospecting or mining either overall or on certain land.

One of the core objectives of the Act was the transformation of the minerals industry. As such, the Act required the development of the code of good practice for the industry, the housing and living conditions standard for the minerals industry (both gazetted in 2009), and a broad-based socio-economic empowerment Charter (2002).
The MPRDA confirms that all mining and prospecting operations are subjugated to the principles set out in the National Environmental Management Act, and must be conducted “in accordance with generally accepted principles of sustainable development by integrating social, economic and environmental factors into the planning and implementation of prospecting and mining projects in order to ensure that exploitation of mineral resources serves present and future generations” (Republic of South Africa, 2002). Specifically, an environmental management plan is required for a reconnaissance permission, prospecting right or mining permit. In addition, the granting of a mining right requires an environmental impact assessment and environmental management programme. The MPRDA Amendment (49 of 2008) intended to align the Act with the National Environmental Management Act of 1998 (NEMA), by making the Minister the responsible authority for implementing environmental matters in terms of NEMA, in order to provide for one environmental management system.

The MPRDA is generally perceived as a good Act, although there are problems relating to its interpretation and implementation (Policy and Intellectual Policy Focus Group, October 2010; McKay, 2010).

A further amendment of the Act is currently underway, scheduled for completion in 2011. One area that will be amended is the current provision that companies have to apply for a right per mineral, even if multiple minerals occur on the same piece of land. This constitutes a return to the Minerals Act of 1991. Another area up for review is that of the transferability of rights (McKay, 2010). The DMR will also be developing a “licence process-tracking” system for its website, which will show the progress of mining applications on its website, in a bid to increase transparency. Whilst government has confirmed that changes will not apply retrospectively (McKay, 2010), the amendment process is nevertheless resulting in a level of uncertainty in the industry.

Closely related to the MPRDA is the Code of Good Practice for the Minerals Sector, the Amended Mining Charter (2010), the Housing and Living Conditions Standard for the Minerals Industry. These are discussed in the section on Socio-economics below. There is less legislation in the area of discards (Policy and Intellectual Property Focus Group, 2010).

The MPRDA made provision for the implementation of a royalty on mineral resources, which was effected by the 2008 Mineral and Petroleum Royalty Act (and administration Act) (28 and 29 of 2008), imposing a royalty on the transfer of mineral resources, serving to compensate the State for the permanent loss of the country’s non-renewable resources. This is in line with international policy (PWC, 2011). The Act came into effect on 1 March 2010. In terms of this Act, royalties are payable by mining companies on their profits rather than revenue, as initially proposed (van der Zwan and Nel, 2010). The royalty payable is determined by multiplying the gross sales of the mineral resource by a percentage that is determined by a formula which distinguishes between refined and unrefined mineral resources. This percentage may not exceed 5 percent in the case of refined mineral resources, and 7 percent in the case of unrefined resources. The Bill leading to the Act was met with heavy criticism from industry, which has remained circumspect about its implications (van der Zwan and Nel, 2010). Analysis of the implications on the South African mining industry conclude that the royalties may discourage exploration, and beneficiation, and should therefore be investigated as experience with the implementation of the Act progresses (van der Zwan and Nel, 2010).

The 1993 Geoscience Act 100 provides for the promotion of research and the extension of knowledge in the field of geoscience, including the establishment of the Council for Geoscience. Its 2010 amendment bill provides for the management of infrastructure development in dolomitic terrains as well as to empower the Council to be an advisory authority in respect of geohazards, and to become the custodian of all geotechnical data and technical information relating to exploration and mining.

Amendments to legislation in the mining sector have gone some way in aligning and consolidating legislation. The Minerals and Energy Laws Amendment Act (11 of 2005) made some correcting amendments to the Deeds Registries Act of 1937, the Mining Titles Registration Amendment Act of 2003, and to the MPRDA by substituting the Schedule to the Mining Titles Registration Amendment Act of 2003, and by repealing certain expressions in Schedule I to the MPRDA. Similarly, the Mining Titles Registration Amendment Act of 2003 updated the Mining Titles Registration Act of 1967 to ensure consistency with the MPRDA, and amended the Deeds Registries Act of 1937, so as to remove certain functions relating to the registration of rights to minerals. However stakeholders indicate that inconsistencies still remain (Policy and Intellectual Property Focus Group, 2010).

Historically, there was only scant attention paid to rehabilitation on mining closure, and largely only to surface rehabilitation, leaving South Africa with a significant negative legacy of social and environmental degradation (Swart, 2003). The MPRDA provides comprehensive statutory requirements enforcing environmental protection including the management of stockpiles and waste throughout the lifecycle of the mine, responsibility of directors, financial recompense, responsibilities on closure, environmental management report etc.). Government is defined has holding ultimate responsibility for abandoned and derelict mines.
RESOURCES AND RESERVES

This section is based on information which is available at the time of writing of this document. The outcomes of the reassessment of South African coal resources and reserves are expected to be released by the Council for Geoscience in late 2011/early 2012.

5.1 Location of coal resources in South Africa

The known coal deposits of Southern Africa are hosted in the Phanerozoic sedimentary rocks of the Karoo Supergroup, specifically formed during two periods, the Early Permian and Late Permian. The Karoo Supergroup is divided into the Dwyka, Ecca, Beaufort and Drakensberg Groups, with the Molteno, Elliot, and Clarens Formations occurring between the Beaufort and Drakensberg Groups. The coal seams occur in the Vryheid and Volksrust formations of the Ecca Group with the exception of the Springbok Flats and Molteno coal which occur in the Beaufort Group. Southern African coals are associated with non-marine clastic sedimentary sequences, generally sandstones and mudstones. Early Permian coals are commonly sandstone hosted whilst the younger Late Permian coals are typically found interbedded with mudstones (Cairncross, 2001). Figure 12 shows major coal occurrences in Southern Africa.

Currently, the main coal mining areas in South Africa are the Witbank, Ermelo and Highveld Coalfield areas of Mpumalanga, around Sasolburg – Vereeniging in the Free State, as well as in north-western KwaZulu Natal, which hosts a number of smaller operations. In Limpopo there is a single large colliery near Lephalale in the Waterberg Coalfield and a small colliery in Soutpansberg East area.

Figure 12: Coalfields, active and abandoned coal mines in South Africa

(Source: Council for Geoscience, 2010a)
5.1.1 Extent of South African coal resources and reserves

It is important to distinguish between resources and reserves when discussing the extent of mineral deposits. Resources refer to the geological occurrence of a mineral, describing the tonnages, quality, geological formation and may include potential economic recoverability. Resources are defined as a concentration or occurrence of material of economic interest in such a form, quality and quantity that there are reasonable and realistic prospects for eventual economic extraction. Resources are subdivided in order of increasing confidence into inferred (lowest), indicated and measured categories. Material that cannot be estimated with sufficient confidence to be classified as an inferred resource is classified as deposits. Reserves, on the other hand, are only those parts of the resource that are proved with reasonable confidence to be currently economically mineable after having done appropriate assessments like feasibility studies. Conventions for reporting coal resources and reserves are laid out in the SAMREC Code (SAMREC, 2009) (Figure 13) and in SANS 10320 (SABS, 2004), which defines coal reserves as:

“...economically mineable coal derived from a measured or indicated coal resource, or both. It is inclusive of diluting and contaminating materials and allows for losses that can occur when the material is mined. Appropriate assessments, which may include feasibility studies, have been carried out, including consideration of, and modification by, realistically assumed mining, coal processing, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction is reasonably justifiable. Coal reserves are subdivided in order of increasing confidence into probable coal reserves and proven coal reserves.”

However, it would appear that this strict definition of reserves is usually only applied to individual deposits or mines.

The SAMREC Code (SANS 10320) is currently being updated and reviewed.

Figure 13: Distinction between resources and reserves from the SAMREC Code

(Source: adapted from SAMREC, 2009)
The distinction between resources and reserves highlights some challenges in estimating the amount of coal available nationally for eventual economically viable extraction. Resources can be estimated from geological knowledge alone, but only a part of these will prove to be exploitable and the data with which to make this classification is often limited. Reserves, on the other hand, provide an operational measure of extractable coal but exclude those parts of the resource base which might be viably extractable but have been insufficiently prospected (inferred resource), and also fluctuate with coal price, economic conditions and technology. A Resource may thus only become a Reserve once all requirements are met and the project proceeds. Coal (even at measured status) will stay a Resource and would thus be targets for future development.

South Africa’s coal resources were estimated in 1987 at 121 Gt, and recoverable reserves of 55 Gt (Baruya et al., 2003) (details shown in Table 11). Recoverable reserves were revised down to 33 Gt in 1999 to reflect mine production over the intervening period (Baruya et al., 2003). The Council for Geoscience is currently undertaking a detailed reassessment of South African resources and reserves, in a project commissioned by Eskom and the Department of Mineral Resources. This is intended to include a coalfield-by-coalfield assessment with information on coal qualities and potential uses, including potential for underground coal gasification (UCG). Results of this study are expected to become available in the course of 2011 (SACRM Resources and Reserves Focus Group, 2010).

Table 11: South Africa’s coal resources and reserves

<table>
<thead>
<tr>
<th>Coalfield/location</th>
<th>Resources (Baruya et al., 2003) [Mt]</th>
<th>Recoverable reserves (Baruya et al., 2003) [Mt]</th>
<th>Reserves 2009 (Prevost, pers. comm. 2011) [Mt]</th>
<th>Coal quality (Jeffrey, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Witbank</td>
<td>16,241</td>
<td>12,460</td>
<td>8,509</td>
<td>No. 1 and 2 seams provide high quality metallurgical and export steam coal. No. 4 seam of low quality, with only lower portion exploited for local power station and steam use. No. 5 seam provides blend coking coal especially from central Witbank area.</td>
</tr>
<tr>
<td>Highveld</td>
<td>16,909</td>
<td>10,979</td>
<td>9,475</td>
<td>No. 2 seam provides low-grade coal, in better-quality areas washable to achieve 27 MJ/kg at &gt;70% yield. No. 4 seam is of variable quality, generally low-grade (c. 25% ash, 22 MJ/kg). No. 5 seam of higher quality, and can be source of metallurgical coal.</td>
</tr>
<tr>
<td>Ermelo*</td>
<td>7,525</td>
<td>4,698</td>
<td>4,388</td>
<td>E Seam of reasonable quality but economic potential declines southwards due to geology. D Seam is of good quality. C Lower Seam is main source of export coal. C Upper Seam of lower quality, although its lower part is usually of good quality and a main target for mining, particularly to supplement C Lower. B Seams of lower quality, dull coal.</td>
</tr>
<tr>
<td>Utrecht*</td>
<td>1,067</td>
<td>649</td>
<td>541</td>
<td>Moderately good coking coal requiring little beneficiation, but sulphur content can be high. Lower Dundas seam varies from medium volatile bituminous to anthracite. Gus Seam of moderate to low quality with high methane content. Alfred Seam is high in ash and sulphur, but can be beneficiated to relatively high quality.</td>
</tr>
<tr>
<td>Kliprivier*</td>
<td>1,157</td>
<td>655</td>
<td>529</td>
<td>Bituminous to anthracite with high sulphur and phosphorus. Producing good coking coal in the past. Bottom Seam (corresponding to Gus Seam) high in sulphur (1.3 – 1.8%) and phosphorus. Top Seam (corresponding to Alfred Seam) has higher proportion bright coal, ranging bituminous to anthracitic.</td>
</tr>
<tr>
<td>Vryheid*</td>
<td>321</td>
<td>204</td>
<td>100</td>
<td>Coking Seam produces high grade coking coal of medium rank with low ash content. Lower Dundas Seam mined for coking and steam coal. Gus Seam produces good quality coking coal where unaffected by dolerite intrusions, and anthracite elsewhere. Alfred Seam is low grade with poor coking qualities. Fritz Seam is of reasonable grade but high in sulphur.</td>
</tr>
<tr>
<td>South Rand</td>
<td>3,072</td>
<td>730</td>
<td>716</td>
<td>No. 2 Seam is largely dull coal but of fairly consistent quality. Ryder Seam is of low quality and prone to spontaneous combustion.</td>
</tr>
<tr>
<td>Coalfield/Location</td>
<td>Resources (Baruya et al., 2003)</td>
<td>Recoverable reserves (Baruya et al., 2003)</td>
<td>Reserves 2009 (Prevost, pers. comm. 2011)</td>
<td>Coal quality (Jeffrey, 2005)</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------</td>
<td>---------------------------------------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Sasolburg</td>
<td>4,757</td>
<td>2,233</td>
<td>1,708</td>
<td></td>
</tr>
<tr>
<td>Free State</td>
<td>8,876</td>
<td>4,919</td>
<td></td>
<td>Bottom Seam is low grade steam coal with poor washing characteristics. Top Seam is lustrous coal of somewhat better quality.</td>
</tr>
<tr>
<td>Waterberg¹</td>
<td>55,614</td>
<td>15,487</td>
<td>6,744</td>
<td>Little published information available. Coal rank increases from west to east. (Early data reflected that zones 5 – 11 held approximately equal proportions of coking coal and middlings suitable for steam raising. The lower zones are of lower quality (Alberts, 1981)).</td>
</tr>
<tr>
<td>Springbok Flats²</td>
<td>3,250</td>
<td>1,700</td>
<td></td>
<td>Linear relationship has been established between ash content and calorific value. Sulphur content ranges 2 – 4%, approx. 1.5% after beneficiation.</td>
</tr>
<tr>
<td>Limpopo³</td>
<td>256</td>
<td>107</td>
<td></td>
<td>After washing: 47 – 53%, 10 – 12% ash, 35.5 – 36.5% volatile, sulphur approx. 1.1%.</td>
</tr>
<tr>
<td>Soutpansberg⁴</td>
<td>1,450</td>
<td>267</td>
<td>257</td>
<td>Known to have some hard coking coal.</td>
</tr>
<tr>
<td>Other fields in KwaZulu-Natal⁵</td>
<td>256</td>
<td>98</td>
<td>Nongoma: 6</td>
<td>Nongoma field: A Zone has ash contents 33 – 42%, with anthracite in the lower parts. B Zone shows ash contents around 25% with anthracite in the upper parts. Somkhele field: Anthracite of high quality, low to medium ash and low sulphur.</td>
</tr>
<tr>
<td>Kangwane⁴</td>
<td>467</td>
<td>147</td>
<td>146</td>
<td>Single anthracite colliery in operation</td>
</tr>
<tr>
<td>Molteno-Indwe**</td>
<td>376</td>
<td>47</td>
<td></td>
<td>Only Indwe, Guba and Molteno Seams have economic potential in places, but are generally of poor quality. Guba and Indwe have high ash content (31 – 51% unwashed, 26 – 27% washed), high moisture (7 - 11%) low volatile matter (7 – 12%) calorific value 23.9 – 25.9 MJ/kg.</td>
</tr>
<tr>
<td>Total</td>
<td>121,218</td>
<td>55,333</td>
<td>33,117</td>
<td></td>
</tr>
</tbody>
</table>

* beneficiation assumed for anthracitic coal

¹ beneficiation assumed

² Not included in the total, as omitted by the main source

The estimation of remaining reserves has been revised down substantially since this assessment. Table 12 provides a summary of more recent estimates. Both WEC estimates made provision for potential coal production from the Waterberg field. The significant reduction between 2007 and 2009 appears to have resulted at least in part from a re-evaluation of the field’s mineability.

Table 12: Past estimates of South African coal reserves

<table>
<thead>
<tr>
<th>Source</th>
<th>Remaining reserves (Mt)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bredell (1987)</td>
<td>55,333</td>
<td>Reproduced in (Baruya et al., 2003)</td>
</tr>
<tr>
<td>Prevost (2005)</td>
<td>34,000</td>
<td>Cited in Blueprint (2007)</td>
</tr>
<tr>
<td>WEC (2007)</td>
<td>48,000</td>
<td>Proved amount in place (resources): 115,000. Value from adjusting 1987 estimates to account for cumulative production.</td>
</tr>
<tr>
<td>WEC (2009) (interim update)</td>
<td>30,408</td>
<td>Based on de Jager (1986) with allowance for cumulative production</td>
</tr>
<tr>
<td>South African Yearbook</td>
<td>27,981</td>
<td>Figure from Department of Mineral Resources</td>
</tr>
</tbody>
</table>

* The WEC data are for “proven recoverable reserves”, defined as “the tonnage within the proved amount in place that can be recovered (extracted from the earth in raw form) under present and expected local economic conditions with existing available technology”.

26 | Overview of the South African Coal Value Chain
It is helpful to compare these country-level estimates to the summed total of reserve estimates for existing or developing mining projects in South Africa. These are estimated at 8.9 billion tonnes in 2010, with 95% of this being thermal coal and the remainder metallurgical. 62% of this total is located in Mpumalanga (5.5 billion tonnes), but this includes only 5% of the total metallurgical coal reserves. Metallurgical coal reserves are largely found in Limpopo (88% of South Africa’s total, primarily semi-soft coking coal and PCI), which holds 32% of the total marketable coal reserves (2.8 billion tonnes) (Wood Mackenzie, 2010b).

5.2 Non-geological resource modelling

Some approaches attempt to model the lifetime of a natural resource without recourse to detailed geological data about the specific case at hand. Most commonly this involves an approach derived from the work of Hubbert, who in 1956 proposed that oil production in the US would follow a bell-shaped curve over time and, using historic production data and an estimate of remaining reserves, predicted that it would peak in the 1970s (Brandt, 2007). His prediction proved to be remarkably accurate. A similar approach has been applied to global coal production, predicting peak production between 2020 and 2050, depending on the estimates of total recoverable coal (Höök et al., 2010). An application of a related approach to South Africa has proposed that remaining recoverable reserves in the country could be as low as 15 Gt (Hartnady, 2010). However, the Hubbert approach is not universally accepted. Brandt (2007) undertook a detailed analysis of its assumptions, with reference to an extensive set of public data on oil production around the world. He found that 36% of production in the data sets was poorly described by any model with a single up-and-down peak, and hence not amenable to any kind of Hubbert-curve fitting. Of the remaining production series, a bell-shaped curve did not provide a definitively best-fit for the data, and in fact there was a strong tendency for asymmetric curves, with post-peak production tending to decline more slowly than it increased prior to the peak (Brandt, 2007). Hubbert-type approaches may be of some value for further modelling of South African coal, but these significant limitations should be taken into account and reliable estimates of recoverable reserves would be of paramount importance whatever approach was adopted. The standpoint of South African coal specialists is that the Hubbert-type approach to South African coal is “hogwash” (SACRM Resources and Reserves Focus Group, 2010).

5.3 Coalbed methane (CBM)

South African coal deposits are considered to have generally low methane gas content and low permeability, which casts doubt on the viability of coalbed methane extraction (Creedy et al., 2001, UNFCCC, 2000). Measurements have been taken of methane release during coal mining with the conclusion that South African mines release substantially less than expected from international experience (Lloyd and Cook, 2005). However, the Council for Geoscience reports that there is potential for CBM extraction from coalfields in the Limpopo province (Council for Geoscience, undated), and it is possible that gassier coal seams will start to be mined as the shallower coalfields are exhausted (Global Methane Initiative, 2010). The CBM resource in South Africa has been estimated at 0.14 – 0.28 trillion m$^3$ (Global Methane Initiative, 2010).

There are some companies showing an interest in the potential of CBM in South Africa (Badimo Gas, 2010) as well as in Botswana, where deep wells drilled in the Kalahari basin have showed some promise (van der Merwe, 2008). Anglo Coal is expanding a previous five-well pilot-phase project in the Waterberg (Creamer, M., 2009a), which has also involved Anglo Platinum in the application of fuel-cell technology to generate electricity from the extracted gas (Creamer, M., 2009b).

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8 Wood Mackenzie estimates “marketable reserves” based on company production forecasts, their own market projections and comparison to other operations. Although the resulting estimates are comparable to proven and probable reserves as reported by companies, they can also include production which is considered highly likely to be exploited but falling outside of strictly defined reserve estimates.
This section unpacks various aspects of this pivotal part of the coal value chain: coal mining. The section begins with an introduction to the techniques used in mining. This is followed by a discussion of the current status of the South African coal mining industry in terms of coal producers and current production followed by the policy context and likely evolution of coal mining in the country.

6.1 Techniques used in mining

Coal mining methods are divided into two broad categories: surface mining and underground mining. Their application depends on geological factors, principally the depth of the seam and the ratio of overburden waste material to the seam width. Some mines make use of both approaches. For deeper coal seams, the application of underground coal gasification is increasingly being investigated.

Surface and underground mining each contribute around half of coal production in South Africa (Chamber of Mines, undated; DoE, undated a). Both opencast and strip mining techniques are applied in surface mining, whilst underground mining is dominated by bord-and-pillar methods. There are, however, a few longwall and shortwall operations in the country (DME, 2009a; Lloyd, 2002a).

6.1.1 Surface mining

Surface mining removes material covering the coal (the overburden) and then systematically extracts the exposed coal. This can allow high recovery rates, but is only applicable to coal seams that are relatively close to the surface.

Approaches to surface mining include (World Coal Institute, 2005; Kentucky Geological Survey, 2006; Lloyd, 2002a):

- Open cast or open-pit mining, in which a large area of the coal deposit is exposed by removing the covering rock (the overburden) from the mined area. The coal is extracted, usually using trucks and mechanised shovels or bucket-wheel excavators (Figure 14).
- Strip mining exposes one strip of the coal deposit at a time and extracts this coal before moving on to remove the overburden along the next strip, with this placed into a previous mined-out strip. Excavation is often achieved using dragline equipment.
- Contour mining is a form of surface mining applied in steep or hilly areas, in a process similar to strip mining.
- Highwall mining uses a continuous mining system to extract coal from a seam exposed to the surface at the edge of a mined pit or contour. Although the coal is extracted from below the ground, the equipment is operated from the surface and the extent of underground operations is minimal.
- Mountaintop removal, practiced in the United States, extracts coal from thick seams near the peaks of mountains by removing the overburden and filling this into adjacent valleys.

Figure 14: Surface mining

(Sources: World Coal Institute, 2005)
6.1.2 Underground mining

The two main forms of underground mining are bord-and-pillar and longwall mining. The information below is collated from the following reference sources: World Coal Institute (2005), Australian Coal Association (2008), Chamber of Mines (undated) and ACARP (undated).

Bord-and-pillar mining leaves columns of coal in place to support the mine roof, removing only 50 – 60% of the coal (Figure 15). This is the most common form of underground mining, particularly suited to relatively shallow coal seams where the pressure of the overlying rock is not so high as to crush the pillars (Chamber of Mines, undated). Sometimes the coal pillars are removed at a later stage of mine life, and the roof is allowed to collapse. This is termed “retreat mining” and is usually done when the mining area is to be closed.

Longwall mining (Figure 16) extracts coal from a face of the coal seam 100 – 350 meters long, using armoured face conveyors to remove coal along the entire length. Hydraulic roof supports advance with the face, and the mined-out areas are allowed to collapse behind the supports. Over 75% of the coal can be extracted by this method, with a “panel” extending as far as 3 km into the seam. In South Africa, bord and pillar mining is mostly applied in underground mining, due to challenging geological conditions. Mostly, the South African geological conditions are not suitable for longwall mining, due to the compartmentalising of reserve areas by faulting and dolerite intrusions.

Figure 15: Bord and pillar mining

Figure 16: Longwall mining

(Source: Arch Coal, 2007)
Rib-pillar extraction is a less common technique, which is also able to extract a high proportion of the coal. This involves a continuous miner cutting a long roadway into the coal block, a few meters inward from its edge. This leaves a long “rib-pillar” of coal, which the continuous miner then systematically cuts away from inside the block, before cutting the next roadway a few meters from the newly formed outside edge (Chamber of Mines, undated).

Shortwall mining is a less capital-intensive form of longwall mining, which utilises similar hydraulic roof supports to mine smaller blocks of coal, employing continuous miners for the coal removal rather than a specially installed system of shearsers (Chamber of Mines, undated).

6.1.3 Underground coal gasification (UCG)

Underground coal gasification (UCG) is a technology first proposed in the 1800’s, whereby coal is ignited underground with a controlled flow of oxidant gas (such as air, enriched air, oxygen/steam or carbon dioxide/oxygen mixtures) and water. This converts the coal into synthetic gas (syngas) comprising hydrogen, carbon monoxide, methane and carbon dioxide, in proportions dependant on the exact conditions (Ergo Exergy, 2010; Eskom, 2009a). Syngas can be used directly as a fuel, be co-fired with other fuels such as natural gas or coal, can power gas turbines for electricity generation (most efficiently using IGCC technology) or be used as a chemical feedstock for the production of synthetic natural gas, liquid fuels or chemicals by the same processes currently applied by Sasol (which currently gasifies coal for this purpose, but does this above ground after mining the coal intact) (Eskom, 2009a; PWC, 2008).

Ignition and supply of the oxidising gases, as well as extraction of the syngas produced, can be achieved through wells drilled down to the coal deposit, and the ash remaining after gasification is left below the surface (Figure 17). The technique therefore enables the high efficiency extraction of energy and chemical value from the coal without the need for conventional mining operations, stockpiling, reclaiming and transportation nor the generation of mining wastes from overburden, discard and ash. Furthermore, the much-reduced underground infrastructure and elimination of below ground personnel make UCG applicable to many deposits, which would otherwise be unsafe, un-mineable or sub-economic (Eskom, 2009a; PWC, 2008). The “coal miners” are essentially drillers, who work from the surface using conventional drilling technologies to access the coal resource. Their work environment is therefore much more controllable, and safer. The shorter coal value chain from resource-in-the-ground to end-product enables UCG to produce lower cost energy than with conventional mining. Due to the absence of personnel below surface, this type of operation also has advantages in terms of safety.

Figure 17: Simplified depiction of the UCG process.
Although UCG is not a new technology, it has not been widely applied on an industrial scale. Early development of the UCG concept was undertaken at the beginning of the 20th century, but was interrupted by the outbreak of the First World War (Klimenko, 2009). The first experiments and longest experience of UCG application have been in the Soviet Union, where several industrial-scale plants were developed from 1937 onwards. Soviet interest waned after the discovery of Siberian natural gas in the 1960s, but one site is still in operation in today’s Uzbekistan, where the industrial-scale Angren electricity plant runs on UCG syngas (PWC, 2008; Shafirovich et al., 2008; Klimenko, 2009). Interest in UCG was rekindled in the US during the 1970s and 80s, with several experimental plants constructed, and in recent years high energy prices have revived interest. It is estimated that there have been over 50 tests or pilot operations worldwide to date (PWC, 2008). The Chinchilla pilot plant in Queensland, Australia, is particularly noteworthy, having run from 1999 to 2003, producing 80 million normal m$^3$ of syngas at 4.5 - 5.7 MJ/m$^3$. It demonstrated process controllability as well as controlled shutdown and restart, with minimal environmental impacts detected (Shafirovich et al., 2008).

In South Africa UCG technologies have been explored by Eskom and Sasol. Eskom has developed a pilot plant on the previously un-mineable Majuba coalfield, which began flaring gas in 2007 (Eskom, 2009a). In October 2010 their Majuba power station began co-firing UCG syngas with its conventional coal fuel, contributing 3 MW to the station’s electricity production (Eskom, 2010b). Eskom is also considering the possibility of direct power generation from syngas in the future (Eskom, 2009a), with plans to commission an open-cycle gas turbine demonstration plant of between 100 and 140 MW in 2015 (Eskom, 2010c). Ergo Exergy, the technology provider for the Chinchilla plant in Australia, has been involved with the Majuba UCG program (Shafirovich, et al., 2008; Eskom, 2009a). Sasol has also shown an interest in UCG to produce syngas for their liquid fuels and chemicals production processes, reportedly having completed basic engineering designs for a demonstration plant at Secunda (Prinsloo, 2009). Subsequently the plans for the demonstration plant at Secunda have been shelved.

One of the significant advantages of UCG is that it could be applied to coal deposits which might be unviable for conventional mining. Table 13 gives a compilation of suitable characteristics for coal extraction by UCG.

Table 13: Compilation of desired coal deposit characteristics for UCG.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>&gt;200 m</td>
<td>100 – 600 m</td>
<td>&gt;150 m</td>
<td>30 – 800 m</td>
</tr>
<tr>
<td>Thickness</td>
<td>&gt;0.4 m</td>
<td>&gt;5 m</td>
<td>&gt;1.5 m</td>
<td>0.5 – 30 m</td>
</tr>
<tr>
<td>CV/rank</td>
<td>&gt;8 MJ/kg</td>
<td>bituminous and lower rank</td>
<td>8.0 - 30.0 MJ/kg</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>&lt;80%</td>
<td>&lt;60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Absence of any good-quality aquifers</td>
<td>Must be below water table; Not a potable water source (TDS &gt; 1000 ppm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geology</td>
<td>competent roof structure</td>
<td>Minimal seam discontinuities</td>
<td>Strong/rigid overlying strata preferable</td>
<td>Dip 0 – 70°</td>
</tr>
<tr>
<td>Other</td>
<td>Volatiles &gt;8%</td>
<td>Ample access for drilling and monitoring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.2 Coal producers in South Africa

The main coal producers in South Africa are Anglo American’s Thermal Coal business unit, Exxaro, Sasol Mining, BHP Billiton and Xstrata, as demonstrated in Figure 18 below.

Figure 18: Coal mining capacities of the largest coal mining companies in South Africa, 2008

The mining operations and recent production volumes are presented in the following sections for both these companies and smaller players. Brief consideration is also given to mining contractors.

6.2.1 Anglo American

Anglo American’s Thermal Coal business unit in South Africa is the largest coal producer in the country (Chamber of Mines, 2009a). Five mines located in the Witbank coalfield, namely: Goedehoop, Greenside, Kleinkopje, Landau and Zibulo, provided 22 Mt of mostly thermal coal to both export and local markets in 2009, while around 747 kt of metallurgical coal was produced and exported in the same period (Anglo American, 2010a).

Table 14: Anglo American coal mines in South Africa

<table>
<thead>
<tr>
<th>Mine</th>
<th>Opencast U/ground</th>
<th>Coalfield</th>
<th>Main Market</th>
<th>Ownership (%)</th>
<th>Mt 2010</th>
<th>Mt 2009</th>
<th>Mt 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goedehoop</td>
<td>U</td>
<td>Witbank</td>
<td>Export</td>
<td>100</td>
<td>6</td>
<td>8.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Greenside</td>
<td>U</td>
<td>Witbank</td>
<td>Export</td>
<td>100</td>
<td>3.4</td>
<td>3.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Kleinkopje</td>
<td>O</td>
<td>Witbank</td>
<td>Export</td>
<td>100</td>
<td>4.4</td>
<td>4.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Landau</td>
<td>O</td>
<td>Witbank</td>
<td>Export</td>
<td>100</td>
<td>4.0</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Kriel</td>
<td>U/O</td>
<td>Witbank</td>
<td>Eskom Kriel</td>
<td>73</td>
<td>9.5</td>
<td>11.1</td>
<td>10.3</td>
</tr>
<tr>
<td>New Denmark</td>
<td>U</td>
<td>Highveld</td>
<td>Eskom Tutuka</td>
<td>100</td>
<td>5.0</td>
<td>3.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Mafube</td>
<td>O</td>
<td>Witbank</td>
<td>Eskom Amot</td>
<td>50</td>
<td>2.4</td>
<td>2.2</td>
<td>1.7</td>
</tr>
<tr>
<td>New Vaal</td>
<td>O</td>
<td>Vereeniging-Sasolburg</td>
<td>Eskom Lethabo</td>
<td>100</td>
<td>17.2</td>
<td>17.5</td>
<td>17.0</td>
</tr>
<tr>
<td>Isibonelo</td>
<td>O</td>
<td>Highveld</td>
<td>Sasol</td>
<td>100</td>
<td>4.5</td>
<td>5</td>
<td>5.1</td>
</tr>
<tr>
<td>Nooitgedacht</td>
<td>U</td>
<td>Highveld</td>
<td>Sasol</td>
<td>100</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Zibulo</td>
<td>U/O</td>
<td></td>
<td></td>
<td>73</td>
<td>1.6</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60.4</td>
<td>59.2</td>
<td></td>
</tr>
</tbody>
</table>

(Records: Eberhard, 2011; Anglo American, 2010a)
In 2010, sales to Eskom accounted for 62% of total Anglo Thermal Coal sales in South Africa. The dedicated coal mines (Kriel and New Denmark in Mpumalanga Province, and the New Vaal mine at Vereeniging, Mafube) have cost-plus, life of mine contracts with the power generator (Anglo American, 2010a).

In 2010, 8% of sales within South Africa were made to Sasol from the Isibonelo mine as part of a long-term contract; 2% of sales were to local industrial sector consumers and the remaining 28% of sales were exported through the RBCT to the main markets of Asia and Europe (Anglo American, 2010a). Exports to Asia increased from 41% of total exports in 2009 to 65% in 2010 as a result of an increase in exports to mainly India. Exports to European markets declined to 30% in 2010 from 42% in 2009 (Anglo American, 2010a).

Anglo Inyosi Coal was established in 2007. It is a broad-based economic empowerment company in which Anglo-America owns 73% and Inyosi, a BEE consortium, owns 27% (Anglo American, 2010b). The new company incorporates several key Anglo Coal SA assets, namely the Kriel colliery and the new projects of Zibulo, Elders, Zondagsfontien, New Largo and Heidelberg (Anglo American, 2010b). Anglo American Thermal Coal announced its intention to dispose of its Kleinkopje Colliery and commenced a formal sale process of the asset in February 2011.

### 6.2.2 Exxaro

Exxaro originated from a black empowerment transaction which merged Eyesizwe, previously a collection of divested coal assets of Anglo American and BHP Billiton, and the unbundled iron ore assets of Kumba Resources (Exxaro, 2011a).

The group owns and operates several coal mines in South Africa (Table 15). In 2010, it produced 46.7 Mt coal, with 79% being thermal coal for Eskom; 16% steam coal; and the remaining 5% coking coal (Exxaro, 2010a).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnot</td>
<td>U</td>
<td>Witbank</td>
<td>Eskom: Arnot</td>
<td>4.9</td>
<td>5.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Matla</td>
<td>U</td>
<td>Witbank</td>
<td>Eskom: Matla</td>
<td>13.2</td>
<td>11.3</td>
<td>12.3</td>
</tr>
<tr>
<td>North Block Complex</td>
<td>O</td>
<td>Witbank</td>
<td>Eskom</td>
<td>2.7</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>North Block Complex</td>
<td>O</td>
<td>Witbank</td>
<td>Domestic</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>New Clydesdale</td>
<td>U</td>
<td>Witbank</td>
<td>Eskom</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Clydesdale</td>
<td>U</td>
<td>Witbank</td>
<td>Export</td>
<td>1.0</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Leeuwpan</td>
<td>O</td>
<td>Witbank</td>
<td>Eskom</td>
<td>1.2</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td>Leeuwpan</td>
<td>O</td>
<td>Witbank</td>
<td>Domestic + Export</td>
<td>1.8</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Inyanda</td>
<td>O</td>
<td>Witbank</td>
<td>Export</td>
<td>0.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Tshikondeni</td>
<td>U</td>
<td>Soutpansberg</td>
<td>Hard coking: ArcelorMittal</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Grootgeluk</td>
<td>O</td>
<td>Waterberg</td>
<td>Eskom: Matimba</td>
<td>14.6</td>
<td>15.3</td>
<td>14.9</td>
</tr>
<tr>
<td>Grootgeluk</td>
<td>O</td>
<td>Waterberg</td>
<td>Steam coal</td>
<td>1.4</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Grootgeluk</td>
<td>O</td>
<td>Waterberg</td>
<td>Semi-soft coking</td>
<td>2.2</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Mafube Coal</td>
<td>O</td>
<td>Middelburg</td>
<td>Eskom: Arnot</td>
<td></td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Mafube (50%)</td>
<td>O</td>
<td>Middelburg</td>
<td>Export</td>
<td>0.8</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>44.8</td>
<td>45.2</td>
<td>46.7</td>
</tr>
</tbody>
</table>

(Source: Exxaro, 2010a and Eberhard, 2011)

At production volumes of 12.3 Mtpa and 14.9 Mtpa respectively, Matla and Grootgeluk mines produce the majority of Exxaro’s thermal coal for Eskom. Exxaro has an export entitlement at the Richards Bay Coal Terminal of 6.3 Mtpa (Exxaro, 2011b).
6.2.3 Sasol

The principal coal feedstock to Sasol's coal liquefaction processes is provided by Sasol Mining (Pty) Ltd, which mines in the Highveld coalfield to produce 43 to 46 Mtpa (Eberhard, 2011). The majority of this coal is consumed by CTL, power requirements and chemicals processing at the group's Secunda facilities. Around 1.7 Mtpa of thermal coal is supplied to the Infrachem plant power generators by Sigma: Mooikraal mine at Sasolburg (Eberhard, 2011).

As described above, Sasol Mining acquires approximately 5 Mtpa from the Isibonelo mine owned by Anglo American. Other Sasol mines operated in the Highveld coalfield include Twistdraai which produces around 3.6 Mtpa coal for export purposes (Eberhard, 2011). Twistdraai is mined by bord and pillar and is fitted with a coal washing plant. The output from the mine is split as follows: 40% low ash steam coal of washed quality which is exported to Europe, 40% middlings for Synfuels processing and 20% fine, discard coal (Mining Technology, undated; Eberhard, 2011).

An empowerment transaction between WIPCoal Investments and Sasol was concluded in 2010 and resulted in the formation of Ixia Coal (Webb, 2010). It is South Africa's first black women owned and operated mining company. A 100% subsidiary of Ixia Coal, Ixia Coal Funding owns 20% of Sasol Mining (Pty) Ltd. The shareholding structure of Ixia Coal is described by Webb (2010).

6.2.4 BHP Billiton

BHP Billiton is a world-leading producer and marketer of export thermal coal with coal mining operations in the United States of America, Australia and South Africa and elsewhere (BHP Billiton, 2011). The company originated in the merger between Billiton, one of the world's premier mining companies, and Australia's BHP, a leading global mineral resources company (BHP Billiton, 2010).

BHP Billiton Energy Coal South Africa (BECISA) produced 30.3 Mt in 2010 from three collieries.

Table 16: BHP Billiton coal mines in South Africa (2008)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas/Middelburg</td>
<td>84</td>
<td>O/U</td>
<td></td>
<td>Witbank</td>
<td>Eskom Kendal, Duvha &amp; export</td>
<td>17.0</td>
<td>14.8</td>
<td>14.7</td>
</tr>
<tr>
<td>Khutala</td>
<td>100</td>
<td>U</td>
<td></td>
<td>Witbank</td>
<td>Eskom Kendal</td>
<td>13.3</td>
<td>11.1</td>
<td>10.8</td>
</tr>
<tr>
<td>Klipspruit</td>
<td>100</td>
<td>O</td>
<td></td>
<td>Witbank</td>
<td>Export</td>
<td>3.4</td>
<td>3.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Optimum</td>
<td>Sold to Optimum Holding</td>
<td>O</td>
<td></td>
<td>Witbank</td>
<td>Eskom Hendrina &amp; export</td>
<td>11.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45</td>
<td>29.8</td>
<td>30.3</td>
</tr>
</tbody>
</table>

(Eberhard, 2011 and BHP Billiton, 2010)

As part of a recent black empowerment transaction, the Optimum colliery was sold in 2008 along with a 6.5 Mtpa export entitlement at the Richards Bay Coal Terminal (Optimum Coal, 2010). This affected BHP Billiton’s ranking amongst the largest coal producers in South Africa, as it now ranks fourth after Anglo, Exxaro and Sasol.

BECISA supplies coal to Eskom’s Duvha and Kendal power stations respectively on a fixed price, guaranteed volume contract and a cost plus arrangement (Eberhard, 2011).

After the sale of Optimum, BHP Billiton retained a 17.95 Mtpa export entitlement in the Richards Bay Coal Terminal (Eberhard, 2011).

6.2.5 Xstrata

Xstrata is a multinational, multiproduct company with operations in Canada, Australia, South Africa and Colombia. Xstrata is the world’s largest producer and exporter of thermal coal; its South African operations originated through the sale of Duiker Mining Ltd and Tweefontein Collieries Ltd, the South African coal mining interests of Lonmin plc, to Glencore (Xstrata, 2011).

Of the 18.7 Mt coal sold by Xstrata Coal South Africa in 2010, 11.1 Mt was export thermal coal while 6.6 Mt was sold locally to Eskom (Xstrata, 2010a).
Table 17: Xstrata’s South African coal mines

<table>
<thead>
<tr>
<th>Mine</th>
<th>O/cast</th>
<th>U/ground</th>
<th>Coalfield</th>
<th>Ownership (%)</th>
<th>2009 [Mtpa] (100% production)</th>
<th>2010 [Mtpa] (100% production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southstock</td>
<td>O</td>
<td></td>
<td>Witbank</td>
<td>79.8</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Southstock</td>
<td>U</td>
<td></td>
<td>Witbank</td>
<td>79.8</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Mpumalanga: Spitzkop</td>
<td>O/U</td>
<td></td>
<td>Ermelo</td>
<td>79.8</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Mpumalanga: Tselentis</td>
<td>O/U</td>
<td></td>
<td>Ermelo</td>
<td>79.8</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Impunzi</td>
<td>O</td>
<td></td>
<td>Witbank</td>
<td>79.8</td>
<td>4.0</td>
<td>4.4</td>
</tr>
<tr>
<td>Tweefontein</td>
<td>O</td>
<td></td>
<td>Witbank</td>
<td>79.8</td>
<td>3.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Tweefontein</td>
<td>U</td>
<td></td>
<td>Witbank</td>
<td>79.8</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Goedgevonden</td>
<td>O</td>
<td></td>
<td>Witbank</td>
<td>74</td>
<td>3.0</td>
<td>4.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.7</td>
<td>18.7</td>
</tr>
</tbody>
</table>

(Sources: Eberhard, 2011; Xstrata, 2010a)

African Rainbow Minerals (ARM), a black empowerment company, owns 10% direct interest in Xstrata Coal South Africa (XCSA) (Eberhard, 2011). XCSA owns 20.9% of the Richards Bay Coal Terminal Company Ltd (Xstrata, 2010b).

6.2.6 Smaller producers

Smaller coal producers include Optimum Coal, Umcebo Mining, Siyanda Coal, Kangra, Shanduka, Coal of Africa, Anker Coal and Riversdale. Sales volumes for mines operated by a selection of these companies and other smaller concerns are listed below.

Table 18: Smaller South African coal mining companies

<table>
<thead>
<tr>
<th>Company – Coal mine(s)</th>
<th>Sales [Mt]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum Coal – Optimum</td>
<td>9.5</td>
</tr>
<tr>
<td>Umcebo Mining – Xantium</td>
<td>6.6</td>
</tr>
<tr>
<td>Siyanda Coal – Koornfontein</td>
<td>3.6</td>
</tr>
<tr>
<td>Kangra – Savmore</td>
<td>2.7</td>
</tr>
<tr>
<td>Kuyasa – Delmas</td>
<td>1.6</td>
</tr>
<tr>
<td>Total Coal SA</td>
<td></td>
</tr>
<tr>
<td>Forzando North</td>
<td>1.0</td>
</tr>
<tr>
<td>Forzando South</td>
<td>0.8</td>
</tr>
<tr>
<td>Dorstfontein</td>
<td>0.5</td>
</tr>
<tr>
<td>Tweewaters Fuel – Springlake</td>
<td>0.4</td>
</tr>
</tbody>
</table>

(Source: Chamber of Mines, 2009a)

6.2.7 Mining contractors

Contractors provide a host of services to the coal mining sector, including mine operation, management, rehabilitation, earth moving services, equipment, drilling and blasting and others. A selection of the larger companies which offer such services includes Benecon (a subsidiary of Sentula Mining), Buildmax, Concor Mining (a subsidiary of Murray and Roberts) and Minxcon. A whole host of smaller contractors also exists, typically specialising in their service offerings.

6.3 Economic contribution of the coal mining industry

In 2009 the coal mining industry contributed roughly R 42 billion (approximately 1.8%) to South Africa’s gross domestic product (Figure 19) (StatsSA, 2010). If a GDP multiplier of 2.5 (as mentioned in Chamber of Mines, 2009a) is applied, it is estimated that a further R 63 billion of GDP was related to coal mining activity as a result of the economic activity of firms that supplied the coal mining industry (indirect effects) and increased expenditure from households as a result of income and other financial flows derived from the mining industry (induced effects).
### 6.3.1 Income and investment

In addition to the value added in the coal mining industry (GDP impact), coal mining also generates significant income, a large proportion of which is invested back into the mining industry to support future growth.

Coal and lignite mining was the largest generator of income in the South African mining sector by commodity grouping in 2009 (Figure 20). The latest data with respect to the value of sales by commodity grouping only, for the 11 months ending November 2010, however, shows that coal ranked second behind platinum group metals, with total sales of roughly R 64 billion versus that of platinum group metals of roughly R 67 billion (see Figure 21).

#### Figure 20: Income in the South African mining industry, 2009 (R million)

- **Coal and lignite** 123,975 (28%)
- **Other mining activities** 124,666 (29%)
- **Manganese ore** 28,645 (7%)
- **Gold and uranium ore** 53,552 (12%)
- **Platinum group metal ore** 106,362 (24%)

#### Figure 21: Value of sales by mineral type, Jan – Nov 2010 (R million)

- **Coal** 63,580 (24%)
- **Iron ore** 38,987 (14%)
- **PGMs** 67,364 (25%)
- **Gold** 48,324 (18%)
- **Other** 52,434 (19%)

(Source: StatsSA, 2009) (Source: StatsSA, 2010)

---

9 Figure 22 and Figure 23 are, however, not directly comparable since the latter only includes the value of sales, while the former also includes other sources of income to the mining industry like fees for services rendered, interest on financial assets, dividends etc (see StatsSA, 2009).
The vast majority of income in the coal mining sector (99.57%) accrues to large enterprises (StatsSA, 2009). Interestingly, micro enterprises in the coal mining industries together earned roughly twice as much of total income of medium and small enterprises combined (R 359 m vs. R 170 m) in 2009. Although the reason for this is unclear, and requires further analysis, it could indicate that there are limited economies of scale in coal mining below a certain production size threshold.

The coal mining industry ploughs a relatively large portion of its income back into the local mining industry, and in 2009 invested R 19.8 billion (it was the second largest source of investment in the South African mining industry in that year) (StatsSA, 2009). Investment in coal mining (as is the case for platinum group metals) is relatively high compared to the rest of the mining industry (StatsSA, 2009). Investment in the South African mining industry in that year was R 359 billion, with coal mining (42.5%) comprising purchases. Coal mining industry is responsible for the largest chunk of operational expenditure within the local mining industry, accounting for almost a third of total expenditure.

The bulk of operational expenditure within the coal mining industry (42.5%) comprises purchases. Coal mining procurement is thus expected to be an important stimulator of secondary activity in and around the local communities in which it operates (Table 19).

### 6.3.2 Operational expenditure patterns

The significant impact of the coal mining industry on the South African economy highlighted above is in part due to its strong linkages with other sectors and local suppliers. The coal mining industry is responsible for the largest chunk of operational expenditure within the local mining industry, accounting for almost a third of total expenditure.

The bulk of operational expenditure within the coal mining industry (42.5%) comprises purchases. Coal mining procurement is thus expected to be an important stimulator of secondary activity in and around the local communities in which it operates (Table 19).

#### Table 19: Operational expenditure within the coal industry by category (2009)

<table>
<thead>
<tr>
<th>Expenditure category</th>
<th>[R million]</th>
<th>[%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries and wages</td>
<td>16,774</td>
<td>16.3%</td>
</tr>
<tr>
<td>Purchases</td>
<td>43,724</td>
<td>42.5%</td>
</tr>
<tr>
<td>Depreciation</td>
<td>6,266</td>
<td>6.1%</td>
</tr>
<tr>
<td>Amortisation</td>
<td>568</td>
<td>0.6%</td>
</tr>
<tr>
<td>Rental of land</td>
<td>410</td>
<td>0.4%</td>
</tr>
<tr>
<td>Operational leasing and hiring of plant, machinery equipment</td>
<td>424</td>
<td>0.4%</td>
</tr>
<tr>
<td>Interest</td>
<td>6,302</td>
<td>6.1%</td>
</tr>
<tr>
<td>Computers</td>
<td>8</td>
<td>0.0%</td>
</tr>
<tr>
<td>Insurance</td>
<td>423</td>
<td>0.4%</td>
</tr>
<tr>
<td>Losses on assets</td>
<td>3,987</td>
<td>3.9%</td>
</tr>
<tr>
<td>Losses on liabilities</td>
<td>480</td>
<td>0.5%</td>
</tr>
<tr>
<td>Losses on foreign exchange</td>
<td>1,861</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

(Source: StatsSA, 2009)

#### 6.4 Existing coal sector policy status

The only formal policy pertaining to the coal sector specifically is the 1998 Energy White Paper. Coal is briefly addressed, in only three pages, with the stated government energy policy for the coal industry being “to maintain a successful and competitive coal market, ensure the efficient utilisation of coal resources and reduce the environmental impacts associated with coal usage” (DME, 1998).

A few areas of specific government activity are additionally referred to, being:

- Continued updating of the national coal resource/reserve database,
- Establishing the resource potential of coal bed methane,
- Monitoring and supporting clean coal technologies, including incentives and/or penalties to facilitate the uptake of these technologies,
- Continued support of efficient coal use by industry,
- A low smoke fuels programme aimed at replacing the use of coal at household level, and
- Continued investigation of the use of discard streams.

The overall formal coal sector policy approach can therefore be summarised as a hands-off one, with an intention to monitor the progress of the sector against the aims of ensuring a successful coal market, efficient utilisation of the coal resources and reduction of environmental impacts.

This has not always been the case. Government has played a policy role of varying degrees and with varying focus in the SA coal sector over the past 100 years, with coal policy being spread across different governments at various times.

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10 StatsSA (2009), using Department of Trade and Industry cut-offs, defines size groupings in the mining industry as follows: large enterprises (turnover > R 39 million), medium enterprises (R 10 million ≤ turnover < R 39 million), small enterprises (R 4 million ≤ turnover < R 10 million), micro enterprises (< R 4 million).
Even today coal related policy-making is spread across many departments including Mineral Resources, Energy, Public Enterprises, Transport, Treasury, Water Affairs and the Environment. The policy approach was initially focused on coal as a mineral resource, but changed to having an industrial focus in the 1970's and 80's, with Sasol and Eskom investing heavily on the basis of coal. The price of domestic coal has been regulated in South Africa's past, and coal exports were restricted for many decades prior to the 1970s. Only in 1992 did government remove all its controls from the coal sector (DME, 1998).

The context within which the coal sector operates has evolved significantly since the last decade of the twentieth century when the Energy White Paper was developed, and it is argued that an updated, strategic and coherent coal policy vision is now overdue (Eberhard, 2011). Pressure is building particularly with regard to the mining investment environment, export opportunities, domestic energy security, and greenhouse gas reductions.

In areas directly impacting on specific elements of the coal value chain there is a far more detailed policy space, particularly relating to reserves and resources, mining and beneficiation, electricity, the environment and socio economic aspects. These policies and their governing and implementing institutions do not necessarily cohere well, and at the level of legislation, there is a need for consolidation and repealing of outdated pieces or parts of legislation. For example, there are currently 33 pieces of legislation just pertaining to the mining sector (Policy Focus Group, 2010).

The issue of mine nationalisation has become a popular favourite recently after a strong lobby from the ANC’s Youth League. The government has commissioned independent research into the proposal, and the Minster of Mineral Resources and her Cabinet colleagues have declared mine nationalisation is not current government policy. Other issues which dominate the current policy discourse include the role of mining in the achievement of employment targets, the importance of beneficiation in this, and the need to attract investment to take advantage of the ongoing export opportunities in commodities. A final policy consideration which has been in the press recently relates to coal being considered by government as a “strategic resource”, and whether measures should be put into place to protect local energy security through limiting exports of certain grades of coal.

6.5 Likely evolution of the South African coal mining industry

Generally, short and medium term growth in coal production has been predicted to be positive. In the next five years, production in South Africa is predicted to increase from 260 Mtpa in 2010 to 333 Mtpa in 2015, and beyond 2019 new ventures are anticipated to continue this trend (Wood Mackenzie, 2010a). This growth trend in South African coal production is anticipated in response to increased growth in domestic power and export demand as shown in Figure 22 (Wood Mackenzie, 2010a).

Figure 22: Marketable production by market

![Figure 22: Marketable production by market](source: Wood Mackenzie, 2010a)
6.5.1 Production by market

South African coal companies aim to increase exports amidst demand from growing markets in Asia and India. For example, demand for imported thermal coal in 2010 rose by 40% and 15% year-on-year in China and India respectively in the 2009-2010 period (Anglo American, 2010a). Thermal coal exports are predicted to increase from 72 Mtpa in 2010 to 93 Mtpa in 2017 while metallurgical coal exports (including anthracite fines for export PCI market) are anticipated to rise to 7.8 Mtpa in 2020 from 1.3 Mtpa in 2010 as shown in Figure 23 (Wood Mackenzie, 2010a).

Figure 23: Marketable production by coal type

[Graph showing marketable production by coal type from 2008 to 2026]

(Source: Wood Mackenzie, 2010a)

6.5.2 Production by coal type and region

While it is estimated that in South Africa thermal coal currently represents 98% of coal produced, this share is expected to decline marginally to 95% by 2019 in anticipation of three coking coal projects owned by Coal of Africa which are to come online in the Soutpansberg coalfield, as described next.

The first phase of the Vele mine commenced in 2010 with the establishment of a modular coal treatment plant and the second phase involves the scale-up to 5 Mtpa production (Coal of Africa Ltd., 2010a). Production at the Makhado mine is anticipated to commence in 2013 (Reuters, 2010) with full-scale operation projected to produce around 5 Mtpa (Coal of Africa Ltd., 2010b). Chapudi Coal Project, a combined thermal and coking coal project is anticipated to come on stream in 2017.

Growth in coal production will largely take place in the thermal coal contingent while metallurgical coal will represent 12% of coal production from new projects by 2020 (Wood Mackenzie, 2010a). Although the Waterberg coalfields will be mined increasingly in the future, the Witbank and Highveld coalfields are predicted to maintain their position as the major producing regions (Wood Mackenzie, 2010a). Of the six new metallurgical coal projects planned (including Vele, Makhado and Chapudi), five will be in the Limpopo province.

It is noted that the last large unexplored metallurgical coal deposit in the world is in Mozambique. Production from Mozambique is expected to increase substantially in the next few years. This will likely give rise to a large unused source of middlings coal, which could be utilised either in Mozambique or regionally.

6.5.3 New production projects by coal mining companies

Expansion plans of the major coal mining companies are presented briefly below. A complete list of new projects and predicted production data is available (Wood Mackenzie, 2010b).

6.5.3.1 Anglo American

The Zibulo (formerly Zondagsfontein project) underground and opencast multi-product mine with beneficiation plant represents the main development project under Anglo American (Wood Mackenzie, 2010b). The production at Zibulo colliery is to be progressively ramped up to reach full capacity 5.3 Mtpa thermal coal in 2012 (Anglo American, 2010a). This mine will supply coal to the export market and supplement the feed to Kusile which will be provided largely by New Largo mine (Anglo American, 2010a). Anglo Inyosi Coal is said to have pledged the supply of 17 Mtpa to Eskom’s new Kusile power station near Witbank over a period of 47 years (Eskom, 2010d). Production at jointly owned Mafube mine is being increased and an extension of the New Vaal colliery is also planned (Eberhard, 2011).
6.5.3.2 Exxaro

Exxaro has entered into a coal supply agreement with Eskom spanning 40 years to supply 14.6 Mtpa to Eskom's new coal-fired plant, Medupi, from an expansion on the Grootgeluk mine in the Waterberg coalfield (Eberhard, 2011). Presently, the Grootgeluk mine and adjoining coal beneficiation plant make Exxaro the sole coal producer in the Waterberg (Eberhard, 2011).

6.5.3.3 Sasol

Sasol mines are owned by Sasol Mining which is 20% owned by Ixia Coal Funding and are located primarily in Mpumalanga with one operation in the Free State (Brandspruit, Bosjespruit, Middelbult, Twistdraai, Syferfontein and Sigma: Mooikraal). The proposed greenfields Mafutha Project is to obtain coal from the Limpopo's Waterberg region from Exxaro and Sasol's own mining initiatives in the Waterberg (Wood Mackenzie, 2010a). Project Mafutha may come on stream in 2016 requiring 10 Mtpa of thermal coal by 2019 (Wood Mackenzie, 2010a). Production from the diminishing reserves of the original Twistdraai shafts and Brandspruit mine will be replaced respectively by the new Twistdraai Thubelisha shaft in the north-east and the Imphumulelo mine in the south-western portion of the Secunda complex respectively. (Eberhard, 2011). The Shondoni project is intended to replace Middelbult by 2015.

6.5.3.4 BHP Billiton

The chief development project for the operations of BHP Billiton Energy Coal South Africa is the Douglas-Middelburg Optimisation Project. This project aims to “optimise development of existing reserves” across Douglas and Middelburg collieries and includes the “development of additional mining areas and construction of a new 14 Mtpa coal processing plant”, a joint venture with Anglo Coal (BHP Billiton, 2010). Coal production commenced in mid-2010 and the coal processing plant, which is to replace the existing facility, is under construction (BHP Billiton, 2010).

6.5.3.5 Xstrata

Investment of USD 2 billion is planned in an effort to develop four local projects in the next five years, including the 2010 commissioned major expansion in open cut mining at Goedgevonden mine (6.8 Mtpa and 4.5 Mtpa), and planned optimisation of Tweefontein and Atcom East (2 Mtpa) and a new mine, Zonnenbloem (7 – 12 Mtpa) (Eberhard, 2011). The ATCOM and Tweefontein expansion projects represent two of the three large-scale, lower-cost, open-cut mine complexes which after Goedgevonden will eventually account for 90% of Xstrata Coal’s South African production (Xstrata, 2010b).

6.5.4 Opportunities and challenges facing the coal mining industry in the future

In looking at the future of the mining industry, a number of opportunities and challenges are identified. These are covered in detail elsewhere in this document, however they are worth summarising in the context of the discussion on the future of the industry:

- Taking advantage of current high export prices and tapping into new markets, particularly in Asia;
- Maximising these export opportunities (both in terms of monetary value and job creation);
- Utilising coal from Botswana;
- Utilising middlings from Mozambique. The middlings product from the coking coal produced is currently a stranded asset;
- Utilising coal discard dumps and slimes dumps;
- Utilising acid mine drainage (AMD);
- Extraction of remaining coal pillars in bord and pillar mined panels, by use of ash backfill. The constraint to wide use implementation of ash backfill includes, but is not limited to the perceived risk to groundwater pollution.

The primary challenges relate to infrastructure, particularly that required to access export markets (i.e. rail capacity at RBCT and a new rail corridor to the Waterberg), and the lack of consistent policies.
COAL PREPARATION AND BENEFICIATION

Extraneous, non-combustible matter in coal includes stones, rocks, wood, ash-forming minerals (silicates, sulphides and carbonates), as well as moisture. These materials reduce the energy content or heating (calorific) value; increase the volumes of material to be handled and transported; increase the wear and tear on handling and combustion equipment; and result in hazardous gaseous and particulate emissions during combustion. The preparation (also known as the cleaning, processing or beneficiation) of run-of-mine (ROM) coal, i.e. the raw, unprocessed coal that is mined, essentially entails the removal of these unwanted impurities, thereby generating a uniform product that is more suitable for transport and commercial markets.

Coal preparation can be considered to occur in two distinct stages: screening (stage 1) and washing (stage 2). In the screening stage, large foreign objects are first removed (scalping), after which the ROM coal is crushed to reduce overall topsize, followed by screening to separate the coal into various size fractions—either for direct sale or for further processing by washing. Coal washing, also known as coal beneficiation, is conducted to reduce the content of ash-forming minerals, thus meeting product specifications that cannot be achieved by screening alone. Coal is typically washed using density separation techniques, due to the differences in density of the inorganic, ash-forming minerals and the valuable carbon in the coal. A major portion of coal beneficiation in South Africa is done to separate the coal into distinct products, a high value export product and a lower value middlings product for local consumption. The waste containing the ash-forming minerals is commonly termed discard.

In accordance with available statistics (Prevost, 2010), approximately 60% of the 312 Mtpa raw coal mined in South Africa in 2007 was beneficiated, resulting in a conversion of ROM coal to washed saleable coal of 41% and to raw (unwashed) saleable coal of 39%. These values indicate a considerable decline in the proportion of washed ROM ore in comparison with 2002/2004 data as reported by de Korte (2004) and Reddick (2006), which indicated that between 80 and 85% of the ROM is washed in some 60 washing plants. Values for overall product yields (typically 76 – 80% of the ROM coal) and deportment to discards (typically 21 – 24% of ROM coal) have, however remained relatively consistent over the past decade. Figure 24 presents the relative proportions of ROM coal that are screened and washed, and ultimately recovered as saleable coal product (including raw coal and beneficiated product) for 2007 (Prevost, 2010).

Figure 24: South African coal chain showing relative distributions of ROM coal

Total saleable coal production has increased from values of around 220 Mtpa at the turn of the century, to current values in the region of 250 Mtpa.
7.1 Coal products and uses

Buyers usually specify the quality of coal products on the basis of characteristics (such as calorific value, ash-forming minerals, sulphur content, total moisture content and volatile matter), and the degree to which the ROM coal is washed (if at all) is thus determined by these specifications. Some of the typical characteristics of local ROM coal and coal products are presented in Table 20.

Table 20: Typical characteristics of South African ROM coal and coal products

<table>
<thead>
<tr>
<th></th>
<th>ROM coal</th>
<th>Metallurgical coal</th>
<th>Export coal</th>
<th>Synfuel coal</th>
<th>Thermal coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur [%]</td>
<td>&lt; 2</td>
<td>&lt; 1.5</td>
<td>0.6 – 0.7</td>
<td>1 – 2</td>
<td>0.7 – 2</td>
</tr>
<tr>
<td>Calorific value [MJ/kg]</td>
<td>16 - 21</td>
<td>n/a</td>
<td>25 – 27</td>
<td>&lt; 21</td>
<td>19 – 23</td>
</tr>
<tr>
<td>Ash [%]</td>
<td>20 – 40</td>
<td>&lt; 15</td>
<td>20 – 35</td>
<td>30 – 35</td>
<td></td>
</tr>
</tbody>
</table>

(Source: (a) de Korte, 2007; Jordan, 2006; (b) Eberhard, 2011; (c) Koper, 2004; (d) Eskom, 2010, cited Eberhard, 2011)

Although relatively low in sulphur (< 2%), South African coal is generally considered to be low grade by international standards, typically having an ash content in the region of 20 – 30% (Eskom, 2010a). Ash contents in the 30 – 40% range are, however, becoming more common, with values as high as 65% having been reported in ROM coal from the Waterberg region (Eberhard, 2011). Metallurgical (also known as coking coal, mainly used in steel production) and export coal grades require washing to reduce the ash content and improve the calorific value. Historically calorific values of between 26 and 27.5 MJ/kg have been required for export grade coal, but average values are declining to less than 25 MJ/kg in some cases and coal with a calorific value as low as 23 MJ/kg is acceptable in India (Eberhard, 2011). Local thermal or steam coal (i.e. coal used for power generation) and coal for synthetic fuel production have much higher ash and lower calorific values, and in many cases local coals can be used without washing. A significant quantity of the coal feed to local power stations (all using conventional pulverised coal technology) and Sasol’s coal-to-fuel plant is, however, derived from the middlings fraction of the export coal washing plants. According to statistics presented by Prevost (2010), only 27% of the coal used for electricity production and < 10% of the coal used for synthetic fuel production was derived from the washed middlings coal after beneficiation in 2007. It should be noted that the need for, and extent of, coal washing is not dictated solely by the ROM coal grade and product specifications. Transport costs account for a significant proportion of the delivered product cost, and hence power plants remote from mines are often supplied with washed coal with higher calorific value (carbon content) for purely economic reasons. Many coal mining operations are viable operations based on the production of a dual product – beneficiated coal for export and a middlings product, suitable for local consumption, after removal of a discard portion. Many of these operations will not be viable if only one of the two products must be produced, not to mention the potential waste of natural resources this potentially represents.

An indication of the relative distributions of saleable coal is provided in Figure 25.

Figure 25: South African coal chain showing relative distributions of saleable coal

(Source: adapted from Prevost, 2010)

11 According to general international standards, high grade bituminous coal typically has a low ash (< 7% ash) and 8% moisture content; thermal coal a medium ash (10 – 12%) and 9% moisture content; and low grade bituminous coal a high ash content (> 20%) with moisture in the region of 10%.

12 Coal middlings is the product obtained by rewashing export-quality raw coal at a relatively high density after extraction of a low-ash coal product for export purposes, and typically contains relatively high ash levels (typically 30%).

Overview of the South African Coal Value Chain
The relative production and distribution of washed versus unwashed (raw) coal product in Figure 25 is based on 2007 statistics data reported by Prevost (2010). According to this data, approximately half the saleable coal is produced by washing, the majority (73%) of which is export thermal coal or sold to local industries and households. Blending of unwashed and washed coal fractions, e.g. raw coal fines with coal middlings, to generate a product of suitable quality for local power consumption is also commonly practiced by local collieries (also shown in the figure above). No statistics on blending practices at South African coal preparation plants are available.

In general, approximately 25 – 30% of saleable coal is exported, with around 180 – 185 Mtpa being consumed locally. As illustrated in Figure 26, statistics for 2009 indicate that around 70% of domestic coal consumption was for electricity generation by Eskom, with Sasol consuming a further 20% in their CTL process. Domestic consumption by households amounted to about 2%, the metallurgical industries about 3% and the cement, chemical and mining sectors the remaining 5%.

### 7.2 Coal beneficiation technologies

Historically, the development of coal beneficiation or washing circuits in South Africa has been driven largely by export markets. The production of a suitable high quality export (low ash, high calorific value) requires the use of low separation densities (between 1.4 and 1.5) corresponding to relatively low yields. A higher density wash will give a higher yield, but produce a lower quality product, with higher ash and lower calorific value.

A generic flowsheet for a modern, complex coal washing plant in South Africa is presented in Figure 27. Not all coal plants separate and wash all the size fractions. A few simple coal-reparation plants only separate and wash the coarse coal fraction sizes, whilst the use of froth flotation to upgrade the ultra-fine coal is still not widely practiced in South Africa, although the fine coal will be suitable for use by Eskom in the boilers. The majority of South African coal preparation plants, however, are relatively complex and use three or more processes to produce a range of coal products for both domestic use and export.
7.2.1 Screening

Effective coal beneficiation requires the prior separation of ROM coal into various size fractions: coarse, intermediate or small, fine and ultra-fine coal. Classification of the various size fractions varies from plant to plant. Typical values, mass distributions and moisture content of the various size fractions are presented in Table 21.

<table>
<thead>
<tr>
<th>Table 21: Typical classification and characteristics of coal size fractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size range (mm)</td>
</tr>
<tr>
<td>minimum</td>
</tr>
<tr>
<td>Coarse</td>
</tr>
<tr>
<td>Small/intermediate</td>
</tr>
<tr>
<td>Fine</td>
</tr>
<tr>
<td>Ultra-fine</td>
</tr>
</tbody>
</table>

(Source: Reddick, 2006)

*Note that mass distribution figures vary from mine to mine

The increased use of mechanised mining is resulting in an increase in the amounts of fines generated, and many mines are reporting up to 6% of the ROM coal in the minus 200 micron size range. In general, the fines and ultra-fines constitute approximately 11% of the total product, and retain the most moisture. The ultra-fines is also reported (de Korte, 2003) to have a higher content of ash-forming minerals, (particularly in the -45 micron range), and is typically classified by means of gravity or pump-fed hydrocyclones prior to beneficiation of the fines (see Figure 27).

7.2.2 Coarse coal washing

Coarse coal can be separated by using either jigs or dense medium baths. Although jigs are cheaper and are commonly used internationally, dense medium separation is the technology of choice in South Africa. This is due to the large amount of near-density material in South African coals at the high separation density required to produce export quality coal. The sharpness of separation with dense medium separation technologies is thus required to give economical yields of export coal. The Wemco drum separator is the simplest and most commonly used dense medium bath in South Africa. Other dense medium separation technologies used for coarse coal washing include the Teska separator, Drewboy separator and Norwalt separator, developed in South Africa. Recently this alternative circuit using dense medium cycles have largely replaced baths.

7.2.3 Intermediate coal washing

The small coal fraction is typically washed in dense medium cyclones, which make use of centrifugal force to separate the particle of different densities from each other. Dense medium cyclone separators that have been used in South Africa include the D.S.M cyclone, the Dynawhirlpool separator and the LARCODEMS separator.

7.2.4 Fine coal washing

Feasible technologies for the beneficiation of fine coal include dense medium cyclones and spirals. Beneficiation of fine coal in South Africa (< 1.0mm – 0.1 mm) is normally conducted in spiral concentrators. Spirals provide a simple, low cost and reasonably efficient separation of coal at his size range, and were first introduced at South African collieries in the mid-1980s. Feed to the spirals plant is normally deslimed by means of hydro-cyclones to remove the ultra-fines (< 0.1 – 0.15mm). Depending on the ease of separation of the various coal types, spiral plants either comprise of a single stage or double stage operation. In recent times, elutriation techniques have been incorporated into fines circuits.

7.2.5 Ultra fine coal washing

Froth flotation is the only viable technique for the beneficiation of ultra-fine coal and is applied widely internationally. Historically beneficiation of the ultra-fine coal fraction has not been common practice in South Africa and has been generally limited to coking coal applications. For Witbank coal the application has been limited due to choice of frother and ultimately by process economics (cost, dewatering, etc.). The resulting product still has a low market value due to its relatively high moisture content (see Table 2), even after dewatering. This results in handling problems in the power plants and reduces the “as received” calorific value (de Korte, 2008). Furthermore, until the early nineties, it was believed that Witbank coal was not amenable to froth flotation (Hand, 2000). This was subsequently found to be incorrect and, driven by environmental and economic pressures, the processing of ultra-fine coal began to receive more attention in the mid 1990s. As at the turn of the century approximately 12% of the South African coal washing plants utilised flotation to beneficiate ultra-fines (de Korte, 2000). The majority of ultra-fine coal produced in washing plants is, however, still disposed of into slurry ponds or underground workings after dewatering and the material handling problems associated with handling of ultra fines, usually by means of thickeners, to recover water for recycling. An efficiently operated thickener is capable of reducing the water content to between 70 to 75% (Reddick, 2006).

7.2.6 Fine coal dewatering

The beneficiation of the fine and ultra-fine coal fractions has presented a new challenge, namely the dewatering of products. Effective dewatering of fine and ultra-fine coal...
products increases the “as received” calorific value, results in fewer handling problems, and reduces transport costs. Conventional pulverised fuel boilers require that the feed coal contains at most ten percent moisture. Ultra-fine flotation product can be dewatered together with spiral concentrate in screen-bowl or solid-bowl centrifuges, the dewatered product subsequently being blended with coarser coal. Blending of the products tends to produce acceptable moisture contents for export purposes (DMR, 2001). Some collieries have installed more sophisticated dewatering equipment such as filter presses (de Korte, 2008) to maximise the reduction of the high moisture content of the slurry. For the most part, however, mechanical dewatering can only reduce the moisture content to roughly 25% in the case of ultra-fine coal and to 15% in the case of fine coal (de Korte and Mangena, 2004). In Canada and the USA thermal drying is commonly used to further reduce the water content in ultra-fines, but is not popular in South Africa (de Korte and Mangena, 2004). This is due to a number of factors including cost, differences in operation compared with conventional drying equipment and the perceived safety risks of the unit due to the potential for coal dust explosions (Reddick, 2006). Furthermore, although thermal drying can reduce the moisture to an acceptable level, there is still concern that the fine coal will re-adsorb moisture during stockpiling and transport. Osman et al. (2011) present a review on recent innovations and patents for dewatering and drying. The use of solar and wind for drying is a sustainable options which is relevant in South Africa.

7.3 Trends and opportunities in coal preparation

Historically, coal preparation plants in South Africa have been specifically designed to upgrade relatively high-grade coal for the export market. The methods used to prepare coal in South Africa are, and will continue, to adapt to change. This can be attributed to declining ore grades, in the face of growing pressures to increase supply at reduced costs and with due consideration of the environment. According to de Korte (2004), coal preparation plants will be increasingly required to produce a number of products of varying quality from lower-grade ROM ores, containing large quantities of stone, shale and pyrite. Reduced processing costs will come mainly from the scale of operations, with newer plants designed to handle large tonnages with maximum throughput. These plants are likely to be automated and have simpler lay-outs than older preparation plants. The efficient recovery of coal from fines and ultra-fines is likely to become increasingly important, whilst the re-processing of discards will soon be increasingly undertaken. Small semi-portable plants may be used to pre-process raw, low-grade ore close to the mine, in order to minimise transport and downstream processing costs.

A number of opportunities exist for optimising the performance of coal preparation plants in the face of these challenges:

- Dry coal processing
- Simultaneous washing of coarse and small coal
- Desliming and upgrading of fines
- Agglomeration of ultra-fine coal
- Upgrading and/or utilisation of ultra-fines
- Thermal drying techniques

Many of these are currently under review and investigation and are discussed in more detail in the section on research and development across the coal value chain.
8

EXPORTS

8.1 Current levels of coal exports

South Africa is currently the sixth largest coal producer in the world, with total South African production being equivalent to approximately 4% of world production. South Africa is able to access both the Atlantic and Pacific coal markets as a result of its geographic location (Eberhard, 2011; World Coal Institute, 2005). A combination of increasing prices in Asian markets as a result of strong demand, and a reduction in prices in the Atlantic market due to weak electricity demand as a result of the recession in the aftermath of the global financial crisis in 2009 led to South African export prices increasing above European import prices, with the effect that South African coal exports were partially diverted from their traditional destination of Europe to Asian markets (IEA, 2010a). This was a continuation of a longer term trend of South African coal exporters to increasingly focus on the growing Asian market rather than the declining European markets, as shown in Figure 28 below (Eberhard, 2011). South African coal exports to India have increased in recent years while exports to Europe have fallen from roughly three-quarters of South African exports in 2005 to less than half in 2009 (Eberhard, 2011).

![Figure 28: Destination of South African coal exports over time](image)

(Source: Eberhard, 2011)

8.2 Contribution to the economy

Coal not only generates significant value locally, but is also an important export commodity, and generated more than R 30 billion of export earnings in 2009 (Table 22). Exports constitute less than half of all sales of South African coal. This is a considerably smaller proportion than for other main commodity groupings like gold and platinum group metals.

<p>| Table 22: Exports vs. local sales by commodity (2009) |</p>
<table>
<thead>
<tr>
<th>Commodity</th>
<th>Local Sales [R’000]</th>
<th>Total Sales [R’000]</th>
<th>Export Sales [R’000]</th>
<th>Exports vs. Total Sales (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>1,701,334</td>
<td>48,695,503</td>
<td>46,994,160</td>
<td>96.5</td>
</tr>
<tr>
<td>PGMs</td>
<td>4,322,869</td>
<td>57,782,176</td>
<td>53,459,307</td>
<td>92.5</td>
</tr>
<tr>
<td>Silver</td>
<td>30,906</td>
<td>287,103</td>
<td>256,196</td>
<td>89.2</td>
</tr>
<tr>
<td>Subtotal</td>
<td>6,055,109</td>
<td>106,764,782</td>
<td>100,709,673</td>
<td></td>
</tr>
<tr>
<td>Chrome</td>
<td>2,066,278</td>
<td>3,262,329</td>
<td>1,196,051</td>
<td>36.7</td>
</tr>
<tr>
<td>Copper</td>
<td>2,835,737</td>
<td>3,858,519</td>
<td>1,022,782</td>
<td>26.5</td>
</tr>
<tr>
<td>Iron ore</td>
<td>1,888,801</td>
<td>27,131,735</td>
<td>25,242,934</td>
<td>93.0</td>
</tr>
<tr>
<td>Lead concentrate</td>
<td>0</td>
<td>482,903</td>
<td>482,903</td>
<td>100.0</td>
</tr>
<tr>
<td>Manganese</td>
<td>583,602</td>
<td>5,586,613</td>
<td>5,003,011</td>
<td>89.6</td>
</tr>
<tr>
<td>Nickel</td>
<td>949,855</td>
<td>4,201,208</td>
<td>3,251,360</td>
<td>77.4</td>
</tr>
<tr>
<td>Commodity</td>
<td>Local Sales (R'000)</td>
<td>Total Sales (R'000)</td>
<td>Export Sales (R'000)</td>
<td>Exports vs. Total Sales (%)</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Other metallic</td>
<td>191,360</td>
<td>277,927</td>
<td>86,566</td>
<td>31.1</td>
</tr>
<tr>
<td>Coal</td>
<td>34,463,054</td>
<td>65,397,974</td>
<td>30,934,920</td>
<td>47.3</td>
</tr>
<tr>
<td>Feldspar</td>
<td>55,248</td>
<td>55,246</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Limestone &amp; lime</td>
<td>2,105,297</td>
<td>21,165,611</td>
<td>11,263</td>
<td>5.1</td>
</tr>
<tr>
<td>Other non-metallic</td>
<td>7,105,622</td>
<td>7,485,345</td>
<td>379,723</td>
<td>5.1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6,655,620</td>
<td>14,724,001</td>
<td>8,068,391</td>
<td>54.8</td>
</tr>
<tr>
<td>Sub-total</td>
<td>58,900,475</td>
<td>134,580,362</td>
<td>75,679,887</td>
<td>56.2</td>
</tr>
<tr>
<td>Grand total</td>
<td>64,955,584</td>
<td>241,345,144</td>
<td>176,389,560</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Chamber of Mines, 2009b)

The figures below (adapted from Chamber of Mines, 2009a) shows that despite fluctuations in the total value of coal sold since 2000, the proportion of exports as total sales have remained relatively stable in both value and volume terms.

*Figure 29: South African coal production and exports (value)*
8.3 Policy and Legislation governing exports

The government has followed a “hands off” policy to the coal sector regarding exports over the past decade. However, as was mentioned in relation to the energy sub-sector above, pressure is starting to mount on government to intervene to ensure that the domestic economy retains sufficient coal for energy purposes. The Mineral Resources Minister has asked industry to work with government to ensure Eskom has sufficient supplies, but has indicated “government doesn’t want to enter the minefield of specifying all the processes” (Creamer, T., 2011a). The National Energy Act allows for the strategic stockpiling of minerals but only after thorough consultation with stakeholders (Creamer, M., 2011).

South Africa’s International Trade Administration Act (2002) enables the Minister of Trade and Industry to restrict the import or export of certain goods. As an item under the 208 tariff sub-headings, fossil fuels can be subject to import control measures. The purpose of import control pertaining to fossil fuels would be to ensure compliance with environmental requirements and international agreements. Fossil fuels and minerals can be subject to export control measures as 177 tariff line items. The purpose of export control pertaining to fossil fuels would be because they are raw materials for local manufacturing, could be regarded as being of strategic nature, national assets and in the national interest, and to ensure that beneficiation happens prior to export (ITAC, 2011).

The international trade in coal is subject to World Trade Organisation (WTO) rulings and procedures. Future international climate policy via border tax adjustments for carbon intensity of exports is becoming a growing possibility, and is likely to pass WTO rulings. It’s unclear how this would affect the export of coal itself, but would have significant implications for South Africa’s remaining exports, which are highly carbon intensive.

8.4 Likely evolution of exports

South African coal companies aim to increase exports amidst demand from growing markets in Asia and India, where demand for imported thermal coal in 2010 rose by 40% and 15% year-on-year in China and India respectively in the 2009 - 2010 period (Anglo American, 2010a). Thermal coal exports are predicted to increase from 72 Mtpa in 2010 to 93 Mtpa in 2017 while metallurgical coal exports (including anthracite fines for export PCI market) are anticipated to rise to 7.8 Mtpa in 2020 from 1.3 Mtpa in 2010 (Wood Mackenzie, 2010a).

In the longer term, suggestions have been made that total export coal volumes along the Richards Bay and Maputo corridors could reach 125 Mtpa in 2040, with most new investment projects completed by 2030 (SACRM Transport Focus Group, 2010). Of this, thermal coal volumes will make up around 115 Mtpa, of which 30 Mtpa could come from the Waterberg. These export volumes are contingent on associated transport infrastructure being in place.
Transport is a key aspect of the coal value chain, making a significant contribution to the total cost of coal as well as the security of supply (Carpenter et al., 2003). This is especially true in South Africa, where the most productive coalfields are inland, lead distances to users and export hubs are often considerable, and no navigable inland watercourses are available.

The following sections provide an overview of the main transport modes available for coal - rail, road, shipping, conveyor systems and pipelines.

Many challenges and opportunities present themselves in the arena of coal transport in South Africa, including a lack of rail capacity, declining road conditions and the possibility of enhanced port facilities, including previously low-profile locations such as Mozambique. These issues become more relevant within the context of a coal mining sector that faces a likely shift toward more distant, less-developed coalfields. These and other issues are also discussed below.

**Figure 31: Rail network in South Africa**

(Source: Transnet, 2009b)
The most important rail route for South African coal is the heavy-haul double line from Mpumalanga to Richards Bay Coal Terminal (RBCT), which is electrified for its entire length. The export line operates as two distinct systems, namely the 3kV DC section north of Ermelo and the 25kV AC section south of Ermelo. Under normal operation, two 100-wagon trains meet at Ermelo and are coupled into a single 200-wagon train for the remaining journey to Richards Bay (Transnet, 2010). This service has a nameplate capacity of around 72 Mtpa, which is below the design capacity of the RBCT (91 Mtpa) and is a significant bottleneck for the expansion of coal export through this port. Transnet has committed to capital investment that will increase the nameplate capacity to 81 Mtpa by 2014/2015. (Crickmay, 2009; Dlamini, 2010; Transnet, 2008; Creamer, M., 2009c; SACRM Transport Focus Group, 2010).

Another important rail connection runs from Gauteng through the Maputo Corridor, with connections from Limpopo and Mpumalanga, and is likely to grow in importance in the future (MCLI, 2010). The Maputo Corridor Logistics Initiative exists to support improvement of transport in general through the corridor, in cooperation with stakeholders. Expansion of the Matola coal terminal in Maputo, spearheaded by Grindrod, could provide a significant exporting alternative to RBCT. Transnet railed ± 1.8 Mt in the fiscal year ending 25 March 2010. The projected railings for 2011/2012 is ± 3.0 Mt. The increase is mainly due to Transnet allocating sufficient rail capacity to the Maputo line as well as improved efficiencies with train TAT (turnaround times) improving from 200 hours to 90 hours. The improved railings will result in the equivalent increased shipping volume via Matola. The stockpile capacity for coal at Matola is 400,000 tonnes.

Two noteworthy regional possibilities are the development of a trans-Kalahari rail line, which would link southern Botswana with the Atlantic port of Walvis Bay in Namibia, and the Ponto-Techobanine line linking Southern Botswana with port facilities in southern Mozambique, via Zimbabwe (Railways Africa, 2010; Mining MX, 2010a). Establishment of such lines faces substantial political and financial obstacles. However, if either of these lines were developed it would provide a route for coal export from Botswana, but could potentially play a role for South African coal as well.

Transnet’s rail services provide coal transport on many other routes as well, linking mines with these export lines, with their domestic customers, and even importing coke from Zimbabwe (Transnet, 2010). However, only 4% of coal for Eskom power stations is transported by rail, partly because these are usually sited near particular mines and equipped with conveyor belt systems (Eskom, 2010a; Creamer, T., 2010a), but also because of lack of rail infrastructure. In some cases there have been rail routes to Eskom power stations in the past, but these have largely been removed (Masianoga, 2008). Majuba is the only Eskom coal-fired power station currently receiving coal directly from rail, but due to a shortage of Transnet rolling stock and limitations of the track only 45% of its coal is delivered by rail, with the remainder by truck (Eskom, 2011a). Part of Eskom’s New Build program entailed the construction of a new 67 km heavy haul, 26 tonne-per-axle rail line from north of Ermelo to the Majuba power station with the intention of supplying coal to Majuba. This project is funded via a loan from the World Bank and will be operational by 2014/2015. Rail is also supplying coal to the Camden power station with a containerised system which facilitates mode switching, as the containers are off-loaded onto trucks for the last leg of the journey, avoiding the construction of a dedicated line to the station. This approach could be expanded to other stations in the future (Eskom, 2010e).

Transnet, in common with several other state-owned enterprises, suffers from institutional inefficiencies and capital investment backlogs (Dlamini, 2010; Truen, 2008; Masianoga, 2008; Crickmay, 2009). Poor performance has led to a loss of general freight market share, as customers have shifted to road transport. Besides the institutional challenges, a lack of rail infrastructure and of rolling stock poses significant hurdles to rail service expansion. One of the most significant transport constraints for coal is the Richards Bay coal line, which only carried 61.8 Mt of coal in 2010 (Transnet, 2010b), a decrease from 2009 and well below its nameplate capacity of 72 Mtpa (Crickmay, 2009). There is a significant mismatch between the line’s capacity and the 91 Mtpa capacity of the Richards Bay Coal Terminal that it serves. Transnet Freight Rail is undertaking feasibility studies for increasing the capacity of the line, but has only committed to raising capacity to 81 Mtpa by 2014/2015. Several factors contribute to the current capacity limitations of the line, including lack of locomotives and wagons, derailments, and cable theft (Eberhard, 2011; Transnet, 2010b; Africoal, 2011). To increase the capacity on the RBCT line from 81.0 to 91.0 Mtpa can only be achieved with an upgrade of the Overvaal tunnel from a single line to a double line. Indications are that it will be at a significant cost. Transnet has recently announced they are investigating the possibility to build a rail line from Ermelo via Swaziland to Richards Bay. It will enable them to move the existing General Freight Business from the RBCT line and re-route it via Swaziland to Richards Bay. It will add 14.0 Mt to the planned capacity on the RBCT and increase it to 95.0 Mtpa. A feasibility study will be completed by October 2011. Transnet has recognised that the Waterberg infrastructure lacks available capacity and is considering upgrade and rail construction options to accommodate both Export and Eskom demand to rail coal. Previous indications were to have it commissioned between 2020 and 2025 (Crickmay, 2009), but it will be required a lot sooner. Looking at about 2014 onward at the latest. It is not known how smoothly these plans are advancing.

Transnet’s monopoly rests principally on the ownership of the rail infrastructure in South Africa, most notably the railway lines themselves. It is not a legislated monopoly, in that no legal restrictions are in place to prevent private rail systems from operating. Indeed, over 2 Mtpa of platinum ore is moved over privately owned and operated rail systems

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near Rustenburg in the North West province, albeit over distances of less than 100 km. There are also precedents for cooperation with Transnet in rail line development, such as the line extension from Thabazimbi to Ellisras (Lephalale) in 1980 which was undertaken with guarantees against Transnet operating losses (NW DoT, undated). Recently Transnet has been exploring the possibility of granting concessions for the operation of branch lines which are currently underutilised or unprofitable, with expressions of interest being gathered in late 2010. Transnet will, however, retain ownership of the infrastructural assets (Creamer, T. , 2010b). A potential barrier to the establishment of any significant competition in the rail freight arena is the absence of any legislated interconnection obligations. Should it wish to do so, Transnet would likely be able to stifle competition by blocking access to the existing rail infrastructure. This would be especially true in areas such as in the vicinity of ports, where construction of parallel rail infrastructure would be prohibitively expensive and dependent on the cooperation of Transnet’s port management division.

An inherent challenge for rail transport in South Africa is the colonial legacy of the Cape gauge. In South Africa the vast majority of the rail network (some 22,500 km) is constructed with a 1,067 mm gauge (inside distance between the tracks). This is substantially narrower than the “standard gauge” of 1,435 mm that is used by about 60% of the world’s rail systems. The Cape gauge has the advantage of lower cost for laying tracks and bridge and tunnel construction, but it carries smaller wagons and supports lower speeds than standard gauge. In addition, the use of a non-standard gauge increases the cost of rolling stock, which cannot be ordered “off the shelf” from train builders or purchased second-hand (Transnet, 2008; DoT, undated; van der Muelen, 2006). Although it has featured in policy debate (DoT, undated), Transnet has estimated the cost of a complete changeover to standard gauge at R 800 billion (Pressly, 2010), and holds the position that this would be unjustifiably costly. However, Transnet has publically committed, through the rail division of Transnet’s management division.

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### 9.2 Road

Road transport has gained immense importance to logistics in South Africa since the industry was deregulated in the 1980s, with especially strong growth after 1999 when private vehicles gained permission to enter port terminals (Truven, 2008). General freight rail tonnage has largely stagnated over this period while truck transport has seen strong growth, with road freight responsible for twice the tonne-km haulage of rail in 2008 (CSIR, 2009). Freight transport by road offers a number of notable advantages over other modes, including (Crickmay, 2009):

- Low initial capital costs, allowing for road construction to coal sources with relatively short lifetimes, as opposed to 15 – 20 year payback periods common for other modes.
- Highly competitive road freight market, which likely leads to more efficient operation than seen in Transnet’s rail monopoly.
- Road gradient and curves are less of a problem than for rail (Carpenter et al., 2003).

However, the current extent of road freight in South Africa is widely viewed as being above efficient levels and unsustainable. This is because:

- On a micro-economic basis, rail freight should be inherently more efficient for long-distance transport of a number of goods, especially non-perishable bulk commodities such as coal (Crickmay, 2009).
- Road freight entails high external costs, most notably road damage and road accidents. These are especially relevant in the South African context, where road deaths involving heavy vehicles are far above international norms (Mining MX, 2009), overloading of trucks is common (CSIR, 1997; KZN DoT, 2010), and the secondary road infrastructure is rapidly deteriorating (CSIR, 2009). There is an underestimation of this real external cost, because the bulk of the external cost due to accidents and damage to vehicles goes unreported and unrecorded.
- Poor road conditions lead to increased vehicle maintenance costs and hence higher logistical costs for the economy as a whole, which could significantly impair economic competitiveness and growth (CSIR, 2009).

It seems likely that the combination of a monopolistic rail system and the extensive externalisation of costs by the road freight sector have substantially distorted the long-haul freight market in South Africa. Due to coal’s high volume and low value, rail is still the major player in its transport, but trucking is used extensively (DME, 2009a), especially for supplying domestic users and connecting to rail routes. For example, 22% of coal for Eskom’s power generation is delivered by road (Creamer, T., 2010b), and benefitted coking coal from Exxaro’s Tshikondeni mine in Limpopo was trucked 140 km to Musina before being loaded onto rail (Exxaro, 2010b). It is estimated that 50 million tonnes of coal was transported by road in 2008 (Crickmay, 2009).

Apart from the medium- to long-haul transport considerations, road transport is very important for shorter-distance transfers between the mine and processing plants, to rail transport hubs and to local users. Many such journeys do not use any public roads and can therefore make use of specialised vehicles outside of public road-legal specifications. The use of road vehicles for these transfers also provides greater flexibility than conveyor systems.

There are some possibilities for optimising coal haulage on public roads, where current legal limits (under the Road...
Traffic Act of 1996 and associated regulations) include a maximum gross vehicle mass of 56 tonnes (NRA, undated). At the simplest level, better trailer designs have been mooted to increase payload capacity to 38 tonnes from a current level of about 33 tonnes, whilst remaining within current legal requirements (Crickmay, 2009). More fundamentally, changes to the regulatory environment have been proposed whereby performance based standards (PBS) are applied instead of prescriptive vehicle specifications. In such systems key parameters of vehicle performance are regulated, such as handling and surface friction characteristics. In South Africa this approach has been spearheaded by the forestry industry, with around 30 such vehicles now operating on a trial basis and showing promising results: substantially increased load capacities and reduced fuel consumption, fewer trucks and reduced road damage (Crickmay, 2009; Morkel, 2009; Nordengen, 2009). Within a PBS system coal payloads might increase to 48 tonnes (Crickmay, 2009). However, the implementation of such a system requires considerable technical expertise and a high level of trust between public, regulatory bodies and industry (Crickmay, 2009). The Road Transport Management System, an industry-led self-regulatory initiative, might contribute to the development of such an environment (Nordengen and Pienaar, 2007).

9.3 Ports

9.3.1 Richards Bay Coal Terminal

The Richards Bay Coal Terminal (RBCT) is one of the largest coal export terminals in the world, with a design capacity of 91 million tonnes per annum and exporting 63 million tonnes in 2010. It is privately owned and operated with a shareholding made up of major coal mining houses and smaller miners, with a portion of its capacity used by non-shareholders (Table 23).

The role of the RBCT is to manage port logistics for efficient and reliable coal export from Richards Bay. It also serves a quality control function through a laboratory at the terminal, independently managed by Inspectorate M&L Pty Ltd, which issues certificates of analysis for each coal shipment. Marketing, negotiation of coal sales contracts and arranging for shipping are the responsibility of the seller, with RBCT playing no role in this regard (RBCT, 2007).

Table 23: RBCT export entitlements for 91 Mtpa

<table>
<thead>
<tr>
<th>Current shareholders</th>
<th>Small miners</th>
<th>SDCT</th>
<th>Subscription tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>72 Mtpa</td>
<td>Small miners</td>
<td>6 Mtpa</td>
<td>9 Mtpa</td>
</tr>
<tr>
<td>4 Mtpa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anglo Operations Ltd</td>
<td>19.80</td>
<td></td>
<td>The new shareholder component of South Dunes Coal Terminal.</td>
</tr>
<tr>
<td>BHP Billiton Energy Coal SA Ltd</td>
<td>17.95</td>
<td></td>
<td>Two thirds BEE with primary shareholders:</td>
</tr>
<tr>
<td>Xstrata SA (Pty) Ltd</td>
<td>15.05</td>
<td></td>
<td>SACMH</td>
</tr>
<tr>
<td>Optimum Coal Terminal (Pty) Ltd</td>
<td>6.50</td>
<td></td>
<td>Mbokodo Mining</td>
</tr>
<tr>
<td>Total Coal SA (Pty) Ltd</td>
<td>4.09</td>
<td></td>
<td>Umcebo Mining</td>
</tr>
<tr>
<td>Sasol Mining (Pty) Ltd</td>
<td>3.60</td>
<td></td>
<td>ARM Coal</td>
</tr>
<tr>
<td>Kangra Coal (Pty) Ltd</td>
<td>1.65</td>
<td></td>
<td>Tumelo Coal</td>
</tr>
<tr>
<td>Siyanda Coal</td>
<td>1.50</td>
<td></td>
<td>Virco</td>
</tr>
<tr>
<td>Exxaro Coal (Pty) Ltd</td>
<td>1.00</td>
<td></td>
<td>Mmakau Mining</td>
</tr>
<tr>
<td>Exxaro Mpumalanga</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Sources: Chirwa, 2010; The bulk of export allocations through RBCT (Table 23) are held by major coal mining houses, who are the main shareholders in the terminal. However, mechanisms exist for access to the terminal by BEE and junior miners. One such arrangement is the 4 Mtpa “Quattro” allocation which is divided up among emerging BEE miners through the Coal Industry Task Team, a stakeholder grouping established by the then Department of Minerals and Energy in 2002 (Nogxina, 2009). The recently completed RBCT Phase V expansion also resulted in 9 Mtpa of subscription tonnage, some of which has been awarded to BEE mining companies.

The RBCT receives coal primarily through the heavy-haul coal rail line from Mpumalanga, although the terminal also has the capability to receive road freight. The coal line and dedicated rolling stock is owned by Transnet Freight Rail, and collaborates closely with RBCT to ensure compliance with standards for handling and quality control, as well as efficient scheduling. For example, RBCT will only accept coal wagons loaded at approved railway sidings which adhere to required standards (RBCT, 2007). Upon arrival at the terminal, mechanical rail tipplers empty the coal wagons onto conveyor belt systems which transfer the coal either to a waiting vessel...
or to the stockpile areas (it is RBCF policy to only allow a ship to berth once the relevant coal is on site (RBCT, 2007)). Coal handling at the stockpiles is achieved with stacker-reclaimer equipment. Stockpiles at the terminal averaged 3.1 Mt in 2010. Total capacity available currently is 7.8 Mt.

RBCT has recently completed its Phase V expansion project to bring its capacity up to 91 Mtpa. One of the stated objectives of this program was the development of export facilities to provide for demand from emerging BEE miners (RBCT, 2010).

A significant concern for coal export from Richards Bay is the limited capacity of the coal rail line from Mpumalanga, which currently stands at 70 Mtpa. Several commentators have pointed to limited rail capacity and reliability as a major constraint to coal export from South Africa (Business Day, 2010; Creamer, M., 2009c).

9.3.2 Richards Bay

The Port of Richards Bay, located opposite RBCT, features a dry bulk terminal and a multipurpose terminal, both under the management of Transnet Port Terminals. The dry bulk terminal handles over 13 Mtpa of various bulk commodities across multipurpose material handling systems which are washed between loads. Coking coal, metallurgical coke and anthracite feature among these (Transnet Port Terminals, 2010), with exports of 0.6 Mt in 2009 (Wood Mackenzie, 2010c).

Grindrod Terminals has Richards Bay operations that provide substantial dry bulk logistics services and infrastructure to bulk exporters through Richards Bay (Grindrod, undated), with Coal of Africa Limited among its clients (Mining MX, 2010b). Coal of Africa Limited has secured rail allocations from Transnet Freight Rail through a “take or pay” agreement, whereby Coal of Africa Limited is liable for 75% of the agreed coal transport volumes whether or not it makes use of the rail capacity.

9.3.3 Port of Durban

The Port of Durban is South Africa’s main general cargo and container port. In 2008/9 it handled 34 Mt of bulk cargo, 6 Mt of break bulk cargo13 and 2.6 million container movements14 (Transnet, 2009a). Several specialised terminals are associated with the port, including the Durban Bulk Connections terminal which handles coal export (1.8 Mt in 2009 (Reuters Africa, 2009)), among other bulk products. It is mainly used by KwaZulu Natal coal producers/exporters. The port is accessible by road and rail. The Natcor rail line to Gauteng is the most important general freight line in the country, with an electrified double track along its entire route. In 2005/6 this line carried 20 Mt of cargo (5.4 Mt end-to-end traffic), which represented around 20 – 25% of capacity. A single-track electrified main line connection also runs from Durban to Empangeni near Richards Bay and without electrification to Swaziland. Both of these main lines are rated to a maximum axle mass of 20 tonnes (gross wagon mass of 80 tonnes) (KZN DoT, undated).

9.3.4 Matola Coal Terminal and Port of Maputo

The Port of Maputo and the nearby Matola Coal Terminal (TCM15), in Mozambique, are the nearest deepwater ports to Limpopo Province and much of Mpumalanga and Gauteng. Grindrod Terminals took full ownership of the Matola Coal Terminal in 2007 and continued with rehabilitation and upgrading, which had already begun in 2003 (MCLI undated; Grindrod, undated). In 2009 South African exports through TCM totalled 1.3 Mt (Wood Mackenzie, 2010c). The current capacity of the terminal after recent upgrade is 4.5 Mtpa for coal with plans to increase it to about 20.0 Mtpa. The expansion will largely depend on the corresponding rail capacity. There are currently about 800 wagons running through the Maputo corridor which will service the current capacity of 4.5 Mtpa. Grindrod are in discussions with Transnet Freight Rail to increase capacity including potentially making an investment in rolling stock should capital problems be an issue (Venter, 2010b). Coal of Africa Limited has been very active in securing export allocations through the Matola terminal, with agreements to assist in covering the cost of the port upgrades in return for exclusive allocation of increased capacity (Thomaz, 2009).

The Maputo Development Corridor has been identified as a major route for transport and development, with bilateral cooperative agreements between the South African and Mozambican governments dating back to 1996. The Maputo Corridor Logistics Initiative was established in 2004 as a non-profit coalition of stakeholders to promote the development of this corridor, particularly as a major transportation route. The main elements of the corridor are the road and rail connections, the Lebombo/Resanno Garcia border post and the ports in Maputo. Beside the port upgrades, development has included concessioning the operation and maintenance of the N4 highway to Trans Africa Concessions (TRAC), which runs from the Botswana border in the west, through Johannesburg and on to Maputo with six toll plaza’s en route; extending border operating hours; and providing a heavy freight bypass road at the border (MCLI, undated). Some constraints to development of the corridor remain, including limited rail capacity and infrastructure and border inefficiencies (USAID, 2008). The Eletheni coal mine to be developed in the Eastern Cape is the only potential exporter of coal via the East London port.

9.3.5 Port Elizabeth, the Port of Ngqura and East London

The Port of Ngqura is South Africa’s most recent port development, situated in the Coega Industrial Development Zone 20 km northeast of Port Elizabeth. It is a deepwater port operated by Transnet Port Terminals (Ports and Ships, 2010). However, although originally proposed as a bulk terminal for ore handling, it has been developed as a container terminal.

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13 Break bulk cargo is non-containerised cargo which must be handled in individual units, such as drums, bags or crates, as opposed to bulk cargo which is suited to continuous handling (e.g. coal, oil and grain) or containerised cargo.
14 Strictly, 2.6 million twenty-foot equivalent units (TEU), a somewhat inexact measure based on a “typical” twenty-foot shipping container.
15 Terminal de Carvao de Matola
Bulk cargo is still handled through Port Elizabeth (Ports and Ships, 2010; Transnet Port Terminals, 2010) totalling 3.8 Mt in 2008, including manganese ore for which Port Elizabeth is South Africa's main export point. Coal is not currently a significant cargo through either of these ports.

East London has a small river port which mainly handles cars, grains and containers. The port has limitations in terms of ship draught, and it does not handle any significant coal quantities at present (Ports and Ships, 2010).

9.3.6 Saldanha Bay

During 2008, 34 Mt of iron ore was exported through the Saldanha Bay Iron Ore Terminal on the west coast, along with an additional 1.7 Mt of transhipment cargo. The multipurpose terminal at Saldanha handled 0.65 Mt, reportedly including coking coal (Ports and Ships, 2010). Saldanha Bay lies at the end of South Africa's second heavy haul rail line (axle masses of up to 26 tonnes, and gross wagon mass of 104 tonnes (Crickmay, 2009), which runs from the iron ore mines at Sishen in the Northern Cape.

9.3.7 Port of Walvis Bay

The Port of Walvis Bay is a deepwater port on the Atlantic, and Namibia's largest commercial port. It handles approximately 5 Mt of cargo per year at present, including substantial containerised landings, and has two privately operated bulk terminals (Namibian Port Authority, 2009). Should the development of a Trans-Kalahari rail link take place, this port could provide an alternative export hub for coal produced in the vicinity of the South Africa-Botswana border.

9.4 Conveyors and cable systems

Belt conveyors are used extensively in mining operations and automated ship loaders. They are used where a relatively short haul is involved and are economic when there is a constant level of output over a long period. Conveyors are the most important transport mode for electricity supply, with 74% of Eskom's coal supplied by conveyors from closely tied mines (Creamer, T., 2010a). There are a variety of conveyor systems available, as well as a number of cable systems such as aerial ropeways (cable cars), and rope conveyors (conveyor systems running on suspended ropes). Grouped together, these transport modes share a number of characteristics (Crickmay, 2009):

• Low operating cost
• High level of automation
• High material throughput, with near continuous flow

• Certain systems are very effective across otherwise difficult terrain
• High capital costs
• Inflexible in terms of routing and tonnage (uneconomic at smaller volumes)

Due to these properties, conveyor systems are likely to remain important for coal transport in South Africa, although they will not be able to compete with road and rail for long-distance movements.

9.5 Pipeline

Pipelines have been applied internationally for the long-distance transport of coal, amongst the longest of which was the Black Mesa coal slurry pipeline in the US, which carried coal over a distance of 440 km (Shebala, 2008; Crickmay, 2009). The coal is pulverised and piped as a slurry with water, in a 1:1 mass ratio. Coal slurry pipelines offer an unobtrusive and safe transport mode providing a continuous flow at low maintenance cost. However, they are only likely to be economical at high volumes and large distances. These systems also have high water requirements and generate contaminated water at the destination, which is likely to be a substantial concern in South Africa. The high water content of the delivered coal is a further difficulty, requiring dewatering prior to use (Crickmay, 2009).

The coal log pipeline, a new technology not as yet applied commercially, offers reduced water consumption and lessens the difficulties with moisture content. In this system coal is compressed into cylindrical logs with a diameter slightly less than the pipeline, and washed through the pipe with water. This increases the coal-water ratio to about 3:1 and the coal remains relatively dry due to the compression. The compression characteristics of the coal can limit the applicability, however, and the technology requires further development (Crickmay, 2009).

9.6 Cost comparison of different transport modes

Many factors influence the cost of coal transport by different modes, including the route distance, required capacity, availability of existing infrastructure and landscape characteristics. Table 24 presents some indicative cost values for the different modes discussed above. Light grey cells in this table indicate that there is limited data on the application of these modes at the relevant distances, whilst dark grey shading indicates that these modes are unlikely to be able to support a capacity of 50 Mtpa.
9.7 Stockpiles

Stockpiles play an important role throughout the coal production, distribution, and use chain as buffers and homogenisation facilities to ensure continuity of supply. Two important types of coal stockpiles in South Africa are Eskom’s stockpiles at power stations and the large number of stockpiles maintained by coal producers, transporters and users. In January 2010, Eskom’s stockpiles stood at 36 days (currently at 38 days) worth of coal (Creamer, T., 2010a) and with all stations in excess of 20 days in 2009. This represents a substantial recovery from the situation in January 2008 when the average was only 12 days (Eskom, 2009b). On the basis of Eskom’s coal usage in 2009, this suggests a current total stockpile of around 12.0 Mt. No official figures are available for other stockpiles on the mines but it is currently estimated to be between 4.0 to 4.5 Mt of export and other domestic coal. The extended TFR shutdown on the RBCT line plus several derailments since January 2011 had a significant impact on the stocks held and under normal circumstances it will not be more than 50% of the of the current estimate.

Substantial stocks of coal are always present at Richards Bay Coal Terminal, averaging 3.1 Mt in 2010. However, RBCT operates only as a shipping hub, and the stock areas are allocated to exporters for storing specific consignments (RBCT, 2007). These stocks therefore do not represent stockpiles in the sense of securing supply, although they comprise perhaps the largest coal stockyard in the country.

Stockpile management is an important aspect of the coal value chain. Firstly, the size of a stockpile is an important cost factor, as the coal value in the stockpile represents a sizeable investment that provides no return. However, this cost needs to be carefully balanced with the risk of supply insecurities. Stockpiles also play an important role in quality control and coal blending to ensure that the supply is not only available but falls most cost-effectively within the necessary specifications (CoalOnline, 2010). This requires more space and equipment, in addition to the stacker/reclaimers (equipment for adding and removing coal) that are usually employed at bulk handling facilities. Other issues that must be considered in stockpile management include:

- Dust control
- Prevention and early detection of spontaneous combustion, especially monitoring of coal temperature
- Minimising coal oxidation by the atmosphere and weathering
- Physical stability of the coal pile
- Prevention of contaminated water runoff

9.8 The policy, legislation and institutional context of coal transport and logistics

The 1996 White Paper on National Transport Policy provides the overarching framework for policy pertaining to the transport of coal. The Paper’s mission for transport infrastructure is “to provide an integrated, well-managed, viable and sustainable transport infrastructure meeting national and regional goals into the 21st century, in order to establish a coherent base to promote accessibility and the safe, reliable, effective and efficient movement of people, goods and services” (DoT, 1996). Government is however very aware of the extent to which the current transport status quo is falling short of this ideal (DoT, 2005; Cronin, 2010).

The national transport infrastructure of relevance to coal is primarily that of rail and ports, although the road system is also becoming increasingly utilised. The Department of Transport (DoT) is responsible for policy related to all three areas of infrastructure, with the State Owned Enterprise (SOE) Transnet a major player in the area of rail and port transport policy, and therefore so too is its managing department, the Department of Public Enterprises (DPE). Transnet is governed by a Strategic Intent Statement (including what government as shareholder intends, a shareholder compact and a corporate plan.)
Apart from the White Paper, there are three key pieces of existing written policy pertinent to coal. These are the National Commercial Ports Policy White Paper (2002), the National Freight Logistics Strategy (2005) and the Department of Public Enterprise’s Strategic Plan (2010). Significantly, no national rail policy has been developed, something which the DoT is currently in the process of undertaking and which is anticipated to enable the development of a Rail Act within the next two years (Cronin, 2010).

The National Freight Logistics Strategy was developed in 2005 in response to the pressure of significantly increased demand on infrastructure and the freight logistics system. It confirms that the DoT is ultimately responsible for ensuring “efficient and effective, seamless inter-modal transportation is achieved in the national interests of South Africa” (DoT, 2002).

The Strategy cites an inappropriate institutional and regulatory structure which “is structurally incapable of appropriately allocating external costs and raising efficiency” (DoT, 2005) as a key reason for the underperformance of the logistics system. The Strategy moves to a more interventionist government approach to regulating the freight system. One of the elements of this is transition from modal regulators (rail, ports, road) towards functional regulators (economic, security, safety and the environment). A critical need with regard to rail is the establishment of an independent rail economic regulator, which the DoT is fast-tracking (Cronin, 2010). This might be established before the Act and even Policy, which is recognised as not being optimal. The National Freight Strategy’s vision identifies different types of infrastructure ownership models, with the government playing an important role in ensuring that national sustainable development objectives are supported by infrastructure. The governments will mostly manage infrastructure, and regulate relationships between owners and operators. The Strategy speaks to the importance of transport planning being done in an integrated fashion, incorporating all three tiers of government, and captured in Integrated Transport Plans. The Strategy is intended to be implemented by the Inter-Departmental Task Team on Logistics, and the development of a Freight Transport Master Plan is envisaged. DoT is currently developing a Road Freight Strategy (Cronin, 2010).

The Policy White Paper on National Commercial Ports (2002) identifies government’s responsibility as being to develop and maintain the national port commercial policy, regulatory and legislative framework (DoT, 2002). The Paper identifies the importance of integrating ports with land transport systems: “The inland transportation capacity will match the ports throughput” (DoT, 2002).

Critically, the White Paper addressed the issue of the National Ports Authority’s (NPA) situation in Transnet as being conflicted. It required that the NPA be made a state-owned corporate entity separate of the SOE. It also required the establishment of an Independent Port regulator which reports directly to the DoT minister and has oversight over the NPA; separation of the port authority and port operations functions and creation of a competitive environment in the commercial ports system. A National Port Development Framework Plan was intended to be developed.

Nine years later the issue of the NPA has yet to be resolved, with both the DoT and DPE in ongoing discussions on the matter, and therefore the full implementation of the Ports Act is a continual challenge (Cronin, 2010). At the heart of the issue is the importance of the NPA’s port levies in cross-subsidising Transnet Freight Rail’s investment programme (Cronin, 2010). The NPA still remains within Transnet.

The Department of Public Enterprise’s Strategic Plan (2010) identifies Strategic Mandates for each State Owned Entity (SOE), which include the issue of infrastructure investment, and which are the responsibility of the DPE to ensure that SOEs fulfil. DPE intends to achieve Cabinet approval for these, and then to integrate them into departmental and industrial policy (DPE, 2010).

The Strategic plan also sets out measurable objectives for the transport sector to 2013. These include:

- Ensuring alignment with governments’ developmental objectives,
- Ensuring a balance between development and commercial returns,
- Strengthening private sector participation in the port and rail sector,
- Achieving multiple operators on the branch line rail network,
- Achieving a turnaround of Transnet Freight Rail,
- Pronouncement on rail policy with clear role for TFR, including restructuring options to ensuring viability of TFR.

The following legislation may impact transport and logistics for coal, however the main impact is anticipated to be felt at a policy level, where the key issues of improving the freight transport infrastructure to support sustained economic development are being engaged.

- National Ports Act, 2004
- National Land Transport Act, 2009
- Transport Agencies General Laws Amendment Act, 2007
- Transport Laws Repeal Act, 2010

Significantly, there is no legislation specific to rail yet (an Act is anticipated to follow the Rail Policy which is currently under development), nor regarding State Owned Enterprises.
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Existing and emerging technologies for electricity generation are discussed here, followed by an analysis of the electricity generation sector in South Africa and some commentary on its likely evolution.

10.1 Coal fired electricity generation technologies

The primary way in which electricity is generated using coal is by heating water to generate steam, which is used to drive turbines. The water is in a closed (primary) circuit and after the energy in the steam is spent in the turbines, it condenses back to water and is recirculated to the boiler for reheating. Cold water (in a secondary circuit) is used to assist in the condensation process – this is referred to as cooling water. The ash that results from burning the coal falls to the bottom of the boiler and is extracted and removed to an external ash dam while the gaseous emissions exit though a chimney (or flue) and is termed flue gas. Certain types of emissions are of environmental concern, such as carbon dioxide (a greenhouse gas) as well as particulate matter (PM), nitrogen oxides (NOₓ) and sulphur dioxide (SO₂). Technologies are available to reduce some of these emissions while further technologies (such as carbon capture and storage) are still under development.

The two main technologies that have been used globally for coal combustion are pulverised fuel and fluidised bed technologies.

In pulverised fuel (PF) technologies (Figure 32), the coal is ground to a particle size of between 5 and 400 µm in diameter. The pulverised coal is blown into the boiler by air through the furnace burners positioned in the walls of the boiler. Combustion takes place in the centre of the boiler at temperatures from 1300°C to 1700°C. The combustion temperature depends largely on the rank of the coal. Some of the coal may be substituted by certain types of biomass or gas, otherwise known as co-firing. Biomass co-firing has been undertaken internationally and is also currently being explored by Eskom, while gas from Eskom’s underground gasification pilot project is being co-fired with coal at Majuba.

Power station cooling and ash management are achieved in several different ways. The power station cooling water gains a lot of heat from the primary water during the condensation process. Where large volumes of cold water are readily available, power stations use once through cooling and the heated cooling water is discharged directly back into the environment. Where such large volumes of water are not available, power stations used to send the heated cooling water into cooling towers where some water evaporates but the remaining water is cooled and can be re-used. Eskom has pioneered the use of dry cooling water systems where the heated cooling water is also in a closed circuit and is itself cooled by air blown fans. Similarly, power stations used to use water to turn the ash from the bottom of the boiler into a slurry which could easily by pumped to the external ash dam but it is also possible to transport the ash to the ash dam using relatively less water, termed dry ashing. Dry cooling and dry ashing systems use considerably less water than wet cooling and wet ashing systems. Dry cooling does, however, come with a thermal efficiency penalty since air-cooling is less effective in decreasing the temperature of the heated cooling water. This is considered further in the discussion on environmental impacts of electricity generation.

All of Eskom’s current coal fired power plants, as well as Medupi, which is under construction at the time of writing, and the future Kusile power plant, are pulverised fuel plants. The latter two power stations will be supercritical plants, discussed further below.

Figure 32: Schematic of a PF power station

(Source: adapted from World Coal Association, 2011b)
In a fluidised bed combustion (FBC) boiler, larger fuel particles are introduced near the base of the boiler and a continuous, upward stream of air from beneath is used to create turbulence in the mixed bed of fuel, inert material and coarse fuel-ash particles as the bed traverses across or around the boiler. Combustion typically occurs at temperatures between 800°C and 900°C. The constant mixing of particles encourages rapid heat transfer and complete combustion. Configurations include bubbling fluidised bed and circulating fluidised beds, with the latter being able to be operated with oxygen instead of air. The coal does not need to be crushed as finely as in pulverised fuel combustion stations.

FBC has a number of benefits over PF. FBC can be designed to handle more variable coal qualities than PF (including those with higher ash contents and lower caloric values) as well as different types of feeds, which may include discards, lower quality coals that are completely unsuitable for export, biomass and even general waste. This technology presents an opportunity for the use of low quality coal and discards. In terms of controlling emissions, a sorbent such as limestone can be introduced directly into the fluidised bed for removal of SO\textsubscript{2} during the combustion process, and due to the lower combustion temperature, NO\textsubscript{x} emissions from FBC are lower than those from PF technologies.

Although FBC is well established in niche applications including those that require fuel flexibility and those that burn poor quality fuels, FBC boilers have not yet achieved the economies of scale that PF boilers have, with a maximum size of 340 - 460 MW (although boiler designs in size range of 800 MW are being developed). Only in 2009 has a FBC boiler been commissioned that operates under supercritical conditions in Lagisza, Poland (Jäntti and Parkkonen, 2009). FBC can be designed to operate at elevated pressures, which provides the opportunity for the boiler exhaust gases to be used for generation of additional power (World Coal Association, 2011c). FBC thus represents only a small fraction of the total installed capacity globally, with no installed plants in South Africa.

Coal quality, including not only the ash content and energy content, but also the moisture content, volatile matter and other characteristics, has a significant impact on power plant operation and performance, including its ignition, capacity, heat rate, availability and maintenance requirements. It is thus essential to know what a coal’s combustion characteristics are both during the design stage of any new power station and boilers, and also when introducing coals from other sources. It is thus essential that combustion equipment be designed and tested based on the coal which is actually going to be burned (Carpenter et al., 2006)

Ongoing power station technology development and advancements are largely focused on cleaner coal technologies, being those that demonstrate higher efficiencies, lower emissions and lower water consumption than traditional PF and FBC configurations. These include Integrated Gasification Combined Cycle (IGCC), Underground Coal Gasification used in conjunction with Combined Cycle turbines (UGGCC) as well as supercritical and ultra-supercritical operating conditions for existing PF plants and IGCC.

The difference between supercritical and ultra-supercritical coal technologies and subcritical technologies is that these make use of higher temperatures, and operate above the critical point for water. Supercritical steam cycle technology is well established globally, and is the preferred option for many new commercial coal-fired plants around the world, achieving net thermal efficiencies of 42% to 45% as compared to the conventional PF technologies which operate at between 30% and 36% efficiency on a HHV basis. Ultra-supercritical units are still in the R&D phase. These will operate at even higher thermal efficiencies, suggested to be up to 50% or 55% (IEA, 2008).

Unlike all of the combustion technologies that burn coal to generate steam to drive turbines for electricity generation discussed thus far, IGCC technologies employ a four-stage process as follows (IEA, 2008):

- Coal is partially combusted or gasified in a pressurised, oxygen limited environment to generate fuel gas;
- Particulates, sulphur and nitrogen compounds are removed;
- The remaining fuel gas is combusted in a gas turbine generator to produce electricity; and
- Residual heat in the exhaust gas from the gas turbine is recovered in a heat recovery steam generator and the steam used to produce additional electricity in a steam turbine generator.

As IGCC is thus a fundamentally different process configuration to steam turbines, it is not possible to retrofit these technologies – their adoption suggests building of new power stations.

IGCC efficiencies can reach the to the order of 40-45% (LHV), although plant designs offering around 50% efficiencies are achievable (World Coal Association, 2011c). Underground coal gasification used in combination with a combined cycle (or simple cycle) gas turbine is expected to achieve up to 15% higher than PF technologies (Eskom, 2009b). A comparison between the efficiencies of coal fired power technologies is shown in Figure 33.
It is likely that in the short to medium term supercritical plants will be built globally, whilst after 2020 ultra-supercritical technologies and IGCC will play an increasing role (IEA, 2010a).

10.2 The electricity generation sector in South Africa

10.2.1 Sector makeup

The electricity sector in South Africa is dominated by coal fired power, with Eskom, a single, vertically integrated, state-owned utility owning, operating and maintaining the bulk of the generation infrastructure, as well as the national transmission grid. Eskom generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa. Eskom is among the top seven utilities in the world in terms of generation capacity, and among the top nine in terms of sales. In 2010 Eskom generated 232,812 GWh of electricity, and consumed 122.7 Mt of coal (Eskom, 2010a). The growth in Eskom’s output and coal consumption is shown in Figure 34.
The majority of Eskom’s generation capacity is vested in coal fired power stations (85% in 2010), which together have a total nominal capacity of 37,755 MW. The net maximum capacity of coal fired power, which excludes the power consumed by their auxiliaries and reduced capacity caused by age of plant and/or low coal quality, is 34,658 MW (Eskom, 2010a). Eskom also owns a nuclear power station, two hydroelectric power stations and various open cycle gas turbines, which are primarily used to meet peak demand. The location and capacity of Eskom’s power stations, as well as the national grid, is presented in Figure 35.

In addition to Eskom, generation capacity is also held by a handful of companies which produce electricity for their own needs (most notably Sasol), and some municipalities which still operate their own power stations, although the latter facilities are mostly small and ageing.
Figure 35: Eskom’s power stations

(Source: Eskom, 2011b)
10.2.2 Coal consumption and supply

Eskom used 122.7 Mt of coal in the 2010 financial year (Eskom, 2010a). Eskom typically burns low quality coal characterised by high ash content (average of 29.6% in 2010) and low calorific values (with an average of 19.22 MJ/kg in 2010). The coal which can be used varies between power stations, however, with the RTS power stations requiring higher grade coal (23 MJ/kg), another group requiring 21 to 23 MJ/kg and only certain power stations being able to burn the lowest grade. There is also a trade-off between the quality of coal burned and power station output – if lower grade coal is burned the power station can deliver less electricity and also requires more maintenance – important considerations in a system where capacity is constrained (SACRM Large Power Generation Focus Group, 2010).

The majority of Eskom’s coal is supplied on conveyors from dedicated coal mines. These mines were typically established at the same time as the power stations, and contracts for coal supply were established for the original planned life of the power stations, operating at specific load factors. The exception to the mine mouth power station model is Majuba, where due to geological problems that were not initially obvious meant that Majuba’s colliery could not be mined economically and coal needed to be sourced from elsewhere (Eskom, 2011c).

In other cases, the contracted supply volumes are insufficient due to extended power station lives (including return to service power stations) and/or operation at higher load factors. In addition, the practice to have cost plus contracts in place at most of these dedicated mines, removed the incentive to the mines to increase profits and productivity and resulted in many mines not being able to meet supply commitments. In these cases, some power stations have, more recently, had to truck or rail in coal from other mines to meet the incremental demand. These power stations include Tutuka, Camden, Hendrina and Grootvlei which all receive coal by road and rail from the Mpumalanga coalfields. Further information on coal transport is provided in the transport section.

The quality of coal burned by Eskom has, until recently, largely been unsuitable for export. However more recently there have been reports of an increase in demand for lower quality coal from abroad, particularly from India, which is of concern to Eskom in procuring supply (Eskom, 2010a).

In addition to the concerns about competition for lower grade power station quality coal from export markets, other supply and demand dynamics in the SA coal supply industry that have affected their operations are identified in the Eskom annual report (Eskom, 2010a). These include:
- Deregulation of the industry;
- Extension of the service lives of most of Eskom’s power stations from 40 to 60 years beyond the contracts with collieries, which were originally set up for 40 years. These contracts start to expire as early as 2013;
- Lack of national coordination on optimisation of the coal reserve for future use, coupled with miners being driven by a need to exploit deposits before their prospecting rights expire;
- Eskom having limited opportunity to ensure consistent pricing and contract terms. It is noted that in securing a mining right, the miner can indicate that the coal is intended for Eskom, but has no obligation to sell to Eskom;
- Challenges in negotiating contracts, with miners delaying conclusion of contracts until Eskom has no option but to agree to the terms of the contract;
- Identified corruption with respect to contract negotiation by some Eskom employees.

These and other factors have resulted in a deterioration in the quality and quantity of coal available to the power stations. This has particularly affected Duvha, Matla and Arnot and to a lesser degree Hendrina and Kendal. These trends, together with higher load factors at which stations are operated to meet increased demand, are reported to have resulted in losses to Eskom to the order of R1 billion (Eskom, 2010a).

More recently, in February 2011, Eskom suggested that their coal stockpiles are currently at an average of more than 40 days, and that approximately 95% of Eskom’s requirements to 2018 have been contracted or committed. This does not negate the challenges to securing long-term coal supplies and that delivery against contracts has to be managed on a day-to-day basis (Eskom, 2011c).

10.3 Economic contribution of the electricity sector

This section considers the various contributions of the electricity sector to the South African economy. This includes contribution to GDP, income and tax revenues, tariff structures, exports and expenditure and investment patterns. Also considered is the cost of unserved electricity, the economic impacts of electricity shortages and the impact of free basic electricity on revenue.

10.3.1 Contribution to GDP

In 2009 the electricity and gas sector contributed R 50.6 billion (2.1%) in value-added to South Africa’s GDP (StatsSA, 2010). Figure 36 below shows that after a number of years in decline, the electricity and gas sector’s contribution as a percentage of GDP has been increasing sharply since 2007 and in 2009 it was once again equal to its contribution in 2000. The declining contribution of GDP during the first half of the 2000s was most likely as a result of the continued under-investment in the South African electricity sector.

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16 PetroSA and Sasol both supply natural gas to the South African market. Sasol via imports from Mozambique and PetroSA from its offshore gas field near Saldana. PetroSA, however, utilises all the gas it produces in its gas-to-liquid plant. In addition, liquefied petroleum gas (LPG) is generated as a by-product by the oil refineries operating in South Africa.
10.3.1.1 Cost of Unserved Energy (COUE)

Unplanned electricity outages result in significant costs to electricity consumers which are not usually borne by the electricity utility. In order to properly optimise the reliability of the system, it is necessary to compare the costs to the utility of improved reliability with the costs to the customer of unplanned outages. This latter cost to the customer is the cost of unserved energy. The true value of the COUE is difficult to estimate as its value varies a great deal between different contexts and uses of electricity. A generally accepted minimum estimation of national COUE may be derived by dividing the GDP by electricity consumption. For South Africa, this yields a cost of R10/kWh. Customer surveys can also be used to derive COUE values, which in South Africa have yielded a range of values with a recent survey arriving at an estimate of R75/kWh unserved (DoE, undated b).

10.3.1.2 Economic impacts of an electricity shortage

While the cost of unserved energy serves to estimate the cost of short-timeframe unplanned power outages, electricity shortages can be managed in various other ways which give rise to less dramatic (though still considerable) economic impacts. The effects of such shortages are complex and dependent on both the management of the problem and the interaction between the various affected economic sectors. When electricity supply cannot be enhanced, two main approaches are available for reducing electricity demand on the system: increasing the price (market-based approach), and rationing consumption. Modelling of the South African economy has suggested that achieving a 10% reduction in electricity demand would carry the following implications (Davies, 2008):

- Electricity prices would have to increase more than 70% to achieve the reduction by a market-based approach.
- However, a market-based approach carries the lightest impacts on GDP and employment, because it allows the reduction to be spread across industries in the least onerous ways.
- The increased electricity price does, however, produce greater consumer inflation than rationing approaches.
- Where rationing is selectively applied, rationing of mining and smelting industries requires a smaller relative reduction in electricity consumption than rationing of the commercial sectors, due to their larger requirement for energy.
- Selectively rationing the mining and smelting industries has lower impacts on GDP and employment than rationing only the commercial industries, or rationing evenly between the two. This is because the greater economic interlinkage of the commercial sectors gives rise to greater knock-on effects than those experienced when rationing the mining and smelting sectors.
10.3.2 Income and tax revenues

In 2009/10, the Eskom Group collected R 71 billion in revenue\(^{17}\). Eskom’s revenue was up 31.4% from R 54 billion the previous year. The Group also reported an operating profit of approximately R 3.6 billion\(^{18}\) which was equivalent to approximately 0.3% of South Africa’s GDP at market prices for the same period. The big swing from a loss in previous years to this profit can be attributed to the 25% increase in electricity tariffs observed. The Group paid approximately R 2 billion in corporate income taxes which equalled 1.75% of the total corporate income taxes collected in 2009 (Eskom, 2010a).

10.3.2.1 Tariff structures

Eskom carries a number of different tariff structures differentiated by user and use characteristics. The prices themselves are made up of several components, combining service and administration fees, transmission and distribution charges, time-of-use and energy demand charges, electrification subsidies and an environmental levy, with the composition of charges differing between tariff structures. Different tariff options are available for urban businesses, urban residential users and rural users. In most cases business and rural energy charges vary with the voltage of supply, whilst most residential electricity prices increase with higher energy consumption. Large, high-voltage electricity consumers pay substantially lower prices than small consumers, yet due to the lower cost of supply, large users nevertheless cross-subsidize small users (Eskom, 2011d). In addition to the predetermined tariff options, three very large users such as smelters had negotiated supply contracts with Eskom directly, outside of these structures (Altman, 2010) which were implemented during a time of excess supply capacity in the 1980’s. Two of these supply contracts have been renegotiated while the third is still in process\(^{17}\). Eskom’s average electricity price is regulated by the National Energy Regulator of South Africa (NERSA), which determines Eskom’s allowable revenue in the Multi-Year Price Determinations (NERSA, 2011).

10.3.2.2 Free basic electricity

In 2003 the Department of Minerals and Energy released the Electricity Basic Services Support Tariff (Free Basic Electricity) Policy, which tasked local government to provide 50 kWh per month of free electricity to poor grid-connected households for poverty alleviation (DME, 2003a). This is identified as an amount that can provide basic lighting, television or radio use, limited water heating and ironing. There is also provision made for subsidising the provision of non-grid electricity systems for poor households, with the intention to provide basic lighting and media access (DoE, undated c). For grid-connected areas, two possible “self-targeting” mechanisms are recommended by the policy for identifying ‘poor’ households for the purpose of the free allocation. The first approach is for consumers to apply for a current-limited grid connection which would qualify them for the free allocation. In the second approach the local government authority identifies those households using below a threshold level of electricity (150 kWh per month) and makes the free 50 kWh available to these consumers. The latter approach has lower administrative burdens, does not require any changes to existing connections, and avoids problems of tripping connections when household usage exceeds a current limit. In both cases any consumption in excess of the 50 kWh per month is charged for at network rates.

As the delivery of basic services is the responsibility of local government, in municipal areas serviced by other parties, such as Eskom, the municipalities must pay the provider for the provision of the free basic electricity to qualifying households (DoE, undated c). It has been argued that the 50 kWh limitation is insufficient for the energy needs of poor urban households (Adam, 2010). The policy does, however, note that its intention is not to provide free electricity, but rather to lessen the energy burden on the poor through free basic electricity provision (DME, 2003a). It has also been argued that the policy has been inconsistently applied, for example with some areas requiring registration as an indigent household whilst others provide blanket free allocations, and that there are numerous institutional and awareness hurdles facing implementation (Adam, 2010; Chetty, 2006).

10.3.3 Electricity exports

To ensure regional security of supply, Eskom’s South African grid is connected to a number of countries that are members of the Southern African Development Community (SADC). The Southern African Power Pool (SAPP) allows Eskom to buy and sell electricity to neighbouring states in order to meet fluctuations in demand and supply (SAPP, 2010). Over the last six years, South Africa has been a net exporter of electricity to the SAPP, as shown in Table 25. Exports are also considered in the analysis of regional considerations.

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\(^{17}\) Income Statement for the year ended 31 March 2010

\(^{18}\) Up from an operating loss of approximately R10 billion for the group
Table 25: Total South African electricity imports and exports

<table>
<thead>
<tr>
<th>Year</th>
<th>GWh</th>
<th>GWh</th>
<th>GWh</th>
<th>GWh</th>
<th>GWh</th>
<th>GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported</td>
<td>9,199</td>
<td>9,782</td>
<td>11,348</td>
<td>10,572</td>
<td>12,295</td>
<td>12,193</td>
</tr>
<tr>
<td>Exported</td>
<td>12,884</td>
<td>13,766</td>
<td>14,496</td>
<td>14,268</td>
<td>14,052</td>
<td>14,645</td>
</tr>
<tr>
<td>Net Imports (-Exports)</td>
<td>-3,685</td>
<td>-3,984</td>
<td>-3,148</td>
<td>-3,696</td>
<td>-1,757</td>
<td>-2,452</td>
</tr>
<tr>
<td>Total exports as % of total energy available in South Africa</td>
<td>6.3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net exports as % of total energy available in South Africa (i.e. exports-imports)</td>
<td>0.93%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: DNAEconomics Calculation based on StatsSA, 2010; Eskom 2010a)

10.3.4 Expenditure and investment patterns

Eskom spent a total of R 98.9 billion between 2005 and 2010 on capital expenditure projects (including capitalised interest). A large proportion of this expenditure has been on new capacity. Eskom embarked on an ambitious build project in 2008 worth an estimated R 385 billion over five years. This project is one of the largest build programmes in South Africa, and Eskom estimates that this programme alone has the potential to create approximately 40,000 jobs directly and indirectly (Eskom, 2010a). Between 2008 and 2010, Eskom’s Generation Division, which is responsible for the running of the power stations, spent a total of approximately R 69 billion on new capacity (Eskom, 2010f). The capacity expansion programme is shown in Table 26 below.

In the short term, as part of the build program, three coal-fired power stations that had been mothballed in 1990 are being recommissioned in order to meet the growing demand for electricity. The three power stations, all located in Mpumalanga, are Camden (1,600 MW), Grootvlei (1,200 MW) and Komati (1,000 MW). The total expenditure on the three projects by Eskom till March 2010 was approximately R 21 billion. This was a substantial investment in a province that in 2005 had a gross geographic product of R 105 billion (DEDP, 2007). Without the electricity generation sector (and the coal reserves on which it is based), this province would thus have been significantly worse off economically.

In the medium term, the build program includes the construction of two new coal fuelled power stations. The first of these new stations is the Medupi power station which will have an installed capacity of 4,788 MW. Coal for this power station is being supplied by the Grootegeluk colliery which also supplies the existing Matimba power station as well as other grades of coal. The construction of this power station in Lephalale began in 200721. It is expected that the station’s six units will be commissioned in phases between 2012 and 2015. Eskom also plans to construct homes and social infrastructure for its employees in the small community (Eskom, 2010g).

The second new coal fuelled power station is the Kusile Power Station which is located near the Kendal power station in the Delmas municipal area of Mpumalanga. The station will have an installed capacity of 4,800 MW using coal from a new Anglo Coal colliery situated near the power station. The station has already entered into a long term supply agreement with the colliery for 17 Mt of coal per year over a period of 47 years (Eskom, 2010h).

Other new build by Eskom includes the Ingula pumped storage and one open cycle gas turbine station which during peak demand will have the capacity to generate 1,332 MW and 1,036 MW respectively.

Table 26: Capacity expansion programme by project (including interest capitalised)

<table>
<thead>
<tr>
<th>Project</th>
<th>Total approved project cost (R millions)</th>
<th>Total expenditure - inception to March 2010 (R millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camden</td>
<td>6,061</td>
<td>5,739</td>
</tr>
<tr>
<td>Grootvlei</td>
<td>7,803</td>
<td>7,107</td>
</tr>
<tr>
<td>Komati</td>
<td>12,965</td>
<td>8,402</td>
</tr>
<tr>
<td>Kriel</td>
<td>1,973</td>
<td>1,035</td>
</tr>
<tr>
<td>Arnot</td>
<td>1,496</td>
<td>1,233</td>
</tr>
<tr>
<td>Matla refurbishment</td>
<td>3,564</td>
<td>689</td>
</tr>
<tr>
<td>Duvha</td>
<td>2,450</td>
<td>58</td>
</tr>
<tr>
<td>Majuba rail</td>
<td>4,235</td>
<td>238</td>
</tr>
<tr>
<td>Ingula</td>
<td>21,800</td>
<td>6,131</td>
</tr>
<tr>
<td>OCGT19 and Gas 1</td>
<td>8,762</td>
<td>7,861</td>
</tr>
<tr>
<td>Sere</td>
<td>3,356</td>
<td>40</td>
</tr>
<tr>
<td>Kusile</td>
<td>141,500</td>
<td>14,697</td>
</tr>
<tr>
<td>Medupi</td>
<td>125,500</td>
<td>32,076</td>
</tr>
<tr>
<td>Tutuka</td>
<td>185</td>
<td>2</td>
</tr>
<tr>
<td>Camden rail</td>
<td>63</td>
<td>9</td>
</tr>
<tr>
<td>Transmission projects</td>
<td>26,800</td>
<td>13,623</td>
</tr>
<tr>
<td>Total</td>
<td>368,513</td>
<td>98,940</td>
</tr>
</tbody>
</table>

(Source: Eskom, 2010a)

19 Of the R69.362 billion, approximately R29.467 billion was spent on capacity expansion rather than new builds.
20 As a rule, a coal fired power station takes about 8 years to build
21 Open Cycle Gas Turbine
As a result of the sheer scale of the investment in coal-fired power stations in the pipeline, the Department of Trade and Industry identified Eskom’s coal-fired electricity build programme (and also Eskom’s nuclear electricity build programme) as an opportunity to use local procurement practices as a way to support local industrial development objectives (dti, 2010a).

At the beginning of 2010, the funding constraints experienced by the power utility resulted in a slowdown of the capital expansion programs. Table 27 illustrates how most of the actual expenditure on Eskom’s approved projects remained well below the budgeted amounts.

Table 27: Capacity Expansion capital expenditure incurred (excluding interest capitalised) from 2005 to March 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Budget (R millions)</th>
<th>Actual (R millions)</th>
<th>Variance (R millions)</th>
<th>Variance [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005/6</td>
<td>3,015</td>
<td>2,835</td>
<td>-180</td>
<td>-5.97%</td>
</tr>
<tr>
<td>2006/7</td>
<td>7,058</td>
<td>8,226</td>
<td>1,168</td>
<td>16.55%</td>
</tr>
<tr>
<td>2007/8</td>
<td>12,112</td>
<td>12,783</td>
<td>671</td>
<td>5.54%</td>
</tr>
<tr>
<td>2008/9</td>
<td>28,655</td>
<td>30,460</td>
<td>1,805</td>
<td>6.30%</td>
</tr>
<tr>
<td>2009/10</td>
<td>50,454</td>
<td>33,713</td>
<td>-16,741</td>
<td>-33.18%</td>
</tr>
<tr>
<td>Cumulative</td>
<td>101,294</td>
<td>88,017</td>
<td>-13,277</td>
<td>-13.11%</td>
</tr>
</tbody>
</table>

(Source: Eskom, 2010a and DNA Economics calculations)

In 2010, the World Bank approved a USD 3.75 billion loan to the South African power utility. The basis for the loan was that no regional source could meet the required base load capacity needed to fuel the growing South African economy. The loan was however made on the understanding that Eskom would make strides to address its high carbon intensity and emissions. Thus clean coal technology would be used in the Medupi power station, and USD 260 million would be invested into wind and solar power projects. The loan also included USD 485 million which would be used to improve energy efficiency (World Bank, 2010).

10.4 Policy related to coal utilisation in electricity generation

Energy policy in South Africa remains governed by the 1998 Energy Policy White Paper (DME, 1998). Whilst this Paper has little to say about coal directly, it has many indirect implications for the coal value chain, given coal’s position as the country’s main primary energy source.

Prior to the White Paper, energy policy was operated out of an energy supply policy paradigm (Marquard, 2007), with the individual energy supply communities of electricity, coal, liquid fuels and nuclear dominating the policy development and implementation process, and largely acting in silos.

The country’s energy services were almost solely delivered through the provision of cheap electricity powered by coal, and very little thought was given to energy efficiency or planning for any alternative mode of energy service delivery in the future (Tyler, 2010). The 1998 White Paper identifies five policy objectives: increasing access to affordable energy services, improving energy governance, stimulating economic development, managing energy related environmental and health impacts and securing supply through diversity. These objectives are significantly broader than the historical energy supply approach to energy policy, with particular emphasis being placed on the demand side and on the need to reduce greenhouse gas emissions.

For over a decade following the White Paper’s release, limited progress was made in consolidating the White Paper’s approach (Tyler, 2010). An example of this is the White Paper’s commitment to electricity liberalisation: government changed their approach in 2007, with Eskom being confirmed as the sole purchaser of generated power by Cabinet (DME, 2008). More recently the commitment to some level of liberalisation has again resurfaced with the announcement of an Independent System and Market Operator (ISMO) outside of Eskom to manage the grid (Zuma, 2010).

The 2008 Energy Act provided some direction, but largely responds to the electricity crisis. The Act aims to ensure that diverse energy resources are available, in sustainable quantities and at affordable prices, to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management requirements and interactions amongst economic sectors.

It requires energy planning, including the development of contingency energy supply, adequate investment in, appropriate upkeep and access to energy infrastructure, and the holding of strategic energy feedstocks and carriers by State Owned Enterprises. This final provision is of particular importance to the coal sector. Coal has not yet been defined as a strategic mineral, but pressure has been building on government in the light of Eskom’s coal contracting difficulties, the increasing demand for lower quality coal from the export markets, and the higher prices to be obtained on the international markets.

Energy efficiency was a strong component of the 1998 Energy White Paper, and despite the development of an Energy Efficiency Strategy (2005) identifying a national energy efficiency target of 12% by 2015, a voluntary Energy Efficiency Accord initiative between business and the Department of Energy (DME), and the electricity supply crisis of 2008, neither policy focus nor implementation has been sustained in this area. The 2008 National Energy Act established the South African National Energy Development Institute (SANEDI), with functions in energy efficiency (the National Energy Efficiency Agency operates under SANEDI) and renewable energy. This institution only recently received a funding allocation in the 2011 budget (Gordhan, 2011), and is in the process of clarifying its mandate and role in light of possible overlap in areas of responsibility between the relevant government departments of Energy and Science and Technology (Tyler, 2010). Treasury, in the 2011 budget, has allocated funding...
for the South African National Energy Efficiency Agency established by the DME in 2006 (Gordhan, 2011), which may indicate an acceleration of activity on energy efficiency. Treasury has introduced a number of tax incentives for investment in energy efficiency (Newman, 2009).

A 2003 Renewable Energy White Paper committed the country to 10,000 GWh contribution of renewable energy to final energy demand by 2013. This Paper has been reviewed, although it is not clear how the review will be used. Indications are that progress towards this target is limited (Agama Energy, 2010). Renewable energy is supported by a Renewable Energy Feed-in Tariff (REFIT), which pays a subsidy to renewable energy generators who are successful in Eskom’s tender process for the provision of renewables generation capacity. Treasury levied a charge on electricity generated from non-renewable sources in 2009, which has been increased to 2.5c/kWh (Gordhan, 2011), and there is some funding of renewable energy generation through the DoE’s Renewable Energy Subsidy Office (DoE, 2010a).

The DoE has developed a twenty year Integrated Resource Plan for Electricity (IRP 2010), which will address much of the uncertainty which has been present in energy policy over the past decade. The Policy Adjusted Scenario which has been adopted sees a progressive move away from coal based electricity generation, and does not prescribe who builds the uncommitted capacity (DoE, 2010b).

The 2009 institutional split of the DME into the DMR and the DoE may reflect or lend support to a move away from the close ties of coal, mining and energy supply. From an energy perspective, the carbon constraints of climate change, potentially in tandem with actual coal resource constraints, may prompt and sustain a move to a resource dominated policy approach to coal (as opposed to the industrial approach favoured in the 1970’s and 80’s, when there was still an active coal policy (Marquard, 2007).

Apart from the 2008 Energy Act, legislation of relevance to the energy sector pertains to its regulation: the National Energy Regulator Act and Electricity Regulation Act of 2006.

Underground Coal Gasification (UCG) is not currently addressed by either policy or legislation, and this is an important area which should be addressed to potentially avoid constraining further investigation of the viability of this energy source.

### 10.5 Likely evolution of the South African electricity supply sector

#### 10.5.1 Proposed generation build plan – IRP2010

The Integrated Resource Plan 2010 (IRP2010) lays out the proposed evolution of the electricity supply sector until 2030 (DoE, 2010b). In particular, the “Policy Adjusted” Scenario was adopted as the preferred scenario by the South African Government for electricity generation. This Scenario identifies that South Africa is already committed to building of two new coal fired power stations (Medupi and Kusile at 4,332 MW and 4,338 MW respectively). Further new generation build options include 6,250 MW of coal-fired power, including coal-generated electricity imports, 2,370 MW of natural gas CCGT, 9,200 MW of Wind, 9,725 MW of other renewables and 9,600 MW of nuclear. The first nuclear units are suggested to come online in 2023. The total net new build (including decommissioning) over the 2010 to 2030 period amounts to 45,637 MW. Figure 37 shows the development of the total system capacity over the IRP period.

![Figure 37: Development of electricity generation capacity under IRP2010 Policy-Adjusted scenario.](image-url)
Included in the IRP2010 is the decommissioning of 10,902 MW of Eskom’s existing fleet by 2029 - or about 25% of the current installed capacity in the country.

A number of factors need to be taken into account when considering the likelihood that the build plan specified in the IRP will be achieved. The following factors could thus determine evolution according to this Plan:

- Whether Eskom or Independent Power Producers (IPPs) will be responsible for building new capacity particularly into the medium to long term. This needs to be explored and determined.
- Financing issues for new coal-fired power stations have already been an issue with Medupi and Kusile, and will likely to become even more challenging with any future build for power stations using non-renewable resources, and particularly those which do not employ Carbon Capture and Sequestration (CCS).
- The upfront cost of building new nuclear plants is significant, and raising the funding for 9,600 MW of nuclear is also likely to represent a significant challenge.
- The lead times for nuclear power stations are also significant.
- The nuclear disaster in Japan has influenced the global appetite for new installed nuclear power stations negatively.
- There is a shortage of expertise in South Africa to install and maintain new technologies.

Thus, while the IRP2010 suggests the build plan for new power stations to 2030, this can change - there are proposals that the IRP should be updated every two years, or even annually.

10.5.2 Entry of Independent Power Producers (IPPs)

Although the responsibility for building new generation infrastructure (beyond that which is already committed) is not explicitly defined as part of IRP2010, there is a drive from government to allow independent power producers to enter the electricity market, including in the generation of electricity from renewable resources. Until 2011 the primary mechanism under consideration for encouraging development of renewable electricity generation supply has been the Renewable Energy Feed-in Tariff (REFIT). This had been intended to stipulate a premium price that power producers would receive for renewable energy fed onto the national grid, and establish systems to guarantee the necessary grid access (Brodsky, 2010).

In May 2011, however, it was announced that the intended REFIT mechanism was not legally compliant, and a new bidding-based process was announced later in the year (van den Berg, J., 2011). The new approach has been criticized for having been developed without consultation with stakeholders, and for burdening the nascent renewable energy sector with heavy compliance costs and requirements. However, there nevertheless appears to be some level of support for the new process (van den Berg, J., 2011; Creamer, 2011a). The bidding process has specified capacity allocations for onshore wind (1850 MW), solar PV (1450 MW), solar CSP (200 MW), biomass (12.5 MW), biogas (12.5 MW) landfill gas (25 MW) and small hydro (75 MW), with 100 MW also available for other small projects of below 5 MW. Although maximum prices have been stipulated, the procurement decision will only place a 70% weighting on bid price, with the remaining 30% for priorities such as job creation, employment equity and empowerment, and community and economic development. Eskom, which will be the power purchaser under the scheme, has been specifically excluded from bidding for the development of renewable energy projects under the programme (Creamer, 2011b).

There are reported to be a number of independent power producer (IPP) generation projects in the pipeline, at various stages of development. Since 2010, around 400 MW had been contracted in by Eskom (the designated Single Buyer of electricity) under their medium term power purchase programme (MTPPP), but at the time of writing no renewable energy IPP’s had been contracted. This is attributed to the lack of an enabling regulatory environment being established and the delays in the finalisation of the arrangements for electricity feed-in.

10.5.3 The Renewable Energy White Paper

A further driver of renewable energy in South Africa is the 2003 White Paper on Renewable Energy, which sets out a target of 10,000 GWh of renewable generation cumulative by 2013 (DME, 2003b). This document has come under criticism for both the way that the target was defined, and details on how it should be achieved. It is suggested that little progress has been made towards meeting this target.

A review of the White Paper was conducted in 2010, however the results of this review have not been made public and there is no clear indication as to whether the review will be released or adopted.
LIQUID FUELS AND CHEMICALS PRODUCTION

Beyond the recovery of the energy value of coal as electricity, a diverse range of products can be derived from coal. Non-fuel coal-derived products include carbon materials (e.g. activated carbons, carbon molecular sieves), speciality carbon materials (e.g. graphite, fullerene, nano tubes and diamonds), composite materials (e.g. coal/polymer composites and coal/conducting polymer composites), aromatic and phenolic chemical feedstocks, coal tar pitch products (e.g. binder pitch, mesocarbon microbeads, carbon fibres, and activated carbon fibres), and humic materials (e.g. soil modifiers and fertilisers) (Song et al., 2005). This section explores liquid fuels and non-energy coal products such as chemicals produced from coal. The use of coal to produce metallurgical coke is covered in the following section.

The production of coal-based liquid fuels and chemicals in South Africa is vested in Sasol. The petrochemical company was formed in 1950 and commenced production in 1955. Today it hosts the largest and only commercial coal-to-liquids operation globally converting low-grade, sub-bituminous coal and natural gas into liquid fuels and chemicals (Sasol, 2009a). The industry has evolved over the past 60 years to produce liquid fuels and various chemicals for the local market, and contributes significantly to the energy security of South Africa (Sasol, 2010a).

11.1 Coal to liquids: Process routes and technologies

The conversion of coal to liquids, or liquefaction, involves reaction with hydrogen, reduction of the hydrocarbon molecular size and elimination of sulphur, nitrogen and oxygen components found in coal. Two process routes are currently used for obtaining liquid fuels from coal by liquefaction, each of which is discussed in detail below:

- **Direct coal liquefaction (DCL):** involves high pressure dissolution of coal in solvents at high temperature and pressure. This process is highly efficient, but the resulting mainly aromatic products require significant further processing to achieve the required product quality.

- **Indirect coal liquefaction (ICL):** involves gasifying the coal to form synthesis gas (syngas) (CO and H₂), which is then cleaned to remove sulphur and other impurities. The cleaned gas is then reacted over a catalyst to produce a wide range of products.

Carbonisation and pyrolysis are alternative but less effective processes that yield liquid fuels by removing carbon from coal. In these processes, liquid fuels are produced as by-products, with coke and char as the main products. These are not considered further here.

11.1.1 Direct liquefaction

In direct liquefaction, solvents at high temperatures and pressures are used to break down the complex coal molecular structure. This is done in the presence of catalysts and hydrogen to maximise the formation of smaller molecules, which results in a synthetic “crude” product. This synthetic crude tends to contain mostly aromatic compounds, which may be difficult to refine to high quality transport fuels. The product spectrum is highly dependent on the molecular composition of the input coal, the impurities present in the coal, as well as the process conditions.

While direct liquefaction is considered to be the most efficient process route to manufacturing synthetic fuels, it has only been demonstrated at a pilot scale and is presently unproven at the commercial scale.

11.1.2 Indirect liquefaction

Indirect coal liquefaction can follow two routes after coal gasification to form syngas (CO and H₂):

- Fischer-Tropsch (FT) synthesis
- Methanol synthesis.

The indirect coal-to-liquids route has a number of advantages. As the first step in the process, gasification effectively removes most of the ash, apart from any volatile components and thereafter sulphur compounds can be readily cleaned from the gas and removed; the products from ICL are thus ultraclean, with no sulphur and near zero aromatics (Couch, 2008). With minimal further refining it is possible to produce ultraclean diesel or jet fuel (Couch, 2008; Minchener, 2007). This process also lends itself to the capture of CO₂ for subsequent storage, discussed under the section on climate change. Further, this process can be operated in a “polygeneration format” for cogeneration of electric power (Couch, 2008).

Some challenges with coal liquefaction include the variability in coal feedstock mineral matter and impurities, the maintenance of high temperature and pressure, the need for precious metal catalysts, and the requirement for cooling water to control the exothermic processes of coal gasification in ICL and hydrogen production in DCL and managing the energy released from several exothermic reactions (Couch, 2008).

11.1.3 Chemicals

The FT process yields different product ranges depending on the process conditions maintained and catalyst employed. While the high temperature FT (HTFT) process is typically used primarily to produce liquid fuels, other chemicals such as alpha olefins are extracted from the “crude synthetic liquid” phase: the aqueous phase yields alcohols, acetic acid and ketones including acetone, methyl ethyl ketone (MEK) and methyl iso butyl ketone (MIBK) upon separation and work up of the aqueous phase from the SAS reactor (van Dyk et al., 2006).

11.1.4 Sasol’s CTL process

Sasol’s CTL process, located at Secunda, includes four main stages: gasification of coal to produce syngas, gas purification, FT synthesis and product workup. Sasol has also co-fed
natural gas from Mozambique into its plant at Secunda since 2004. Initially, coal is blended for gasification where a syngas mixture of CO and H₂ and other pyrolysis co-products is produced. Once cooled, the condensate yields the first set of co-products: tars, oils, pitches, ammonia, sulphur and phenols (Sasol, 2010a). The purified syngas is fed to the reactors, where under pressure and in the presence of catalysts it reacts to form hydrocarbons in the C₁ - C₂₀ range (automotive fuels and light olefin used as feedstock for chemical manufacturing) and also reaction water and oxygenated hydrocarbons. The latter are recovered and further processed to yield solvents.

The intermediate products (alkane, oxygenate, olefin and aromatic products) are separated and processed further into various final products including polymers, solvents, surfactants and olefins.

The FT process at Sasol is currently biased towards the production of transport fuels – chemical intermediate products from the FT process are presently produced in lower volumes than synfuels. As the price of crude oil rises, coal is increasingly being looked to as an alternative feedstock to crude oil for the production of chemicals as it represents a more profitable use of coal compared to producing liquid transport fuels.

The process flowsheet is illustrated in Figure 38, and shows both the complexity of the process and the wide range of products that can be produced.

Figure 38: Sasol flowsheet

(Source: Sasol, 2010a)
11.2 Overview of Sasol’s operations

Box 4, replicated primarily from (Sasol, 2010a), presents an overview of Sasol’s global operations. In South Africa, Sasol Mining and Sasol Gas secure feedstocks to the process, Sasol Oil markets liquid fuels, while Sasol Polymers, Sasol Solvents, Sasol Wax and Sasol Nitro business units, markets chemical products.

Table 28 shows the products, production and sales figures of Sasol business units for 2010. The figures presented in this Table include the international business units.

Table 28: Sasol production and sales for 2010

<table>
<thead>
<tr>
<th>Business unit</th>
<th>Sales</th>
<th>Turnover (R million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sasol Synfuels (Mt) (transport fuels and chemicals precursors)</td>
<td>7.34</td>
<td>879</td>
</tr>
<tr>
<td>Sasol Mining (Mt)</td>
<td>44.3</td>
<td>1696</td>
</tr>
<tr>
<td>Sasol Gas (MGJ)</td>
<td>123.7</td>
<td>2986</td>
</tr>
<tr>
<td>Sasol Oil (Mt)</td>
<td>43.7</td>
<td>47932</td>
</tr>
<tr>
<td>Sasol Synfuels International (Mt)</td>
<td>42.7</td>
<td>2282</td>
</tr>
<tr>
<td>Sasol Petroleum International Gas (MGJ)</td>
<td></td>
<td>961</td>
</tr>
<tr>
<td>Condensate (M bbl)</td>
<td>75.1</td>
<td></td>
</tr>
<tr>
<td>Oil (M bbl)</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sasol Polymers (Mt)</td>
<td>1.6</td>
<td>14236</td>
</tr>
<tr>
<td>Sasol Solvents (Mt)</td>
<td>1.7</td>
<td>13425</td>
</tr>
<tr>
<td>O&amp;S (Mt)</td>
<td>19.25</td>
<td>24774</td>
</tr>
<tr>
<td>Other (including Sasol Nitro, Sasol Wax, Infrachem, Merisol) (Mt)</td>
<td></td>
<td>11951</td>
</tr>
</tbody>
</table>

(Source: Sasol, 2010b)\textsuperscript{23}

\textsuperscript{22} Syngas purification occurs at the Rectisol process. Carbon dioxide and sulphur-containing compounds released from coal during coal gasification are removed along with methane and other light hydrocarbons. Carbon dioxide is further removed after reaction of syngas in the Syngas reactor by means of the Benfield process.

\textsuperscript{23} Production and sales volumes are reported for CTL and GTL combined
Box 4: A summary of Sasol’s business units

The principal coal feedstock for Sasol’s processes is mined by Sasol Mining (Pty) Ltd, with current production of around 40 Mt/aud of coal. The majority of this coal (~70%) is used as inputs to CTL processes, and the remainder for meeting power requirements, and for chemicals processing at the group’s Secunda facilities. Mines are located in the Highveld coalfield and the Free State (see coal mining section).

Sasol Gas markets and distributes natural gas from Mozambique and methane-rich gas produced by Sasol Synfuels at Secunda. It delivers gas through a 2,118 kilometre pipeline network to approximately 550 industrial and commercial customers in the Gauteng, Free State, Mpumalanga and KwaZulu-Natal Provinces. Sasol has co-fed natural gas from Mozambique into its process at Secunda since 2004, and at Sasolburg, natural gas is reformed to produce waxes, ammonia, solvents and other chemicals.

Sasol Synfuels operates the world’s only commercial coal-based synfuels manufacturing facility in Secunda.

Sasol Oil markets fuels blended at Secunda and refined through its 63,6% share in Natref oil refinery at Sasolburg. Products include petrol, diesel, jet fuel, illuminating paraffin, liquefied petroleum gas, fuel oils, bitumen and lubricants. It imports fuels to balance its product slate and meet contractual commitments. Sasol Oil operates 418 Sasol- and Exel®-branded retail convenience centres in South Africa and exports fuels to Southern Africa.

Sasol Synfuels International (SSI) pursues international coal-to-liquids (CTL) and gas-to-liquids (GTL) synfuels opportunities. In partnership with Qatar Petroleum, SSI brought the first international GTL plant, Oryx GTL, into operation at Ras Laffan, Qatar in 2007. The company has established liaison offices in Beijing, China; Mumbai, India; Doha, United Arab Emirates, and Tashkent in Uzbekistan to promote CTL and GTL interests in these regions.

Sasol Petrochemicals International (SPI) develops and manages the upstream interests in oil and gas exploration and production in Mozambique, South Africa, Gabon, Nigeria, Papua New Guinea and Australia. It produces gas and condensate from Mozambique’s onshore Temane and Pande fields and oil from Gabon’s offshore Etame oilfield cluster. SPI pursues gas exploration opportunities to enable it to supply feedstock to potential future gas-to-liquids plants.

Sasol Polymers has plants at Sasolburg and Secunda and supplies ethylene, propylene, polyethylene, polypropylene, polyvinyl chloride, chlor-alkali chemicals and mining reagents to domestic and international customers. It has joint-venture monomer and polymer interests in Malaysia and Iran.

Sasol Solvents has plants in South Africa and Germany and supplies alcohols, ketones, esters, acrylic acid esters, ethyl acetate, ethers, propionic acid, acetic acid, comonomers and mining chemicals to customers worldwide. It has a German maleic anhydride joint venture with Huntsman.

Sasol Olefins & Surfactants (O&S) operates plants in Germany, Italy, the USA, China, Dubai, South Africa and the Slovak Republic. The company supplies C6-C22 alcohols, linear alkylbenzenes, surfactants, inorganic specialty chemicals and oleochemicals as well as chemical intermediates to customers worldwide. It has a joint-venture alcohols plant in China.

Sasol Nitro has production operations at Sasolburg, Secunda, Rustenburg and Bronkhorstspruit in South Africa and markets ammonia, nitric acid, explosives, fertilisers, ammonium sulphate and blasting accessories. It also markets ammonia, sulphur and specialty gases produced by other Sasol businesses.

Sasol Infrachem provides a services platform for reforming natural gas and providing utilities, infrastructure and site support at their Sasolburg complex. It is responsible for Sasolburg site governance and reputation management in the Free State Province.

Sasol’s Merisol joint venture with Merichem of the USA has plants in South Africa and in the USA and a joint-venture production facility at Sasolburg, South Africa. It supplies cresols, xyleneols, alkylphenols and other phenolics and their derivatives to customers on all continents.

Sasol Technology manages research and development, technology management and innovation, engineering services and project management portfolios. It assists the fuels and chemical businesses to maintain growth and sustainability through appropriate technological solutions and services.

Sasol New Energy (SNE) was created to focus on new technologies that can be integrated with core technologies to result in a lower greenhouse gas footprint. In an effort to reduce production of CO2 in their operations and integrate new technologies into their Fischer-Tropsch processes, SNE will explore renewable and lower-carbon energy options such as solar, biofuels and biomass, as well as nuclear, hydro and natural gas. Carbon capture and storage (CCS) will be targeted to sequester the CO2 produced through the Fischer-Tropsch process.

(Sources: Sasol, 2010a; Sasol, 2005; Aasberg-Petersen et al., 2004)
11.3 Sasol’s economic contribution

This section attempts to illustrate the significant role that Sasol plays within the South African economy.

11.3.1 Income and tax revenues

In the financial year-ending 30 June 2010, the Sasol Group of companies had a turnover of R 122.256 billion and declared an after tax profit of R 16.387 billion. In this period, R18 billion was distributed to employees, and 19%, or R6 billion, to government in the form of taxes and related revenues. Sasol’s contribution to corporate income taxes in South Africa for the past four years is shown in Table 29 (Sasol, 2010c).

Table 29: The Sasol Group’s contribution to the total corporate income tax revenue in South Africa

<table>
<thead>
<tr>
<th>Period</th>
<th>Sasol corporate income tax (R million)</th>
<th>Total taxes on South African companies (R million)</th>
<th>% of total taxes on Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006/2007</td>
<td>8,153</td>
<td>118,999</td>
<td>5.35%</td>
</tr>
<tr>
<td>2007/2008</td>
<td>10,129</td>
<td>140,120</td>
<td>6.34%</td>
</tr>
<tr>
<td>2008/2009</td>
<td>10,480</td>
<td>165,378</td>
<td>7.23%</td>
</tr>
<tr>
<td>2009/2010</td>
<td>6,985</td>
<td>130,500**</td>
<td>6.85%</td>
</tr>
</tbody>
</table>

(Source: Sasol, 2010b; SA Ministry of Finance, 2010a & 2010b; and DNEconomics calculation)

* Sasol period is for the financial year ending in June, for the government statistics the financial year ends in March.

** Estimate

11.3.2 Balance of Payments impact

Crude oil accounts for 17% of South Africa’s primary energy needs. Coal-to-liquid technology accounts for 27% of South Africa’s liquid petroleum production, reducing South Africa’s dependence on foreign oil (Kopler, 2009). Products refined locally from imported crude oil meet the balance (Nkomo, 2009). Imported crude oil is paid for in US dollars. This dependence on imports leaves South Africa vulnerable to fluctuations in the global oil price as well as the Rand-Dollar exchange rate. It is estimated that a USD 10 a barrel shock on the price of crude leads to a 0.8% decline in South Africa’s national output and a 1.2% increase in inflation (Nkomo, 2009).

11.3.3 Capital expenditure

Between 2007 and 2010, Sasol invested R 43 billion in capital projects, with R 16 billion invested in 2010 alone. The biggest was Secunda Growth Phase 1, followed by Wax Expansion, the Twistdraai shaft and only then by the open cycle turbines (Sasol, 2010a).

As identified previously, Sasol is investigating the development of another inland CTL facility plant in the north-west province of Limpopo. The CTL facility, with its associated coal mine and infrastructure (if it goes ahead), will be the first new town since the democratisation of South Africa. Up until 2010, Sasol has invested nearly R1 billion for the pre-feasibility study, drilling, sampling, gasification trials, and land acquisition (Sasol, 2010a).

11.4 Policy related to liquid fuels

Liquid fuels policy and legislation focuses largely on the regulation of the industry (Petroleum Pipelines Act, 2003), and energy issues are not addressed in liquid fuels policy (Marquard, 2007). This has been remedied to some extent in the Energy Security Master Plan: Liquid Fuels (2007). The strategy has short, medium and long-term intents. The short-term objective is to “secure adequate supplies of affordable energy for continued economic growth and development” (DME, 2007a). The medium term goal is to enable informed decisions about “complex inter-dependent energy outcomes” (DME, 2007a), and the long term is to ensure sustainability. Climate change and localisation of supply are mentioned as particular issues in the Plan, together with the immediate and important need for integrated energy planning in the country. Liquid fuels policy is the remit of both the Departments of Energy and the Department of Transport.

The use of coal for liquid fuels, metallurgy and industrial heat and power are additionally governed by the National Industrial Policy Framework (2007), and subsequent Industrial Policy Action Plans. The objectives of these policy documents are to diversify the economy beyond traditional commodities and non-tradable services; to intensify industrialisation towards a knowledge economy; to promote labour-intensive industrialisation; to promote broad based industrialisation and to support industrial development in Africa (Cloete and Robb, 2010).

11.5 Likely evolution of coal-to-liquids in South Africa

In exploring the evolution of the coal sector in South Africa, there is merit in identifying Sasol’s potential future activities. Firstly, Sasol is undertaking a pre-feasibility study for another CTL 80,000 bbl/d liquid fuels plant, in north-west Limpopo. Related recent activities include “prospecting, drilling, bulk sampling, gasification trials and land acquisition” (Sasol, 2010a).

Given potential environmental benefits such as reduced above-ground emissions, reduced surface raw water demand and the elimination of environmental problems associated with coal mining and transportation to the gasification facility, underground coal gasification holds potential as an alternative, cleaner coal technology to the current processing route (Sasol, 2010d). Sasol is investigating possible underground coal gasification options.
In terms of coal supply, production from the diminishing reserves of the original Twistdraai shafts and Brandspruit mines will be replaced respectively by the new Twistdraai shaft in the north-east and the Impumulelo mine in the south-western portion of the Secunda complex (Eberhard, 2011; Creamer, T., 2011b). The proposed Mafutha Project is to obtain coal from the Limpopo’s Waterberg region from Exxaro and Sasol’s own mining initiatives in the Waterberg (Wood Mackenzie, 2010d).
METALLURGICAL USE

The iron and steel value chain consists of four stages, mining, iron making (either from iron ore in blast furnaces or scrap steel primarily in EAF furnaces), primary steel production (which involves the production of flat products and long products) and finally fabrication. Coal is used in blast furnaces as a reductant and energy source. Vanadium, manganese, silicon and chromium may be added to improve the properties of steel. The resultant product suite, known as ferroalloys, includes (FeSi), ferromanganese (FeMn), ferrosilicon manganese (FeSiMn), and ferrochrome (FeCr). Coal is also used in the manufacture of ferroalloys.

The use of coal in blast furnaces represents the second largest market for coal globally, after thermal use. This includes both the production of iron for steelmaking, and in the production of ferroalloys. It is estimated that coal is used to produce almost 70% of steel globally. World crude steel production was about 1.3 billion tonnes in 2008, with the associated use of an estimated 590 Mt of coking coal (World Coal Institute, 2005).

South Africa produces both iron and steel, and is a significant exporter of ferroalloys including ferromanganese, ferrochrome and ferrovanadium. South Africa is the continent's largest steel producer, accounting for approximately 48% of total crude steel production in 2008 (CMRC Africa, 2009). A comparison between South African and global steel production is shown in Figure 39.

Figure 39: Comparison of South African versus global crude steel production

![Figure 39: Comparison of South African versus global crude steel production](image)

(Source: South African Iron and Steel Institute (SAISI), 2011)

12.1 The production of coke for steel and ferroalloy manufacture

Many iron and steel and ferroalloy processes require the conversion of coal into coke through carbonisation, prior to feeding into the blast furnaces. Carbonisation involves heating the coal to temperatures of up to 1100 °C in an oxygen-free environment to drive off liquids, gases and volatile matter. The remaining solid macroporous material is almost pure carbon, and is characterised by high strength and relatively large lump size suitable for use in blast furnaces (Carpenter et al., 2010). The measures of quality of the coke product include those of mechanical strength to withstand handling and movement within the furnace, size distribution and levels of ash and sulphur. Smaller lumps of coke called coke breeze are also formed. Gas and tar are produced as by-products and are recovered for their energy value. Approximately 1.5 tonnes of metallurgical coal is needed to produce one tonne of coke. The traditional technology for making coke is the slot coking oven.

Coke is fed with metal ores into a blast furnace, where it reduces metal oxides (typically iron to make steel). The carbon in the coke provides the reducing agent which converts the Fe₂O₃ in the iron ore to its metallic form to yield pig iron. It also provides an energy source to raise the temperature. Pig iron is either used as is (although its high carbon content makes it brittle), or is further purified into steel. Blast-furnace technology can also be used for smelting other metals such as copper, nickel, zinc and lead.
The metallurgical or coking coal used in coke production is a mid-rank or blended bituminous coal. Important properties of coking coal include mechanical properties at high temperature that give rise to good caking and coking behaviour (fluidity, crucible swelling number, etc.); low ash; low moisture; low sulphur and phosphorus (Evolution Markets, 2010).

### 12.2 Alternatives to coke

The high capital and operating cost of equipment for coking, environmental pressures (particularly in developed countries) and the reduced availability of metallurgical coal have together led to the development of both alternative technologies for coke manufacture, and iron and steel processing routes other than those which use coke. These include the following:

- Coal injection is increasingly being used to displace some of the coke in blast furnaces. This is not only less greenhouse gas intensive than using coke alone, but has significant economic benefits in that coal for injection is cheaper than metallurgical coal used in coke production.
- Alternative technologies for coke manufacture are more flexible in terms of coal input quality and have reduced environmental impacts. These include the Jumbo coking reactor and the non-recovery oven. Various modifications to the smelting process have been seen in recent years.
- Technologies other than the blast furnace are also being used for refining. The primary process used for direct reduction of iron ore is the natural gas-fuelled Midrex® process. Coal-based technologies account for only a small proportion of annual output of direct-reduced iron (DRI) worldwide and in South Africa. Of these new coal-based technologies, only the Corex® and Hismelt® processes have been operated at a commercial scale, with several others at various stages of evaluation (Carpenter et al., 2010). Saldanha Steel makes use of the Corex® process.
- The Electric Arc Furnace (EAF) process produces steel primarily from scrap, rather than virgin iron ore. As a result is less energy-intensive per unit product than other technologies which use virgin ore, as it cuts out the need to reduce iron ore to iron, and the ore preparation, coke-making and iron-making steps (International Energy Agency, 2008). Application of the process can, however, be limited by scrap availability.
- Other reductants may be used, including bituminous metallurgical coal used directly in the process, char/gascoke (from degasified bituminous coal) and anthracite. It is also possible to use pet coke (a by-product of crude oil refining) and charcoal made from wood, although these are less common.

### 12.3 Technologies in place in South Africa

In South Africa, 55% of iron is produced in blast furnaces, 23% through direct reduction processes, 8% in “other” processes (e.g. COREX), and 14% in electric furnaces. The Southern African coke industry produces two types of coke, being Market coke which is used by the ferro-alloy industry, and Metallurgical coke for steel plants (van Rensburg, 2006).

![Figure 40: Breakdown of technology types for iron production in South Africa in 2009](source: adapted from SAISI, 2010)

### 12.4 Metallurgical coal consumption in South Africa

Four main users of coal for iron and steel production are identified in South Africa. Two of these use coal to make coke for production, being the ArcelorMittal operations in Newcastle and Vanderbijlpark. The ArcelorMittal operation at Saldanha uses the Corex® process, which uses coal directly without conversion to coke. Finally, the Evraz Highveld Steel and Vanadium operation in Witbank uses coal in a process for production of iron and steel from magnetite.

DMR (2010a) suggests metallurgical coal consumption to have been 5.33 Mt in 2009. van Rensburg (2006) suggests the split of coal usage in the ferroalloy industry only (i.e. excluding iron and steel) in South Africa is as shown in Table 30.

<table>
<thead>
<tr>
<th>Bituminous metallurgical coal</th>
<th>High carbon ferrochromium</th>
<th>High carbon ferromanganese and silico-manganese</th>
<th>Ferrosilicon and silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.454</td>
<td>0.32</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Metallurgical coke (from degasified coking coal)</td>
<td>0.79</td>
<td>0.132</td>
<td></td>
</tr>
<tr>
<td>Char/gascoke (from degasified bituminous coal)</td>
<td>0.632</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Anthracite</td>
<td>0.527</td>
<td>0.160</td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td>2.403</td>
<td>0.612</td>
<td>0.274</td>
</tr>
</tbody>
</table>

(Source: van Rensburg, 2006)
In addition to the above, it is estimated that 84,000 tpa of charcoal made from wood is used in the ferrosilicon and silicon industry.

Supply contracts for metallurgical coal are typically negotiated for 3 – 6 year terms. Spot markets are also in operation but are relatively stable and operate on set volumes on a monthly basis over long periods of time due to little fluctuation in local demand. However, a scarcity of supply is changing the trade of metallurgical coal, with contract periods becoming shorter. Exports are all on the spot market (SACRM Metallurgical Focus Group, 2010). The last large unexplored metallurgical coal deposit in the world is in Mozambique. Production from Mozambique is expected to increase substantially in the next few years. The result will be the availability of a large unused source of middlings coal, which can be utilised.

12.5 Economic contribution of the metallurgical sector

In 2006, South Africa was ranked as the 21st largest crude steel producing country in the world. Including the ferrous metals sector, the basic iron and steel industry contributes approximately 1.4% to the country’s GDP. Although small by global standards, the South African iron and steel industry is the largest in Africa, producing 48% of the total crude steel production on the continent in 2008 (CMRC Africa, 2009).

South African chromium deposits make up a large proportion of the world’s reserves. Xstrata is currently the largest and one of the lowest cost producers of ferrochrome, and Xstrata and South Africa’s Evraz Highveld Steel and Vanadium are two of the largest vanadium producers in the world.

The production of ferroalloys, and basic iron and steel is not only an important source of national income but is also an important input in many downstream sectors of the economy. The basic iron and steel industry contributes approximately 7.9% to the total value of sales of the manufacturing industry (Dieterich, 2007). South African steel sales are predominantly to the construction industry as well as for the manufacture of cables, wires and gates (see Figure 41).

Figure 41: Sales of iron and steel to South African industry groups, 2009 (tonnes of steel)

(Source: South African Iron and Steel Institute (SAISI), 2011)

In 2009 the broader metals, metal products, machinery and equipment sector contributed just more than R 72 billion (approximately 3%) to South Africa’s GDP²⁴.

²⁴ Authors’ calculations based on StatsSA (2010)
Based on projected increases in the global demand for ferrochrome, Xstrata has approved plans to expand its Lion ferrochrome complex in South Africa. The planned development will involve the development of a 600 MW self-generation thermal power station, the construction and commissioning of a smelter, as well as the concurrent development of the Magareng mine. The total cost of this build has been placed at R 4.9 billion (USD 710 million) with construction scheduled to begin in 2011 and commissioning planned for 2013 (Xstrata, 2010c).

12.5.2 Exports

South Africa is a net primary steel exporting country, and in 2004 was ranked as the 9th largest net exporter of primary steel in the world (Dieterich, 2007). At the peak of the “Dotcom” bubble in 2002 and the commodity bubble in 2008, the rate of growth in the value of South African ferrous metal exports reached highs of 39% and 51% respectively. In 2008, due to the global recession, the value of South African ferrous metal exports declined sharply by 41%. Export values rebounded in 2010, however, on the back of recovering Asian markets.
12.5.3 Operational expenditure patterns

The basic metal, metal products, machinery and equipment sector was responsible for operational expenditure of roughly R 290 million in 2008. This was equal to roughly 21% of the total operational expenditure within the South African manufacturing industry (StatsSA, 2008).

More than two-thirds of operational expenditure within industry (67.5%) is comprised of purchases. Procurement is thus expected to be an important stimulator of secondary activity in and around the local communities in which it operates (see Table 31).

Table 31: Operational expenditure within the Basic metals, metal products, machinery and equipment sector by category (2008)

<table>
<thead>
<tr>
<th>Expenditure category</th>
<th>[R million]</th>
<th>[%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchases</td>
<td>195,469</td>
<td>67.5%</td>
</tr>
<tr>
<td>Salaries and wages</td>
<td>39,051</td>
<td>13.5%</td>
</tr>
<tr>
<td>Depreciation</td>
<td>6,172</td>
<td>2.1%</td>
</tr>
<tr>
<td>Advertising</td>
<td>730</td>
<td>0.3%</td>
</tr>
<tr>
<td>Total expenditure</td>
<td>289,670</td>
<td>100%</td>
</tr>
</tbody>
</table>

(Source: StatsSA, 2008)

25 Based on the Harmonised System (HS) Codes, chapter 72.
OTHER INDUSTRIAL AND COMMERCIAL USERS OF COAL

In South Africa, the main uses of coal are for power generation, liquid fuels production and in metallurgical processes. However, for many other industries, coal remains an important fuel source to generate steam to provide heat and power. This is particularly the case in Gauteng and KwaZulu-Natal, where coal is relatively cheap and readily available. While coal consumption varies according to the nature and size of the industry or end-user, collectively, these other users are significant consumers of coal. The table below highlights the volumes of coal that are consumed by: other industries and construction (6.3 Mt); Agriculture (0.03 Mt); and other consumers (e.g. commercial and institutional burning) (2.8 Mt).

Table 32: South African domestic uses of coal in 2007

<table>
<thead>
<tr>
<th>Domestic uses of coal (2007)</th>
<th>(Mt)</th>
<th>(Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion to other forms of energy</td>
<td>161.369</td>
<td></td>
</tr>
<tr>
<td>in coke ovens</td>
<td>2.589</td>
<td></td>
</tr>
<tr>
<td>in gas works</td>
<td>6.695</td>
<td></td>
</tr>
<tr>
<td>in thermal power plants</td>
<td>116.387</td>
<td></td>
</tr>
<tr>
<td>in other energy-producing plants (e.g. Sasol)</td>
<td>35.698</td>
<td></td>
</tr>
<tr>
<td>Non-energy uses</td>
<td>1.973</td>
<td></td>
</tr>
<tr>
<td>Industry and Construction</td>
<td>10.397</td>
<td></td>
</tr>
<tr>
<td>Iron and steel industry</td>
<td>4.071</td>
<td></td>
</tr>
<tr>
<td>Other industries and construction</td>
<td>6.326</td>
<td></td>
</tr>
<tr>
<td>Households and other consumers</td>
<td>8.435</td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>5.602</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>Other consumers</td>
<td>2.805</td>
<td></td>
</tr>
</tbody>
</table>

(Source: UNdata, 2011)

The category “other industries and construction” is made up of a variety of subsectors including:

- Chemicals and petrochemicals (excluding coal-to-liquids)
- Pulp and paper manufacturers
- Food and tobacco (particularly sugar refining and breweries)
- Cement manufacturers
- Brick and refractory manufacturers
- Textile manufacture
- Mining

Monitoring and reporting of coal use (or even associated greenhouse gas emissions) is not commonplace for these industrial subsectors. While consumption figures may be available for individual companies, it is not possible to fully disaggregate the approximately 9 Mtpa of coal used by these subsectors. The sections that follow provide some indicative consumption figures for those subsectors for which disaggregated data is either available or can be inferred.

13.1 Cement manufacturers

The cement industry uses coal as a fuel source in the high temperature kilns. Cement manufacture involves heating limestone (calcium carbonate – CaCO₃) and clay to above 1400°C, liberating carbon dioxide (CO₂) and producing an agglomerated mixture of quicklime (calcium oxide – CaO) and other minerals called clinker (CEMEX, 2011). The clinker is then ground and blended with other additives such as gypsum (CaSO₄) to produce Portland cement, which is widely used throughout the building and construction industry. The coal combustion products (fly ash) play an important role in cement manufacture and product properties.

South African cement manufacturers PPC, AfriSam, La Farge and Natal Portland Cement consume an estimated 1.75 - 2 Mtpa of coal (Own calculation, 2010). However, as the cement manufacturing industry is under pressure to reduce its greenhouse gas emissions, various strategies are being employed to reduce coal consumption. For example, coal may be supplemented with waste streams such as used car tyres, biomass and waste plastics (Natal Portland Cement, 2011). More recently, cement producers have begun increasing the relative ratio of additives to clinker in Portland cement. This reduces the amount of coal burnt per unit cement and thus results in lower carbon dioxide emissions. Additives include the fly ash filtered from flue gas emissions, silica and blast furnace slag (Cembureau, 2011).

13.2 Pulp and paper manufacturers

The pulp and paper industry in South Africa is dominated by three firms: Mondi, NamPak and SAPPi. The majority of South African paper is produced by chemically converting woody biomass such as pine and eucalyptus to fibrous pulp (PAMSA, 2007). The pulp is then bleached, dried, pressed and coated to produce paper products. The pulping process occurs at elevated temperatures and pressures, and pulping chemicals are regenerated by reacting with quick lime, which is produced by calcining limestone at 1450°C in a lime kiln. As such, chemical pulp is associated with a high energy demand that is met to some extent by burning waste wood or bark as well as the pulp digester waste “black-liquor” stream. The remaining energy demand is typically met by burning fossil fuels, most often coal.

Pulp and paper mills in South Africa burn 35,068 TJ of thermal coal (estimated at 1.75 Mtpa (Own calculation, 2010)) to meet their heat and power requirements. Individual firms have recently reduced their coal consumption compared with previous years.
13.3 Sugar mills

South African sugar mills have moved from being nearly entirely energy self-sufficient to relying on significant amounts of coal to meet their energy demand (Reid, 2006). Energy is needed for a number of unit operations, including the evaporation of large volumes of water from the dissolved sugar syrup. Where this energy was once met by burning residual sugarcane milling waste (bagasse), coal is now used where bagasse is diverted for by-product manufacturing operations such as the production of high-valued Furfural.

The overall consumption of coal in South African sugar mills is estimated at 0.25 Mtpa (Own calculation, 2010), burned to meet both heating and power demand.
RESIDENTIAL USE OF COAL

Coal is a preferred energy source for many households across South Africa, with an estimated 1 Mt being used nationally each year (Strydom and Surridge, 2009). The level of household income has been identified as the main factor influencing fuel choices for residential use (Senatla, 2010). As indicated in Table 33, coal is a relatively cheap fuel, which is attractive to informal households that rely on inconsistent levels of income, particularly those that are situated inland near coal mines.

Table 33: Comparison of cost of different energy sources

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Cost [R/GJ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>R 20.58</td>
</tr>
<tr>
<td>Paraffin</td>
<td>R 187.00</td>
</tr>
<tr>
<td>Electricity</td>
<td>R185.35</td>
</tr>
<tr>
<td>LPG</td>
<td>R404.93</td>
</tr>
</tbody>
</table>

(Source: Senatla, 2010)

The dual utility provided by a coal stove (simultaneous space and water heating as well as cooking) and perceptions around the affordability of electrical appliances ensure that coal remains a popular fuel choice for most energy intensive activities, despite progressive electrification of rural and informal households, and the low energy efficiency of coal use (Afane-Okeke, 1998; Wenzel, 2006; Howells et al., 2005; Mdluli, 2007; Visagie, 2008). For inland regions such as Gauteng, coal use persists for domestic applications in preference to fuels derived from crude oil (paraffin and liquefied petroleum gas) due to amongst other factors, the proximity to coal fields and the associated cost for transportation of crude oil to inland refineries (Strydom and Surridge, 2009). Coal use peaks during the cold winter months in areas which experience cold winters (Highveld, Free State and Mpumalanga). Coal of low quality and heating value is usually purchased from coal merchants or collected from dumping sites (Balmer, 2007).

Coal is burnt in shop-bought or makeshift, home-made technologies such as coal braziers, coal stoves or, as they are known locally, mbaula/imbhawula (Pemberton-Pigott et al., 2009 Balmer, 2007; Barnes et al., 2009). Coal braziers typically consist of a metal vessel with holes drilled in the bottom and with a wire mesh or grate placed in the bottom half – holes and the mesh aid air access to the burning coal thus improving the burning rate, and reducing cooking time and fuel consumption. The fire in a coal brazier is generally initiated through a sequence of layering and lighting of coal and wood kindling upon the wire support. An empty and bottomless vessel caps the fire in order to increase the draft through the brazier and thus accelerate the ignition process (Pemberton-Pigott et al., 2009). Finally, a burning coke bed with which can be cooked or heated is produced. This technique is said to reduce the amount of visible smoke during cooking, although harmful albeit invisible emissions (CO and H,S) still result when braziers are taken indoors for space heating. This technique also does not circumvent the energy inefficiency of this technology: It has been estimated that up to 25 to 40% of fuel is burnt prior to actual cooking or heating and that only 5% heat energy is delivered to the pot that is heated (Pemberton-Pigott et al., 2009).

14.1 Environmental and social impacts of residential coal use

14.1.1 Environmental aspects

Coal burning appliances used by low income households are characterised by inefficient combustion which leads to high emission rates of particulate matter, volatile hydrocarbons, carbon monoxide and sulphur-containing gases (H,S and SO, ) (Pemberton-Pigott et al., 2009). It has been estimated that 65% of ambient pollution in Gauteng (Scorgie et al., 2003) and 48% of quantifiable particulate emissions in the Johannesburg region (Mathee, 2004) are a result of residential coal use.

Further environmental impacts include those associated with the disposal of ash. If not collected by ash collectors, ash may be disposed of in local streams or dumped on vacant land, thus resulting in the generation of leachate and subsequent pollution of land and water bodies. Local air pollution in these areas may be exacerbated by the mobilisation of fine ash particles by wind.

14.1.2 Social aspects

Several impacts result from the operation of coal braziers indoors. Coal braziers are typically brought indoors for space heating and cooking once most visible smoke has stopped. The likelihood of fires and burns resulting in damage or loss of property and life is increased when fires are brought indoors (Wenzel, 2006). Poor ventilation within dwellings of low-income communities implies that these emissions are slow moving and affect the air quality and health of the inhabitants (von Blottnitz et al., 2009). Respiratory infections resulting from exposure to indoor air pollution results in the deaths of around 2,000 children annually (Scorgie et al., 2003), and the cost to treat illnesses related to air pollution amount to R 1.2 billion per annum (Bentley West and Airshed Planning Professionals, 2004). There are also indirect effects of poor indoor air quality on the economy: economic production is impacted negatively as a result of absenteeism of employees affected by illness.

Houses constructed and roofed with corrugated iron have been shown to result in greater energy losses than brick-faced houses, with shacks losing energy through the walls and roof. Energy loss is exacerbated when windows and doors are opened to evacuate odourous emissions and this requires higher expenditure on heating by low-income households (Ward and Schäffler, 2008).

The transition to clean fuel alternatives provides communities with an opportunity to transcend disadvantages associated...
with coal. However, several challenges and drawbacks are associated with the transition from solid fuels to electricity or alternative fuels.

- New appliances need to be purchased (Visagie, 2008)
- Disturbance of livelihoods of established traders within the coal supply network (sellers, ash collectors etc.) (Mdluli, 2007)
- Cultural acceptance of using electricity as opposed to coal (Mdluli, 2007)
- Economic status of users needs to improve first; alternative fuels need to be competitive with regard to price, heating and ignition properties (Mdluli, 2007; Visagie 2008; DME 2002)

Ongoing use of coal and other solid/liquid fuels instead of electricity is further reinforced by intimidation of “shack-lords” and gangsters who control access to electricity, thus making it unaffordable to residents who thus continue to make use of relatively cheaper coal and other non-renewable sources (Visagie, 2008).

### 14.2 Clean technology alternatives for residential use of coal

Although electrification of informal households has been ongoing during the last two decades, the use of coal for domestic applications persists (Gaunt, 2002). Options to address the social and environmental impacts associated with the use of coal in residential applications include improved designs for coal burning technologies, in addition to alternative energy carriers, primarily electricity.

#### 14.2.1 Basa Njengo Magogo (BNM)

Also known as “top-lit up-draft stoves”, this is an alternative method for fuel stacking and top-down ignition (Leiman et al., 2007), which both ignites the volatile gases released from the coal below and heats the coal by radiant energy rather than thermal convection (Pemberton-Pigott et al., 2009).

A significant advantage of this method is that no major alterations to the basic operation of the coal stove are required to achieve a vast reduction in visible emissions. Further, since the method allows the stove to establish a hot coke bed sooner, it has been found that less fuel is consumed and high CO emissions occur over a shorter timeframe (Pemberton-Pigott et al., 2009).

#### 14.2.2 Down-draft stoves

The principle of operation of this technology is a downward draft which removes emissions through a chimney (natural draft), while gravity and air draft ensure that ash falls away to the bottom of the stove, thus continually exposing burning coke to air. Ash collects in a sloping pipe while the pot is heated from the bottom by means of flames.

The main benefit of this technology is smokeless operation: volatile and semi-volatile gases are drawn downwards through the coke bed where it reacts, thus eliminating the major source of particulate matter usually associated with domestic coal burning; the design reduces CO emissions by around 95% compared to the mbaula, and it is expected that the same reduction in particulate matter is achievable (Pemberton-Pigott et al., 2009).
ALTERNATIVES TO COAL

In understanding the status quo and future of the coal industry, there is value in exploring the alternatives to coal. Consideration is given here to the following: alternative energy technologies, liquid fuels, biomass for red雯ants and co-firing, gas and alternatives to coal in domestic use.

15.1 Alternative electricity generation technologies

Alternative energy technologies include both renewable and non-renewable energy technologies, and are considered as competing supply chains to coal. Alternative energy technologies need to be considered in terms of their ability to generate base load and peaking power. Furthermore, certain technologies may be restricted in the overall potential for penetration into the grid. Examples are wind which, due to the intermittency of the wind resource, can only be used to make up a certain proportion of the grid energy, or certain solar technologies which can only be used when the sun is shining. Storage of energy thus also has to be considered in this context. The table below compares South Africa’s baseload and intermittent installed capacity under the promulgated IRP2010 “Policy Adjusted” scenario with China and Europe.

<table>
<thead>
<tr>
<th>Source</th>
<th>China**</th>
<th>Europe**</th>
<th>South Africa***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>43</td>
<td>10</td>
<td>47</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>9</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Nuclear</td>
<td>6</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Hydro</td>
<td>19</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>Bio-/ Waste</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Geo- &amp; Marine</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Wind</td>
<td>15</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Solar PV</td>
<td>4</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Solar CSP</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>“Base load”</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Intermittent renewables</strong></td>
</tr>
</tbody>
</table>

*i.e. GW not GWh
** Average of IEA WEO 2010 “New Policies” and “450” scenarios
*** Promulgated IRP2010 “Policy Adjusted” scenario

The alternative electricity generation technologies are discussed in the sections that follow. In addition to these, interventions exist which can be used to reduce the demand for coal fired power. These include energy efficiency activities, solar water heaters (SWH and combined heat and power technologies (CHP) as discussed in detail in the climate change section.

Box 5: Considerations in a transition to renewables

“Arguments for an accelerated transition to a non-fossil world are predicated on concerns about climate change and on depleting resources, especially in the case of oil and gas. A non-fossil world may be highly desirable, and determination, commitment and persistence could accelerate its arrival, but the transition will be difficult and prolonged even if it were not complicated by specific national conditions and trends creating a new constellation of world order.

There are several important factors to be considered in understanding the rate of this transition.

Firstly, there is today no readily available non-fossil energy source that is large enough to be exploited on the requisite scale. While energy carried by solar radiation is several orders of magnitude larger than any conceivable global energy demand, so far practical conversions into electricity or large-scale industrial heat are small.

Secondly, in the last two historical energy solid/liquid fuel transitions, from biomass to coal and then from coal to hydrocarbons, lower energy-density fuels were supplanted by more concentrated sources of energy. The next transition will be in reverse: replacing crude oil-derived fuels with less energy dense biofuels.

Thirdly, fossil fuel deposits are an extraordinarily concentrated source of high-quality energy. The energy supply chain of today’s fossil-fuelled civilisation works by producing fuels and thermal electricity with power densities that are one to three orders of magnitude higher than the common power densities with which buildings, factories and cities use commercial energies. In a future solar-based society inheriting today’s urban and industrial systems, various renewable energies would be harnessed with at best the same power densities with which they would be used in dwellings and factories. A transition to renewable energy would greatly increase the fixed land requirements of energy production and would also necessitate more extensive rights-of-way for transmission.

Fourthly, modern societies are dependent on massive continuous flows of energies; growing demand for fuels and electricity fluctuates daily and seasonally, but the base load – the minimum energy needed to meet the needs of the day – has also been increasing. Easily storable high-energy density fossil fuels and thermal electricity generating stations operate with high load factors and so can meet these needs. In contrast, because wind and direct solar radiation are intermittent and far from predictable, they can never deliver such high load factors. On top of this, the means to be able to store wind- or solar-generated electricity on a large scale are still lacking.

Fifthly, while oil and gas are unevenly distributed geographically, renewable flows are also spread out unevenly: cloudiness in the equatorial zone reduces direct solar radiation and whole stretches of continent have insufficient wind. Some densely populated regions have no significant locally available sources at all and many reliably windy or sunny sites are far from major load centres, which means their exploitation would require entirely new mega-infrastructures.”

Source: Smill (2005)
15.1.1 Nuclear

Nuclear power uses fission (splitting) of uranium atoms as an energy source. The energy released in this atomic process is harnessed to raise steam, which in turn drives turbines to generate electricity. Nuclear power is well established internationally, providing some 14% of the world’s electricity supply (IAEA, 2010b). In South Africa, Eskom’s 1,800 MW Koeberg nuclear power station operates in the Western Cape (Eskom, 2010a), and the government’s Integrated Resource Plan has indicated that 9,600 MW of new nuclear power is to be commissioned from 2023.

Nuclear power is a non-renewable energy source as it requires the mining and isotopic enrichment of uranium. However, reasonably assured and inferred uranium resources internationally totalled 6.3 Mt U in 2009 (for a production cost of below USD 260/kg U), which is sufficient to support current rates of exploitation for nearly 100 years without considering undiscovered or speculative resources (WEC, 2010). Nuclear energy is therefore not expected to be constrained by uranium resource availability in the short to medium future.

A significant advantage of nuclear power is that normal plant operation does not generate greenhouse gas emissions, and the technology is therefore promoted as a climate change mitigation option to replace emissions-intensive baseload power such as coal. Capital costs for nuclear generation capacity are generally very high, but fuel and operating costs are relatively low per kWh (EPRI, 2010). Nuclear power stations can provide baseload power at high capacity factors, an advantage over many renewable energy technologies.

There are significant safety and security disadvantages associated with nuclear power, which often fuel public resistance to nuclear generation. The fission process produces waste materials with high levels of radioactivity, which can be severely hazardous to humans and environment (Rao, 2001). In general the history of nuclear power generation has shown that safe operation can be achieved without significant release of radioactive material (VGB, 2010), although there have been several serious accidents in which containment has proved impossible, most recently at the Fukushima plant in Japan (IAEA, 2011a). A longer term concern is the disposal of high-level radioactive waste, particularly spent fuel, which must be safely contained and isolated for periods in the range of ten thousand years before its radioactivity falls to safe levels (VGB, 2010). Although numerous disposal options are being researched, and parts of the waste can be reprocessed into fuel, there is at present no consensus on safe disposal methods for high-level waste (Rao, 2001). The majority of this waste remains in on-site temporary storage at nuclear facilities worldwide. A further concern regarding nuclear power is the potential for radioactive materials to be applied to non-peaceful ends, including the theft of nuclear materials, the use of uranium enrichment or waste management to conceal the development of nuclear weapons, and the targeting of nuclear facilities for terrorist attack (IAEA, 2001; Holt and Andrews, 2010). Nuclear activities are therefore subject to strong regulation by a number of international treaties (IAEA, 2011b).

In spite of all the negative sentiment about nuclear, it is noted that many studies on the fatalities per MWh of electricity produced generally put nuclear as one of the safer technologies, and significantly, coal as the most dangerous. Public perceptions on both coal and nuclear could swing in opposite directions in the future.

It is noted that there are some concerns surrounding on the reality of the timing of the first new nuclear plant scheduled to come on line in 2023. This was the case even before the Fukushima accident, and recent comments by the Minister of Energy since then can be interpreted to indicate some delay while the lessons of Fukushima are considered. If there is any delay in nuclear, the gap will have to be filled by either coal or renewables. Since the IRP is already reasonably ambitious in its plan for intermittent renewables (22% of installed capacity in 2030, compared to 20% for China and 33% for Europe), there may be some reluctance to rely more heavily on renewables. If this is the case, the coal industry should make every effort to position itself to fill the gap.

15.1.2 Wind

Wind is harnessed to drive turbines for the generation of electricity. In large-scale wind farms, a number of large turbines are co-located, and often feed into the distribution grid. Smaller stand-alone turbines can be used for distributed generation purposes, such as powering of remote equipment or for single buildings or houses. Efficient wind generation requires a wind resource of suitable speed and direction.

In centralised wind farms, turbines may be located either on or off shore. The advantages of offshore compared with onshore wind include higher capacity factors, wind speeds yielding as much as 50% greater output, and lower visual impact. Offshore turbine costs are largely dependent on water depth and the distance from shore, but are significantly higher than those located on shore, although, the cost of offshore wind is expected to fall.

Significant technological advances have been made over the years in increasing output from turbines – in 1985 turbines had an average output of 50 kW compared to the 3,600 kW turbines produced in 2005. Ongoing technological development includes a focus on production forecasting, storage, grid integration and power-system design (IEA, 2008).

Wind power is well established, with numerous large installations around the world. Most notable of these is Denmark, which has the highest proportional contribution of wind power to its grid of any other country in the world, and is also one of the leading countries in provision of wind energy technologies. Wind farms are also located in the United States, China, Australia, UK and India to name a few.

Installed capacity in South Africa is very small, with a total of 21.8 MW installed capacity in 2009 (WWEA, 2010). This is
despite South Africa having been demonstrated to have high potential for wind generation. Having said this, the Policy Adjusted Scenario of the IRP2010 (discussed in the electricity section), makes provision for 9,200 MW of wind capacity to be installed by 2030 (DoE, 2010b).

15.1.3 Solar CSP

Concentrated solar power (CSP) technologies use sunlight for the generation of electricity. Unlike solar PV (discussed below), where sunlight is converted directly into electric current, the heat gathered in CSP technologies is used to operate a conventional power cycle, e.g. through a steam turbine or a Stirling engine, which in turn drives a generator. Because CSP uses a thermal energy intermediate phase, it has the potential to deliver power on demand, e.g. by using stored heat in various forms. Heat storage also offers the potential for continuous solar-only generation. Alternatively, CSP can be used together with conventional fuels in a hybrid power plant to produce electricity on a continuous basis. Furthermore, CSP can provide combined heat and power although the benefit of this depends on a local need for the heat (this may not have any value in remote locations).

Four main types of CSP technology are identified:

- **Troughs**: parabolic trough-shaped mirror reflectors linearly concentrate sunlight onto receiver tubes, heating a thermal transfer fluid.
- **Linear Fresnel reflectors**, which use an array of long mirror strips to concentrate sunlight onto a common receiver tube running along the array. This construction avoids the costly fabrication of parabolic mirrors.
- **Towers**: numerous mirrors concentrate sunlight onto a central receiver on the top of a tower where it heats a fluid. This is sometimes coupled with a second concentration step.
- **Dishes**: Parabolic dish-shaped reflectors concentrate sunlight in two dimensions and run a small engine or turbine at the focal point.

CSP is best suited for areas with high direct solar radiation. A number of installations of all of these technologies exist internationally, most notably in Spain and California in the USA, each of which is less than 100 MW. Although South Africa is one of the areas identified by the IEA (2008) as having significant potential for CSP, there have been no local installations to date. However the IRP2010 makes provision for 1,200 MW of CSP capacity to be commissioned in the period to 2030, with commitments already made for 200 MW (DoE, 2010b).

The key technology development needs for CSP are to increase the efficiency of mirrors, heat receivers, heat storage systems and balancing mechanisms (IEA, 2008). The limitations facing the technology include the significant land area required for construction of a large scale CSP station, and constraints on water availability in many of the regions where direct solar radiation is highest as well as high installation and maintenance costs.

15.1.4 Solar photovoltaics (PV)

Photovoltaic (PV) systems convert solar energy directly into electricity. The basic building block of a PV system is the PV cell, a semiconductor device that absorbs sunlight and converts it into direct-current (DC) electricity. PV systems can be grid-connected or stand-alone (off-grid).

PV systems have been used extensively around the world, and their use continues to grow. In addition, PV has a number of off-grid applications, including water pumping and rural electrification. They are also increasingly being used to generate electricity for feeding into the grid. In South Africa, however, installations are thus far limited to off-grid applications. Furthermore, at present solar PV technologies are largely imported into South Africa, although there is a limited amount of local manufacturing capacity. The IRP2010 Policy-Adjusted Scenario sees 8,400 MW of solar PV generating capacity commissioned by 2030, with the first grid connections in 2012 (DoE, 2010b).

At this stage the investment costs of PV systems are still high, and represents the most important barrier to further penetration of PV in electricity supply. Having said this, costs are reported to have dropped 40% in 2008/09 (IEA, 2010b). PV systems do not have moving parts, so operating and maintenance costs are much less significant – at around 0.5% of capital investment per year. PV modules account for roughly 60% of total system costs, with mounting structures, inverters, cabling, etc. accounting for the rest. Advances in thin film solar will ultimately bring down the costs of these systems, although they are likely to increase their market share only after 2020. A further factor which influences the profitability of these systems is that availability is low (they generate electricity for, on average, 23% of the time) which increases the levelised costs of the technologies (IEA, 2008).

A further range of technologies, including organic solar cells, is emerging with significant potential for performance increases and cost reductions (IEA, 2010b).

15.1.5 Hydro

Hydropower is derived from moving water, the energy of which is used to drive turbines. Mini and micro systems, with capacities of <1 MW, operate off-grid, while small (1 – 10 MW) and large (>10 MW) scale hydro are better suited to feeding into the grid (Genesis Analytics, 2010).

Although hydropower is a significant source of renewable power globally (IEA, 2010a), South Africa has limited hydropower potential, and a current installed capacity of 668 MW (Merven et al., 2010). South Africa also imports power from the Cahora Bassa hydroelectric scheme in Mozambique.

Sub-Saharan Africa has been demonstrated to have significant further hydropower potential. Much of this is in the DRC, which is reported to have a potential of up to 100,000 MW (Flak, 2009). There is ongoing interest in accessing this resource, which includes the development of the Grand Inga hydroelectric project, with 40,000 MW of generating
technologies for extraction and utilisation of LFG are well minor modifications to existing combustion equipment. The collection of LFG can be used to produce electricity or as an alternative fuel source in industrial and other applications. Collected LFG can be used to produce electricity or as an alternative fuel source. LFG production begins approximately 9 months after the landfill site has been covered, and continues to be generated over a period of several decades. LFG may be extracted from landfills using a series of wells and a vacuum system that directs the gas to a central collection point. The collected LFG can be used to produce electricity or as an alternative fuel source in industrial and other applications. The latter application requires minimal processing and minor modifications to existing combustion equipment. Technologies for extraction and utilisation of LFG are well established internationally with thousands of installations around the world, with some limited customisation of equipment required depending on site conditions. Ideally gas collection systems should be fitted to the landfill is being established, although fitting to an already capped landfill is possible.

South Africa has a selection of landfill gas installations, including the Marianhill and La Mercy landfill sites in Durban. The IRP2010 Policy-Adjusted Scenario includes a small amount of landfill gas-powered electricity generation (DoE, 2010b).

15.1.8 Hydrogen as energy carrier

Hydrogen is not considered a fuel source as it does not occur abundantly on earth, but rather acts as an energy carrier. This is because it is produced using other fuels – either fossil fuels (coal, crude oil, gas) or by splitting it from water, which in turn requires input electricity recovered from either fossil fuels or renewables. Hydrogen has a very high energy density per unit mass, but not per unit volume as it is a gas. However the energy pathway to using hydrogen is more efficient than through, for example, use of petrol in internal combustion engines. The energy value of hydrogen can either be recovered by burning it directly or by use in hydrogen fuel cells.

The concept of the hydrogen economy considers the potential for hydrogen to be supplied through an infrastructure system to provide power to buildings, industry as well as the transport system. The primary focus is on the transportation system. Hydrogen can either be produced on-site where it is used (i.e. distributed production) or centrally and then distribute it via pipelines, tankers and tanks.

Storage and distribution of hydrogen remains a significant challenge, as does the significant cost of the establishment of the infrastructure for large scale implementation of the hydrogen economy. Utilisation technologies are currently more expensive than, for example, internal combustion engines, but this could change if the technologies become used more widely.

A number of small installations of hydrogen fuel cells can be found in South Africa, primarily funded by a subsidy from the World Bank’s International Finance Corporation. These have mostly been as back-up power for telecommunications and in hospitals and clinics. No larger scale applications have been found.

15.2 Liquid fuels

South Africa’s liquid fuel supply is unusual, in that 27% of liquid fuel demand is met by synthetic fuels produced from coal and gas (Kopler, 2009). The liquid fuels sector is therefore closely connected to the coal industry and both influences and is influenced by it, with implications for coal demand and security of liquid fuel supply. Sasol and PetroSA produce synthetic fuels from coal and gas with a total capacity...
equivalent to 195,000 bbl/day (SAPIA, 2009). Consideration is given here to the balance of the liquid fuels demand which is produced from crude oil. Some thoughts on the potential for biofuels are also presented.

15.2.1 Petroleum products

South Africa’s oil reserves are minimal, estimated at only 15 million barrels (WEC, 2010), located offshore in the Bredasdorp basin on the south coast and off the west coast (US EIA, 2010). Virtually all of the crude oil processed in South Africa is therefore imported, principally from the Middle East and Africa (US EIA, 2010). South Africa has four crude oil refineries, with nameplate capacities and locations presented in Table 35.

Table 35: Major crude oil refineries in South Africa

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Feedstock</th>
<th>Capacity (bbl/day)</th>
<th>Ownership</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapref</td>
<td>Durban</td>
<td>Crude oil</td>
<td>180,000</td>
<td>Shell and BP</td>
<td>Durban</td>
</tr>
<tr>
<td>Enref</td>
<td>Durban</td>
<td>Crude oil</td>
<td>125,000</td>
<td>Engen</td>
<td>Durban</td>
</tr>
<tr>
<td>Chevref</td>
<td>Cape Town</td>
<td>Crude oil</td>
<td>100,000</td>
<td>Chevron</td>
<td>Cape Town</td>
</tr>
<tr>
<td>Natref</td>
<td>Sasolburg</td>
<td>Crude oil</td>
<td>92,000</td>
<td>Sasol and Total</td>
<td>Sasolburg</td>
</tr>
</tbody>
</table>

(Source: Sapia, 2009; US EIA, 2010)

South African consumption of petroleum products in 2009 is summarised in Table 36, alongside imports and exports of refined products.

Table 36: Consumption, import and export of petroleum products in 2008 (million litres)

<table>
<thead>
<tr>
<th></th>
<th>Consumption</th>
<th>Import</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>11,069</td>
<td>1,432</td>
<td>835</td>
</tr>
<tr>
<td>Diesel</td>
<td>9,762</td>
<td>2,322</td>
<td>788</td>
</tr>
<tr>
<td>Paraffin</td>
<td>532</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jet fuel</td>
<td>2,376</td>
<td>148</td>
<td>103</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>555</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td>613</td>
<td>11</td>
<td>63</td>
</tr>
</tbody>
</table>

(Source: Sapia, 2009)

There is currently an under-supply of refinery capacity in South Africa, leading to the importation of liquid fuels in refined form. This is expected to increase significantly in coming years due to increased demand, unless further refinery capacity comes on-stream (de Bruyn, 2009; Wright, 2010). It has been estimated that by 2015 South Africa could be importing 8.5 billion litres of fuel each year (PetroSA, undated).

PetroSA, the South African state-owned petroleum company, is planning a 360,000 bbl/day refinery in the Coega Industrial Development Zone east of Port Elizabeth. The new refinery is entering the initial engineering stages, with the intention to begin production in 2016 (PetroSA, undated). However, it has been suggested that the commissioning of such a large facility will result in substantial oversupply of refined products for several years and necessitate large volumes of sub-economic export (Wright, 2010).

South African liquid fuel supply could also be augmented by the development of Sasol’s Mafutha project in the Waterberg or similar developments by other parties.

Petroleum fuels do not make up a significant proportion of the generation of South Africa’s electricity supply but Eskom, the state electricity utility, does maintain 2.4 GW of diesel and kerosene-fired generation capacity as back-up supply when other supply channels are out of operation or insufficient for peak demand (Eskom, 2010a).

15.2.2 Biofuels

Development of biofuel production capacity in South Africa has been slow, despite the objective of the Biofuels Industrial Strategy, approved in 2007, to achieve a 2% penetration into the national liquid fuels market within 5 years (400 Ml per year). The Strategy focused primarily on the development of biofuels as a mechanism of rural upliftment and black economic empowerment, and recognised bioethanol production from sugar cane and sugar beet, and biodiesel production from sunflower, canola and sugar beet. Maize and Jatropha were excluded as a result of food security concerns, although it is possible that the exclusions might be reconsidered (DME, 2007b; USDA, 2009; Pressly, 2010).

Although some plans for large-scale production are in development, there is no large-scale biofuel production taking place in the country. Amongst the projects in development, the following are noteworthy:

- Rainbow Nations Renewable Fuels has begun construction of a soya processing facility in the Coega Industrial Development area east of Port Elizabeth. In 2008 the company was granted a manufacturing license for the production of 288 Ml of biodiesel per year (RNRF, undated).
- PhytoEnergy South Africa is undertaking a project to produce up to 400,000 tonnes of biodiesel per year from canola in the Eastern Cape (PhytoEnergy, 2010). However, some doubts have been raised regarding the suitability of the Eastern Cape for canola production, as current canola production is at a much lower scale and centred in the Western Cape (USDA, 2009).
- The Industrial Development Corporation is supporting some significant biofuel projects, including a 90 Ml per annum sugar beet bioethanol project in the Eastern Cape and a 100 Ml per annum sugar cane bioethanol project in Mpumalanga (USDA, 2009).
However, most current commercial biodiesel production in South Africa makes use of waste cooking oil as a feedstock, all by small to micro-producers. It has been estimated that annual biodiesel production in South Africa stands at around 2 – 3 Ml (Murray, 2010, pers. comm.)

15.3 Biomass

Apart from production of biofuels discussed above, conversion pathways for biomass to into other energy forms include converting biomass to electricity by co-firing with coal, anaerobic digestion of biomass to produce biogas, producing biogas from sewage waste, biomass gasification and direct combustion and converting biomass to electricity through combustion at dedicated power stations.

15.3.1 Co-firing of coal with biomass

Co-firing of coal and biomass is achieved when a fraction of the coal feed to coal-fired power stations is replaced with biomass. Biomass is generally incorporated along one of three paths: direct co-firing, indirect co-firing and parallel co-firing as illustrated in Figure 44.

Figure 44: Biomass co-firing technologies a) direct co-firing, b) indirect co-firing and c) parallel co-firing

Co-firing with biomass has several advantages. It represents a way of reducing carbon intensity and emissions of NOx and SOx, gases associated with electricity generation. Consumption of non-renewable resources is reduced. Pressure on landfill waste sites may be reduced by diverting biomass from landfill, and the associated methane emissions when the biomass degrades in landfill is avoided. Finally, co-firing is more efficient than waste incineration. Modern waste incinerators have overall electrical efficiencies of around 21% whereas electrical power stations have efficiencies which range between 36 – 38% (Davidson et al., 2010).

Co-firing biomass is included in Eskom’s short-term future plans to achieve a reduction of carbon footprint, through replacing 10% of coal with biomass (Eskom, 2010a). A study has been commissioned to determine the availability and supply of wood-based biomass fuels in the Southern African region (de Bruyn, 2010). Implementation of co-firing is likely to face certain technical challenges, which include those brought about by differences between the combustion behaviour of coal and biomass.

Co-firing takes place at several international power stations where biomass is typically incorporated on around a 5 – 10% basis (Al-Mansour and Zwala, 2010). Achieving higher levels in traditional boilers result in technological challenges that may include problematic materials handling, poor flame stability, low thermal efficiency, and slagging and fouling. Further, biomass is associated with a lower energy density compared to coal and thus transport costs associated with biomass co-firing needs to be considered.

The Drax Power Station represents England’s main co-firing initiative. The power station co-fires petroleum coke and 10% biomass by means of direct injection of imported sustainable wood-based products, forestry residues and residual agricultural products such as seed and nut husks (Drax Group, 2011). Future plans include the construction of three biomass-fired power plants at a capacity of 300 MW each which should increase the total renewable capacity of the group to 1400 MW (reportedly equivalent to provision of ‘2 million homes and the equivalent output of 2,000 wind turbines’) (Drax Group, 2011).

15.3.2 Bio-coke - biomass as reductant in metallurgical processes

As discussed previously, metallurgical coke is predominantly used for the production of iron in blast furnaces and secondarily in other metallurgical processes such as base metals smelting. The conversion of coal into metallurgical coke for the use in iron manufacture in blast furnaces is the second largest market for coal (Carpenter et al., 2010).

In these processes, reducing agents are required for removal of oxygen from the metal oxide through the reaction with carbon to release carbon monoxide (Pistorius, 2002). This is illustrated in the following simplified reaction for manganese:

\[
\text{MnO} + C \rightarrow \text{Mn} + \text{CO}
\]
Conventional carbonaceous reducing materials include coal, coke and char. These have high carbon content but given their origin as fossil fuels, the use of these materials is undesirable from a climate change perspective. The use of wood-based charcoal as a reducing agent for iron-ore refining declined after the 18th century (although it continued in regions where wood is plentiful such as Brazil) and is now being reintroduced (Carpenter et al., 2010). Biomass may also be used as an auxiliary fuel to substitute coal, oil or natural gas which is injected directly through the tuyeres of the blast furnace.

15.3.3 Biomass-to-Liquids technology

There is potential opportunity for conversion of biomass to liquids in the same process configuration that is used for coal-to-liquids. No further details were found on the extent to which Sasol is exploring this route.

15.4 Natural gas

South Africa has some reserves of natural gas, but these are limited in extent, and lower than those of neighbouring Namibia and Mozambique (Table 37). The South African reserves are located off the southern and western coasts. Only the southern reserves have been commercially exploited, feeding PetroSA’s gas-to-liquids production facility in Mossel Bay. In addition, gas is imported by pipeline from Mozambique to Secunda to co-feed into the Sasol processes and Sasolburg as feedstock for Sasol’s chemical production facilities (DME, 2006). South Africa produced 3.3 million cubic meters of natural gas in 2008, and consumed 6.5 million cubic meters, with the difference supplied by this pipeline (US EIA, 2010).

<table>
<thead>
<tr>
<th>Country</th>
<th>Natural gas reserves [billion m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>10</td>
</tr>
<tr>
<td>Namibia</td>
<td>20</td>
</tr>
<tr>
<td>Mozambique</td>
<td>130</td>
</tr>
</tbody>
</table>

(Source: WEC, 2010)

The possibility of importing gas from Namibia is also under consideration (GCIS, 2010) and recently there has been interest in prospecting for shale gas in the Karoo, although this has faced strong public resistance (Creamer, T., 2011c). There have been some indications that the Karoo shale gas resource could be significant (485 tcf, or about 510 EJ, compared to SA’s coal reserve of 30 GT or about 625 EJ) (US DoE, 2011). At present, natural gas is a minor player in South Africa’s energy system, contributing less than 5% of primary energy (DME, 2006). However, the IRP2010 Policy-Adjusted Scenario provides for the commissioning of 2,370 MW of combined-cycle gas turbine (CCGT) electricity generation capacity by 2030 for peaking capacity. It is acknowledged that this will require the development of gas infrastructure, including a liquefied natural gas port terminal or development of domestic supply (DoE, 2010b).

15.5 Alternative fuels to coal in domestic use

Low-income communities particularly in un-electrified areas are known to make use of multiple fuels and appliances concurrently or interchangeably (Barnes et al., 2009; Balmer, 2007; Visagie, 2008; Naidoo and Matlala, 2005; Mdluli, 2007; Howells et al., 2005; Davis, 1998). Table 38 below compares the emissions of carbon dioxide associated with different fuel types and technologies typically employed by low-income communities.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Stove type</th>
<th>Fuel use [kg]</th>
<th>CO₂ generated [g/kg]</th>
<th>CO₂ emission [g/meal]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>Gas burner</td>
<td>0.188</td>
<td>3,028</td>
<td>569</td>
</tr>
<tr>
<td>Paraffin</td>
<td>Wick</td>
<td>0.205</td>
<td>3,137</td>
<td>643</td>
</tr>
<tr>
<td></td>
<td>Pressurised</td>
<td>0.203</td>
<td>3,137</td>
<td>637</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Traditional</td>
<td>0.413</td>
<td>3,298</td>
<td>1,362</td>
</tr>
<tr>
<td></td>
<td>Improved</td>
<td>0.282</td>
<td>3,298</td>
<td>930</td>
</tr>
<tr>
<td>Fuelwood</td>
<td>Traditional</td>
<td>0.874</td>
<td>1,832</td>
<td>1,601</td>
</tr>
<tr>
<td></td>
<td>Improved</td>
<td>0.605</td>
<td>1,832</td>
<td>1,108</td>
</tr>
<tr>
<td>Millennium Gefuel</td>
<td>Cover and regulator</td>
<td>0.310</td>
<td>1,533</td>
<td>475</td>
</tr>
</tbody>
</table>

(Source: Uttr, 2004)

Three fuels are considered here, being low smoke fuel, ethanol gels and liquefied petroleum gas (LPG). These have been proposed in recent research as cleaner alternatives to low-grade coal for low-income communities.

15.5.1 Low smoke fuel (LSF)

At 12% of the annual ROM tonnage in South Africa, coal fine discards represent a problematic solid waste. Discards are difficult to handle and recover, since processing by means of conventional water-based beneficiation is costly, and makes dewatering, handling and storage of the final product problematic (Mangen and du Cann, 2007; Bada et al., 2010). Having said this, discards represent a substantial resource which has either been used as-is, or beneficiated to produce LSFs.

Bench and pilot scale research into the production of LSF from coal discards has been ongoing since the early 1990’s, with varying levels of success (Mangen and de Korte, 2005). Coaltech has investigated numerous agglomeration techniques for coal fines including pelleting, extrusion, and briquetting with binders and binder-less briquetting. Binder-less briquetting emerged as the most economical method and has been the subject of subsequent research (England, 2000; Mangena and de Korte, 2005).
The success of coal-fines briquettes as a viable alternative to traditional low grade coal has been controversial. It has been suggested that the cost of briquetting significantly outweighs that of D-grade coal, which implies that its adoption by the domestic market would only be realistic if subsidised (England, 2000). However, research conducted by the CSIR (Mangena and de Korte, 2005) has indicated that this fuel type may be produced at a price comparable to coal.

15.5.2 Ethanol gel fuel

An objective of the White Paper on Renewable Energy (2003) is to “promote biomass energy conservation through the use of more efficient renewable technologies” including, amongst others, ethanol gel stoves. Ethanol gel fuel is composed of 76% denatured ethyl alcohol, 5% organic pulp or cellulose (which acts as a thickening agent) and 19% water by weight (Mhazo, 2001). Ethanol produced via fermentation and distillation of sugars or starch crops is gelatinised into a “clear and transparent compound with a gel-like consistency” (Mhazo, 2001; Utria, 2004).

Unlike a coal stove, cooking with a gel burner is more flexible in that it allows for controlled heat intensity ranging from high power phase to low power phase (Mhazo, 2001). However, emissions from gel appliances are generally higher when run at higher power to such an extent that standards are breached, whereas LPG and paraffin appliances are able to run at higher power without incurring higher emissions (Lloyd and Visagie, 2007).

Gel fuels have been developed as an alternative to paraffin and LP gas mainly for cooking purposes due to its improved handling and use properties. Compared to paraffin, gel is more viscous and thus less likely to splash and result in fewer incidents of fire and burns. Comparatively greater emissions of CO and CO₂ associated with gel cookers have been found to be due to the poor mixing of gel and air which implies that gel stoves operate primarily by diffusion flames (Lloyd and Visagie, 2007). Diffusion flames are inherently more polluting, especially at higher fuel flowrates for which poor mixing is exacerbated (Lloyd and Visagie, 2007). This negative property together with the low inherent energy value of gel fuels (more fuel is required to cook the same amount of water/food) has limited the immediate success of its implementation and widespread application (Lloyd and Visagie, 2007).

The RPTES Program of the World Bank has developed and distributed a marketable gel fuel and stove package under the banner of the Millennium Gelfuel Initiative in Africa (Utria, 2004). A gelfuel producer in Durban, which produces around 20,000 litres of gel fuel per month, was established by the initiative’s drive to introduce clean, renewable cooking fuels in Africa with the distinct objective of addressing poverty (Utria, 2004).

15.5.3 Liquefied Petroleum Gas (LPG)

LPG appliances are considered to be safer than paraffin ones, with an incident rate of at least two orders of magnitude lower than those involving paraffin (Lloyd, 2002b). Although LPG may be considered to be a safer compared to paraffin (no spillage or accidental consumption), fires which result from this fuel remain problematic when stoves are accidentally toppled (Lloyd, 2002b). This fuel has been also shown to be flexible in its application (heating rates can be adjusted), resulting in the consumption of comparatively less fuel since the power can be adjusted to a low level during simmering (Lloyd and Visagie, 2007).
SOCIAL IMPACTS OF THE VALUE CHAIN

Beyond the direct and indirect contribution to the economy in terms of GDP, the coal value chain impacts on other areas of the economy and society, through employment, industrial relations, health and occupational safety, training and skills development, and broad-based black economic empowerment. The impacts, however, go much further than just the direct value chain activities with many positive impacts due to Corporate Social Responsibility and community development activities together with the positive benefits associated with electrification. Similarly, the coal value chain is also associated with the unavoidable externality costs associated with mine closure and pollution.

Box 6: The Stakeholders’ Declaration on Strategy for the Sustainable Growth and Meaningful Transformation of South Africa’s Mining Industry

In 2010, mining stakeholders including DMR, the National Union of Mineworkers, the Chamber of Mines of South Africa, the South African Mineral Development Association, Solidarity, and UASA – The Union, developed and released the Stakeholders’ Declaration on Strategy for the Sustainable Growth and Meaningful Transformation of South Africa’s Mining industry. The declaration “lays a foundation for a strategy to position South Africa’s mining industry on a trajectory of sustainable growth and meaningful transformation… emphasising the complementary nature and interdependence of competitiveness and transformation” (Mining stakeholders, 2010). The declaration commits the stakeholders to principles of integrity and transparency, and to initiatives focused on infrastructure, innovation, sustainable development, beneficiation, strengthening the regulatory framework, skills development, employment equity, mine community development, housing and living conditions improvement, and transformation of procurement ownership and funding.

16.1 Employment along the value chain

16.1.1 Employment and earnings trends in the coal mining sector

Since the 1980’s there has been a steady decline in the number of people employed on South African coal mines. This trend was largely driven by productivity gains as a result of the introduction of labour-saving technologies. The increased drive for productivity was necessitated by South Africa emerging from international isolation and the mining industry re-engaging with international capital markets, a decline in commodity prices and changes in the demand for mining products (MQA, 2009a).

Figure 45 shows that in the early 1990s, however, employment trends started tracking output trends more closely and employment in the local coal mining industry has increased in line with increases in local production of coal. Currently the coal mining sector is the 3rd largest employer within the local mining industry behind the gold mining and platinum group metals sectors. In 2009 coal mining employed just over 70,000 people, and accounted for 14.4% of mining employment in South Africa.

Figure 45: Production and employment in the South African coal mining industry

(Source: DMR, 2009; Chamber of Mines, 2009a)
In 2009 the coal mining industry paid R 12.8 billion in wages (including contractors), which constituted 14.4% of total wage income in the mining industry as a whole. 57% of workers on coal mines were company employees and the remaining 43% were contractors in 2008 (Chamber of Mines, 2009a).

The vast majority of employment in the coal mining industry is concentrated in firms that employ 150 people or more (98.8%). Within this grouping of firms, employment is strongly weighted towards firms that employ less than 5,000 employees (accounting for 74.7% of total employment) (MQA, 2009a).

It is not clear whether the DMR employment data shown in Figure 45 above includes contractors and services providers. It has been suggested that part of the reason for the dramatic decline in the number of coal mine employees is that many company employees have been replaced by contractors and service providers over time. The Chamber of Mines of South Africa (2010) stated that the total estimated employment by coal mines belonging to the Chamber (including contractors) was 57,343 in 2008. This number is closely related to the 65,412 employees that DMR (2009) believed to be employed in the overall coal mining industry in South Africa. It also corresponds with the findings of (MQA, 2009a) that the bulk of employment on South African coal mines are concentrated in larger mines (see previous paragraph), and these mines are likely to be members of the Chamber of Mines of South Africa. As a result, it would seem that the employment figures shown in Figure 45 include contractors.

16.1.1.1 Employment by occupation

The productivity drive mentioned in the previous section led to a move towards multi-skilled individuals working in teams, which increased the responsibilities on work teams. Work teams now largely comprise team members that perform multiple tasks. This provides flexibility and allows team members to utilise their time underground more efficiently since team members can monitor each other’s work and can cope more easily with absences. As a result, teams now have much more autonomy and decision-making responsibility in the way they operate and this has necessitated higher levels of literacy in general from workers as well as higher levels of production and business skills. Thus, although the mining industry traditionally demanded relatively low levels of education from employees, this is changing quite rapidly and companies now require at least some education from new recruits (MQA, 2009a). These requirements are stricter in the coal mining industry than the mining industry as a whole due to the high level of mechanisation within the coal mining industry, and coal mining companies generally do not employ anyone with less than a Grade 10 – 12 education26. The information in the table below indicates that employment in the coal mining industry is heavily weighted towards Plant and Machine Operators and Assemblers, accounting for more than 40% of the total workforce.

**Table 39: Employment by occupation in the coal mining industry, 2009 (including contractors)**

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Employees</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Officials, Managers and Owner Managers</td>
<td>654</td>
<td>1.0%</td>
</tr>
<tr>
<td>Professionals</td>
<td>3,077</td>
<td>4.5%</td>
</tr>
<tr>
<td>Technicians and Associated Professionals</td>
<td>5,251</td>
<td>7.6%</td>
</tr>
<tr>
<td>Clerks</td>
<td>4,295</td>
<td>6.2%</td>
</tr>
<tr>
<td>Service Workers, Shop and Market Sales Workers</td>
<td>916</td>
<td>1.3%</td>
</tr>
<tr>
<td>Craft and Related Trade Workers</td>
<td>12,875</td>
<td>18.7%</td>
</tr>
<tr>
<td>Plant and Machine Operators and Assemblers</td>
<td>28,489</td>
<td>41.4%</td>
</tr>
<tr>
<td>Labourers and Related Workers</td>
<td>11,692</td>
<td>17.0%</td>
</tr>
<tr>
<td>Apprentices and Section 18 (1) Learners</td>
<td>1,535</td>
<td>2.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>68,783</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

(Source: MQA, 2009a)

16.1.1.2 Gender balance

Employment in the coal mining industry by gender and population group is shown in Table 40 below. Based on the information in the table, a number of conclusions can be drawn: Employment in the coal mining industry is heavily skewed towards males, with females making up just less than 10% of the total workforce. There are also large differences with respect to female employment by population group, with Africans having the largest gender imbalance (11.6 males employed for every 1 female) while the gender imbalance is smallest in the Coloured population group (2.9 males employed for every 1 female).

**Table 40: Population group and gender profile of the coal mining industry, 2009**

<table>
<thead>
<tr>
<th>Population group</th>
<th>Gender</th>
<th>Employees</th>
<th>% of total employees</th>
<th>Gender balance by race28</th>
</tr>
</thead>
<tbody>
<tr>
<td>African</td>
<td>Male</td>
<td>48,991</td>
<td>71.2%</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>4,220</td>
<td>6.1%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>53,211</td>
<td>77.4%</td>
<td></td>
</tr>
<tr>
<td>Coloured</td>
<td>Male</td>
<td>334</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>115</td>
<td>0.2%</td>
<td>2.9</td>
</tr>
</tbody>
</table>

26 Personal communication with Chamber of Mines, 2011.
27 Note, that the Chamber of Mines estimates employment in coal mining to be slightly higher at 70,703 employees.
28 Number of males employed per female employed.
The proportion of total earnings accruing to women within the coal mining industry has been larger than the proportion of total employment comprised by women, suggesting that women are currently paid more on average than men. The number of women as a percentage of total employment has more than doubled in the coal mining industry since the late 1980s, albeit admittedly off a very small base.

The proportion of women to men in the coal mining industry is uncertain. Calculations based on figures in DMR (2009a) suggest the percentage of women in the workforce in 2008 to be approximately 7.1%, while the annual Analysis of Workplace Skills Plans and Annual Training Reports published by the Mining Qualifications Authority reports a higher proportion of women in the coal mining workforce. The proportions for 2007 and 2008 are 8.1% and 9.4% (MQA, 2008a; MQA, 2008b). This may indicate that companies who submit annual Workplace Skills Plan and Annual Training Report submission to the MQA (likely to be larger firms) may employ a larger proportion of women than companies that do not submit reports.

### 16.1.2 Employment and remuneration in the electricity sector

At the end of the 2009/10 financial year Eskom reported that it had 36,547 employees, up from 32,954 two years earlier, as shown in Table 41. Benefits distributed to employees in 2010 were reported to be R17.4 billion.

#### Table 41: Number of Eskem employees

<table>
<thead>
<tr>
<th>End of period</th>
<th>Total no. of employees</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/10</td>
<td>36,547</td>
<td>3.8%</td>
</tr>
<tr>
<td>2008/09</td>
<td>35,196</td>
<td>6.8%</td>
</tr>
<tr>
<td>2007/08</td>
<td>32,954</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Eskom, 2010a and DNA Economics calculation)

16.1.3 Employment: Sasol

Over the last decade Sasol has had on average 31,810 employees worldwide. The bulk of these, 28,978, were employed in its South African operations (Sasol, 2010a).

The Sasol Group reported that previously disadvantaged individuals constituted 56% of total employment in June 2009 (Sasol 2010b). Sasol is a highly skills-intensive business and in support of increasing this percentage, Sasol directs at least 50% of university bursaries to previously disadvantaged students (Sasol 2010a).

16.1.4 Employment and remuneration: iron and steel industry

The number of employees in the iron and steel industry declined sharply between 1989 and 2003, as the industry shed approximately two thirds of the jobs in the industry in 1989. This decrease in employment was in line with the global decline of steel prices. As the global steel price began to recover in 2002, spurred by mainly by Asian demand for steel, the number of workers employed in the South African metals, metal products, machinery and equipment sub-sector began to recover (see Figure 46 below). Today employment in basic iron and steel manufacture sits at just over 52,000 people, with the metals, metal products, machinery and equipment sub-sector employing just over 200,000 (StatsSA, 2010). Despite the decline in employment, however, the metals, metal products, machinery and equipment sub-sector was still the largest employer within the South African manufacturing industry in 2008, employing 319,685 people (which constituted 24% of total manufacturing employment) (StatsSA, 2008).

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29 Sasol estimates that 85% of the jobs at Sasol involve skilled labour (Sasol 2010b).
In 2008, women constituted only 17% of the employees within the Basic metals, metal products, machinery and equipment sector (StatsSA, 2008). This was the smallest proportion of woman employed in any of the manufacturing sub-sectors in South Africa.

The characteristics of the iron and steel industry mean that different levels of the production process have vastly different employment effects per unit of investment, as shown in Table 42. As the level of local beneficiation increases, the amount of investment required to create a single job will decrease. This implies that whilst primary operations tend to be capital intensive, secondary operations tend to be more labour intensive and therefore have greater employment effects.

**Table 42: Value added, employment & investment per tonne of steel produced**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Selling price per tonne of steel (USD)</th>
<th>Employment per 1,000 tonnes per annum steel</th>
<th>Investment R million per job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron ore</td>
<td>180</td>
<td>0.17</td>
<td>8.5</td>
</tr>
<tr>
<td>Iron</td>
<td>500</td>
<td>0.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Hot rolled coil</td>
<td>585</td>
<td>0.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Cold rolled coil</td>
<td>685</td>
<td>0.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Pipe &amp; tube</td>
<td>960</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>Structural steel (avg. heavy &amp; light)</td>
<td>3,000</td>
<td>30</td>
<td>0.5</td>
</tr>
<tr>
<td>Yellow metals (ADT)</td>
<td>13,700</td>
<td>150</td>
<td>0.6</td>
</tr>
</tbody>
</table>

(Source: dtI, 2010b)
Even though the total employment levels declined between 1989 and 2000, in terms of remuneration, the nominal average earnings rose steadily during the same period. From 2003, the boom in commodity prices resulted in a marked increase in both the average earnings and total employment levels (Figure 47). In South Africa, the average steel industry income continued to rise even though the total number of employees appeared to plateau. This was probably because in South Africa the construction projects associated with the country’s hosting of the FIFA World Cup 2010 had acted to offset the lower global demand for steel resulting in higher wages. This did not translate into higher employment however due to continued global uncertainty about the future.

Figure 47: Employment and average earnings in South African manufacturing industry: basic metals

![Graph showing employment and average earnings in South African manufacturing industry: basic metals](image)

(Source: StatsSA, 2010)

16.2 Industrial relations

16.2.1 Coal mining: Industrial relations

Coal and gold mining are currently the only sectors of the mining industry in which centralised wage negotiations are conducted. In the coal mining sector, the Chamber of Mines does not negotiate on behalf of all its members, only on behalf of a few companies.

The sector has three main unions: the National Union of Mineworkers which is the largest, Solidarity, and UASA or “The Union”. The latter two are small in comparison to the NUM and have historically represented the interests of Miners, Artisans and Officials. The Chamber of Mines estimates that more than 80% of the approximately 70,000 people employed in the coal mining sector in 2009 were unionised (Chamber of Mines, 2011b). The distribution of employees by union in 2005 is shown in table 43.

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30 This section is based on correspondence with the Chamber of Mines of South Africa and information obtained from Chamber of Mines (2009b) and (2011a).
31 Anglo Thermal Coal SA, Delmas Colliery, Kangra Coal, Exxaro Coal Mpumalanga, Optimun Coal, Springlake Colliery, and Xstrata Coal.
After a two-year agreement was negotiated in 2009, negotiations are scheduled to take place again in 2011 at the Chamber. The process followed is that the unions submit their demands to the Chamber at the end of April and negotiations begin in May. In the last round of negotiations, the final agreement was signed in July. The body formulating the employer positions is set up by the Chamber of Mines and comprises representatives from each company. Senior Chamber Officials then negotiate on the companies’ behalf. The unions hold separate caucuses although these do interact. They bring members from the mines themselves to the negotiations. Only certain issues are dealt with through this process, namely bargaining on basic wages and conditions of employment. Other issues such as bargaining on organisational, operational and workplace issues are dealt with at mine or company level. The agreements reached often result in different provisions for different companies, particularly in respect of wage rates - basic wage rates are negotiated on a company-by-company basis. In terms of non-wage issues, however, outcomes are generally uniform.

In the 2009 negotiations, further issues on which agreement was reached included:

- The establishment of an industry-level working group to develop a framework of principles on appropriate entry levels for the coal industry;
- An investigation into protective clothing for female underground employees;
- Addressing the affordability of medical aid contributions;
- Increasing the medical incapacity benefit to R 20,000 by July 2010;
- Guaranteed employment for employees who cannot perform risk work while pregnant;
- Six days paid family responsibility leave per annum; and,
- The appointment of a multi-party task team to investigate how effectively to promote home ownership.

The Chamber endeavours to continually improve the relationship between the parties and between themselves and the unions. One example of this is the series of quarterly meetings which they held with the unions at both leadership and negotiator level during 2010. The system appears to work well as there have been no national strikes in the industry since the gold and coal strike in 1987 besides the strike to protest unsafe working conditions in 2007, although there has been industrial action at individual collieries.

There are currently plans under discussion to implement a sector-wide bargaining council for the mining industry which will result in changes to the practices described above. Discussion on the issue began in 2003, precipitated by demands from the NUM that a bargaining council be established for the mining industry. Since then, the three unions have been negotiating with the Chamber around the principles by which a council for the industry would work. The plan is that eventually all sectors and not just gold and coal will be brought into sub-chambers of the bargaining council. The Labour Relations Act provides for agreements concluded in a bargaining council to be extended to all employers and employees in the sector, so all employers will be affected by the agreements reached, regardless of whether or not they are members of the Chamber of Mines. Companies are only able to opt out of any agreement reached if the bargaining council grants an exemption. These exemption rules are particularly important for small mining companies who may be disadvantaged by being forced to adhere to overly onerous wages and conditions agreed by the council. A first draft of a constitution for the bargaining council is currently being considered by employers and the unions.

### 16.2.2 Electricity generation: Industrial relations

Approximately 84% of Eskom’s staff occupy non-managerial positions and are therefore subject to the collective bargaining process. Employees are represented by three major unions, namely: National Union of Mineworkers (NUM); National Union of Metalworkers South Africa (NUMSA); and Solidarity (Eskom, 2010a).
16.3.1 Training and skills development

16.3.1.1 Analysis of skills availability and shortages in the coal mining sector

One of the outcomes of the productivity drive in the mining industry since the late 1980s has been the centralisation of high level skills such as engineering, geological, metallurgical, accounting, legal and treasury skills at a mine house or group level. By centralising skills mining companies were able to maximise their utilisation and although large-scale productivity gains are typically associated with a steep increase in the demand for professional and technical skills, the mining sector has been able to contain the growth in demand for advanced skills (MQA, 2009a). As a result, the skills shortage felt at the height of previous commodity boom is not as evident in the current environment, although the local mining industry does face significant competition for its skills base from international operators. The latter was particularly exacerbated as a result of South Africa not participating in the last commodity boom, due largely to infrastructure constraints. This will only intensify as the length of the current coal boom increases. Significant investment is still required in skills development to ensure a productive workforce that can support future growth in the mining industry (PWC, 2010)

It has been suggested that the “scarce skills” shortage in coal mining was 879 individuals in 2009, representing 2.8% of employment. Skills shortages are more severe in the coal mining industry that the mining industry as a whole. The number of positions not filled in the coal mining industry (as a percentage of total employment) was more than double the average for the overall mining industry. “Scarce skills” refers to a shortage of candidates with the required attributes to fill positions available in the labour market. The required attributes may be specific skills and experience, qualifications, a specific race or gender, or a combination of these attributes. Scarcce skills are typically expressed in terms of the occupations or job description for which there are not enough candidates available (i.e. “accountants” rather than “financial management skills” (MQA, 2009b)).

16.3.1.1 Training

The coal mining industry trained 72.1% of its employees in 2008. This was second only to the petroleum and gas industry (which trained 78.4% of its employees). The coal mining industry spent R 368 million on training in 2008, which was less than the gold and platinum group metals sectors in terms of absolute spend, but significantly more in terms of training spending as a percentage of payroll.

The coal mining industry not only trained their own employees, but also invested in training the employees of contractors. In 2007 the coal mining industry trained 19,439 contractor employees (19.2% of contractor employees) and in 2008, 39,958 (or 26.6%) of contractor employees. As a percentage of contractor employees trained, this was second only to the platinum group metals mining sub-sector, which trained 43.1% of contractor employees in 2007 and 30.8% in 2008 (MQA, 2009b).

16.3.2 Training and skills development: coal-based electricity generation

As a capital-intensive industry, electricity generation employs a relatively large proportion of skilled labour. Training and skills development are thus important issues within this industry. Although not discussed here, skills in the electricity generation sector beyond Eskom are a critical issue, particularly with the planned introduction of independent power producers (IPPs).

16.3.2.1 Analysis of skills availability and shortages

The recruitment and retention of skilled labour needed for Eskom’s daily operations, maintenance and capacity expansion have been identified as a strategic risk. Eskom projects that by 2014, the five year cumulative additional core, critical and scarce skills requirements would reach 3,300 (Eskom, 2010a). In order to meet this additional labour demand, Eskom will need to hire approximately two additional skilled workers per day between 2010 and 2014. Eskom expects to meet some of its future skilled labour demands through enhancing its learnership programmes, attracting skilled labour from abroad and supporting mathematics and science subjects in secondary and tertiary learning institutions. In light of the employment equity and black economic empowerment requirements however, it is not clear if Eskom will be able to meet these targets.

16.3.2.2 Sector contribution to training and skills development

Eskom has a centralised learning system offering over 6,000 courses, and in 2010 Eskom invested R758 million in training their personnel. The company has 28 learning facilities run by 530 training practitioners with 28 instructors (Eskom, 2010a).

In its second year of operating, the Eskom Academy of Learning that was set up in 2009 had 5,255 learners studying in various fields. There were 3,780 learners studying in technical fields as engineering trainees, apprentices,
technologists, technicians and artisans. Once learners have completed their training they are absorbed into the company either as engineers or graduates-in-training (Eskom, 2010a). Along with five other companies, Eskom joined the Technical Skills Business Partnership (TSBP) which seeks to train 5,400 people for the national pool (ArcelorMittal, 2010a). In this regard, Eskom has provided a grant to the Nkangala further education and training (FET) college that would allow the college to become a fully operational centre offering its national vocational certificate learnerships facilities to prepare for trade tests. The grant would equip learners with fitting and turning skills and allow the centre to conduct automotive workshops. The centre would also become an accredited trade test centre. Eskom also sponsors the Eskom Expo for Young Scientists (Eskom, 2010a).

16.3.3 Training and skills development: CTL

Sasol is facing major skills challenges such as an ageing workforce, the gap between the advancement of technology and human capability, and increasing operational complexity. When Sasol was established in 1950, 80% of its workforce was unskilled. The trend has been reversed in recent years as currently 85% of the jobs require skilled labour (Sasol, 2010a).

In order to try and address the skills constraint, Sasol is involved in a number of skills development initiatives. As part of the Inzalo empowerment deal in 2008, Sasol reserved a 1.5% shareholding in their holding company for the Inzalo Foundation. This Foundation was established in 2007 with the objective of developing mathematics, science and technology in previously disadvantaged communities (Sasol, 2010a). In 2010, Sasol invested R 51 million into their bursary scheme and an additional R 25 million into South African universities.

Sasol also offers an undergraduate bursary programme aimed at developing skilled professionals in science, engineering, geology and related technical areas accounting business management and related commercial areas. In 2008, the bursary funded 622 undergraduates and 122 post-graduate students at a cost of R 51 million (Sasol, 2010a).

Significant amounts are invested in training Sasol’s employees. In the 2009 financial year, Sasol invested R 386 million on training and skills development activities aimed at its employees (Sasol 2010b). In 2010, Sasol increased this investment to R 421 million. Project TalentGro coordinates the skills development activities of the Sasol Group. Sasol’s graduate program exposes graduates to their areas of specialisation such as engineering and accounting (Sasol, 2010a).

In addition to their own training and skills development projects, Sasol maintains strategic partnerships with tertiary institutions such as the Gordon Institute of Business Science, the University of the Free State, the University of Cape Town and the University of Stellenbosch (Sasol, 2010a). Under the Technical Skills Business Partnership (TSBP) Sasol is one of six companies that have pledged to train 5,400 people for the national pool (Sasol, 2009b). The company also invests substantially in research and development, discussed further in the section on coal R&D.

16.3.4 Training and skills development: Metallurgical sector

ArcelorMittal, Xstrata and Evraz Highveld Steel and Vanadium have recognised that their core business activities all rely heavily on being able to access skilled labour in the scientific, engineering, technological and artisanal sectors. These companies therefore tend to focus much of their non-operational expenditure on education and training, especially in mathematics and science subjects. ArcelorMittal runs an extensive bursary program for artisans and engineers, and has representatives on the advisory committees of various universities, providing input on the relevant content for their engineering and related science degrees. ArcelorMittal also has a bursary program that finances the studies of university engineering students who will join the company on the completion of their studies (ArcelorMittal, 2010a).

In terms of internal skills development and training, Xstrata offers an Adult Basic Education program for employees from previously disadvantaged communities (Xstrata, 2010d). ArcelorMittal runs a leadership development program supported by the global ArcelorMittal University and in 2008, the company offered 96 management development courses to 1,402 employees (ArcelorMittal, 2010a).

ArcelorMittal’s graduate-in-training program offers graduates from various fields a two year internship. The company also offers an artisan training program that in 2009 had 655 candidates in the pipeline (ArcelorMittal, 2010a). The Xstrata-Merafe Chrome Venture offers technical training to employees and members of the local community in the form of learnerships (Xstrata, 2010d).

ArcelorMittal is the first South African company to offer the three National Qualifications Framework levels (NQF2, NQF3, and NQF4). Along with five other companies, ArcelorMittal joined the Technical Skills Business Partnership (TSBP) which seeks to train 5,400 people for the national pool (ArcelorMittal, 2010a).

16.4 Impacts on health

16.4.1 Health issues in coal mining sector

The health challenges faced within the coal mining industry are HIV/AIDS, TB and other communicable diseases, silicosis, and noise induced hearing loss. In order to address these issues, the coal mining industry has introduced a number of programmes to prevent and address these issues (Chamber of Mines, 2007). Consideration is given here to HIV/AIDS and TB, while silicosis and noise induced hearing loss is considered in Section 16.5.

16.4.1.1 HIV/AIDS

In addition to the broader social and economic impact of HIV/AIDS on the South African economy, it also imposes specific
costs and challenges on the coal mining industry in South Africa. As an industry where the bulk of employment consists of a limited number of machine operators each performing specialised tasks, the loss of a relatively few operators can cause substantial delays or reductions in production (Steinberg et al., 2000).

The cost of providing making antiretroviral (ART) to HIV positive employees (which the coal mining industry started providing on a large scale in 2003) has increased the operational costs of coal mining firms (Chamber of Mines, 2007; Kyereh and Hoffman, 2008). The benefits of providing ART treatment to HIV positive employees in terms of reduced absenteeism and increase productivity is, however, believed to far outweigh the costs of providing ARTs. This cost was estimated to be R 1,001 per patient per month over a 3 year treatment programme in 2007 (Kyereh and Hoffman, 2008).

The coal mining industry is striving to achieve a target of providing 80% of HIV positive employees with ART treatment (Chamber of Mines, 2007). Although the coal mining industry is increasing the coverage of ART treatment for HIV positive employees (in 2006 14% of HIV positive employees had access to ART treatment, up from only 10% in 2005) (Chamber of Mines, 2007), it seems that the industry may still be some way off from reaching its goal of 80% coverage.

The coal mining industry places great emphasis on employees knowing their HIV status and using this knowledge to effectively prevent new infections and engage with wellness treatment programmes. Voluntary counselling and testing (VCT) and wellness programmes are now widely provided via coal mining healthcare infrastructure (Chamber of Mines, 2007).

The coal mining industry has set itself the target of increasing participation in both VCT (for all employees) and wellness programmes (HIV positive employees) to 100% by 2011 (Chamber of Mines, 2007).

16.4.1.2 TB and other communicable diseases

The key driver of the TB epidemic in the South African mining sector is HIV/AIDS, while silicosis also plays a part (Chamber of Mines, 2009a). The TB-HIV/AIDS co-infection rates are high, with up to 73% of adult TB patients also being HIV positive (Chamber of Mines, 2009a). As a result, the mining industry has decided to integrate care for TB and HIV/AIDS patients to the extent that is feasible, since the high co-infection rate makes it practically impossible to spate the two diseases.

TB is seen as a significant risk factor within the South African mining industry and as a result a lot of emphasis is placed on addressing the problem. TB programmes within the local mining industry are generally believed to surpass WHO best practice and include components such as (Chamber of Mines, 2007):

- reducing the high pool of latently infected individuals;
- improving living and working conditions e.g. hostel living, underground mining; informal communities;
- improving occupational dust control; especially silica dust that causes silicosis;
- improving control of infected individuals i.e. active case finding, reducing high rates of treatment interruption and improving treatment completion; and
- controlling the HIV/AIDS epidemic.

Although disaggregated numbers for the coal mining industry are not available, the incidence rate of TB for the South African mining industry as a whole fell from 1,219 per 10,000 individuals in 2005 to 884 per 10,000 individuals in 2008 (Chamber of Mines, 2009a). Given that the reported incidence of all forms of TB in South Africa was 918 per 10,000 people in 2007, the TB rate on mines seem to be significantly lower than the South African average.

The Chamber of Mines of South Africa’s overall approach to combating TB centres on elimination of silicosis and reducing HIV/AIDS prevalence, since these are the key drivers of the TB epidemic. The Chamber also seeks to refine its TB programmes to increase their efficiency (Chamber of Mines, 2009a).

16.4.2 Eskom’s employee health and HIV/AIDS programme

Eskom has a comprehensive health and wellness programme that provides occupational health services, sport and recreation facilities, and an employee assistance programme that offers chronic disease (including HIV/AIDS) management facilities (Eskom, 2010a).

Eskom initiated its first HIV/AIDS management programme in 1988. This led to the commissioning of an impact assessment study in the 1990’s. The study projected that in ten years the prevalence of HIV in the organisation would be 26% in the absence of intervention. The study also estimated that the 550 to 600 new AIDS cases a year within the organisation would cost the organisation between R 275 and R 300 million annually. Eskom responded by establishing two committees; one to deal with the effects of infected workers and the other to deal with the formulation of strategies to counter further infection.

The approach adopted by Eskom includes offering education and training beyond awareness, free voluntary counselling and testing and access to antiretrovirals through the Eskom medical scheme.

The company has also invested in programmes beyond just their employees. It has donated over R 100 million to the South African AIDS Vaccine Initiative (SAAVI), as well as R 6 million for the development of primary care givers. This program has benefited over 5,200 health care workers.

16.4.3 Health issues in the CTL sector

In 2006, Sasol introduced a disease management program aimed at proactively identifying and treating diseases such as high cholesterol, asthma, hypertension and diabetes. The
administrators of Sasol's medical aid schemes reported that a
decrease in average claims and the days lost per employee as
a result of illness at Sasol have decreased from 10.59 to 8.56
days per annum (Sasol 2010d).

16.4.3.1 HIV/AIDS

In response to the pandemic, Sasol set up the Sasol HIV/AIDS Response Program (SHARP) in 2002. SHARP seeks to reduce
the incidence of HIV infection and extend the quality of life for
those infected throughout Sasol's southern African operations.
Between 2002 and 2005, Sasol conducted a voluntary
counselling and testing (VCT) drive throughout its South African operations and the HIV incidence rate was 7.1% based
on 82% uptake of testing (Sasol, 2010b). This was substantially
lower than the 15.5% prevalence rate that was reported for all South African adults aged 25 years and older during the same period (HSRC, 2005).

Sasol employees have access to the following (Sasol, 2010e):

- HIV/AIDS education sessions conducted on site by peer educators. Training is also provided for managers and supervisors to help them to more effectively manage and be more sensitive to subordinates living with the virus.
- Sasol employees have the opportunity to be voluntarily tested at work.
- Access to confidential and multilingual counselling for all permanent employees and their family members through the Employee Assistance Programme (EAP).
- Access to medical aid schemes that offer access to HIV benefits such as antiretroviral therapy.

In terms of the broader community, Sasol's health related social expenditure has been targeted mainly at the communities affected by HIV/Aids that surround their operations (Sasol, 2010e). For example, Sasol sponsors the following initiatives:

- The Topsy Foundation in Grootvlei, Mpumalanga which operates a sanctuary for orphans affected and infected by HIV.
- The Sasolburg Matlafala Centre which provides training, voluntary counselling and testing facilities.
- The construction of the Esperado and Amazing Grace children’s Aids shelters in Barberton and Malelane respectively.

16.4.4 Health issues in the metallurgical sector

Like many others in South Africa, firms in the ferrous metal industry have identified HIV/AIDS as one of the main public health challenges faced by the industry. As such, much of the non-occupational health expenditure has been targeted at raising awareness, voluntary counselling and treatment (VCT)\(^35\) and the treatment of those infected.

For example, in 2007 Xstrata partnered up with Re-Action, the Mpumalanga provincial government, NGO’s and the US President’s Emergency Plan for AIDS Relief (PEPFAR) to strengthen community based health systems in areas surrounding their operations. Xstrata has also committed to eradicate contributing factors such single sex hostels for workers (Xstrata, 2010e). Similarly, Evraz Highveld Steel and Vanadium has adopted an approach that includes providing access to HIV/AIDS health services for employees and their life partners (Evraz, 2010).

16.5 Occupational safety

The mining industry is heavily regulated with regard to health and safety, socio-economic transformation and the social implications of mining activities. The 1996 Mine Health and Safety Act (29 of 1996) provides for the protection of the health and safety of employees and other persons at mines through promoting a culture of health and safety, in accordance with South Africa’s international obligations in this regard. Under the Act both employers and employees have duties to identify hazards and eliminate them, and to control and minimise risks. Employees have the right to refuse to work in dangerous conditions. Health and safety measures are enforced through effective monitoring systems and inspections.

The Act provides for employee, employer and government co-operation and participation in health and safety matters, establishing representative tripartite institutions to review legislation, promote health and enhance properly targeted research. Training and human resource development is promoted through the Act. These provisions were reviewed and strengthened in the 2008 Amendment of the Act, and it was aligned with other laws, particularly the MPRDA.

Whilst the Act is acknowledged as being good, South Africa has particularly difficult mining operating environments, and there are insufficient skills to implement the Act consistently (Policy and IP Contact Group, 2010). Many chapters of the act are also cited as being empty or refer back to past acts, which requires consolidating and sorting out (SACRM Policy and IP Focus Group, 2010).

The Occupational Health and Safety Act (85 of 1993) provides for the health and safety of persons at work, including atmospheric emission from workplaces. It requires any employer to ensure that their activities do not expose non-employees to health hazards, which has implications along the coal value chain.

16.5.1 OHS in the coal mining sector

16.5.1.1 Accidents and fatalities

Accidents and fatalities have significant negative social and economic implications for individuals, families, communities and also mining companies. Direct costs include costs associated with damage in the workplace, the costs of

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\(^{35}\) In 2009, Evraz Highveld Steel and Vanadium reported that 2,072 employees (89% of the total work force) received voluntary counseling and testing.
interruption of production and compensation costs and loss of valuable human assets and invested capital in training. Indirect costs include the value of livelihoods lost, income to dependents foregone, and the cost associated with care provided by families and the community. The bulk of these costs were historically borne by individuals and communities, mining companies are increasingly being affected by loss of reputation and withdrawal of investment capital (Hermanus, 2007). The coal mining industry recorded 332 injuries in 2008 and 295 injuries in 2009 (DME, 2010). The number of fatalities has reduced significantly over time (from 31 in 2000 to 13 in 2010).

Although the number of fatalities and fatality frequency rate in coal mines has reduced over time, the reductions are below the 2003 Mine Health and Safety Council target level of an average 20% a year reduction from 2003 levels (Chamber of Mines, 2007). In order to be on target, the fatality frequency rate would have had to have been reduced to close to 0.05 in 2009.

One way of trying to reduce injuries and fatalities is through training. Induction or refresher training refers to mandatory occupational health and safety training that workers have to undergo on a regular basis. This type of training does not contribute to the technical skills of employees, but is rather aimed at ensuring a safer working environment. The coal mining industry has the highest level of compliance of all the mining sub-sectors, with almost 90% of targeted employees trained within induction/refresher training requirements in 2008 (MQA, 2009b).

**16.5.1.2 Dust and respiratory problems**

The respiratory problem caused by the exposure to coal dust (technically a mixture of coal dust and silica) that is currently receiving the most focus is silicosis (Chamber of Mines, 2007; Du Toit, 2010)36. Silicosis is an incurable respiratory disease caused by inhaling dust containing crystalline silica. The disease typically takes many years to develop, although intense exposure can cause acute cases (Du Toit, 2010). Silicosis can increase vulnerability to TB, and thus by extension also impacts on HIV/AIDS prevalence (Chamber of Mines, 2007).

The bulk of the new silicosis cases in South Africa are likely to have been in the gold mining industry, since gold mining has the highest concentration of silica in the ore mined of all the mining commodity groups in South Africa (Chamber of Mines, 2009a). The estimated prevalence rate in the coal mining industry in 2009 was 5.2%, based on autopsies in the mining industry37 (NHLS, 2010).

Given the long lead times for silicosis to develop, the appropriate measure to use to gauge prevention activities in the mining industry is exposure to silica-containing dust (Chamber of Mines, 2009a). The percentage of silica dust samples at South African mines below the legislated occupational exposure limit (OEL) has increased over time for all commodity groupings, which shows improved dust control and a reduced risk of developing silicosis (Chamber of Mines, 2009a). The coal industry, however, while it has also increased the percentage of readings below the OEL over time, seems to be lagging the other mining sub-sectors in dust control as it was the only commodity grouping that did not manage to meet 2003 Mine Health and Safety Council resolution milestone of 95% of individual readings being below the OEL in 2008 (Chamber of Mines of South Africa, 2007 and 2010).

**16.5.1.3 Noise-induced hearing loss**

The mining industry as a whole is striving to meet the 2003 Mine Health and Safety Council commitments that by 2008 to ensure that is no deterioration in hearing greater than 10% amongst employees as result of amongst occupational exposure to noise, and by December 2013, that the total noise emitted by equipment installed in the workplace must never exceed a sound pressure level of 110 dB(A). While the industry has made significant progress in this regard, cases of noise-induced hearing loss (NIHL) are still occurring (Chamber of Mines, 2009a).

Although the industry targets refer to bringing noise levels down to 110 dB(A), the legislated occupational exposure limit (OEL) is set at 85 dB(A), since it has been shown that NIHL can occur if employees are consistently exposed to noise levels above 85 dB(A) level for of eight hours a day (Chamber of Mines, 2007).

In 2006, 30% of employees in the coal mining industry were being exposed to noise levels above the OEL. This was the highest level of exposure of any of the main commodity groupings.

**16.5.2 OHS in electricity generation**

Contractors and visitors on all Eskom sites are expected to comply with Eskom’s safety, health and environment (SHE) policy. To ensure contractor compliance, Eskom management engages in quarterly forums with contractors to ensure that they are complying with best practices.

Eskom maintains separate safety data for employee fatalities, contractor fatalities and public fatalities. Table 44 shows that while Eskom has show a consistent improvement in the occupational safety related to employees (only 2 fatalities were reported in 2010 – both linked to vehicle accidents), the performance with respect to contractors has worsened and its public safety record has not improved significantly on average over the last three years.

Even though Eskom has been running a public safety campaign, members of the public consistently have the

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36 Other respiratory diseases linked to exposure to coal dust include coal workers’ pneumoconiosis and chronic obstructive pulmonary disease (Du Toit, 2010).
37 The overall disease rate based on number of autopsies (237 cases per 1000 autopsies) is significantly higher than the number of reported cases. This could be due to the fact that the diseases takes up to 20 years (Chamber of Mines, 2009a) to develop and even at death may not be at a stage where the affected individual is aware that he/she has the condition.
worst safety record. While this is partly attributable to illegal connections and cable thefts, deaths involving motor vehicles remains a significant contributor (Eskom, 2010a).

Of the 14 contractor fatalities in 2010, six were attributable to vehicle accidents, three to gunshot wounds, three to being struck by falling objects, one to an electrical contact incident and one to a fall from height (Eskom, 2010a).

**Table 44: Employee, contractor and public safety**

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2009</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employees</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fatalities</td>
<td>number</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Electrical contact injuries</td>
<td>number</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>Electrical contact fatalities</td>
<td>number</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Other fatalities (incl. vehicle accidents)</td>
<td>number</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lost time incidence rate</td>
<td>index</td>
<td>0.54</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Contractors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fatalities</td>
<td>number</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Electrical contact fatalities</td>
<td>number</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other fatalities (incl. vehicle accidents)</td>
<td>number</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td><strong>Public safety</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total public fatalities</td>
<td>number</td>
<td>41</td>
<td>28</td>
</tr>
<tr>
<td>Electrical contact fatalities</td>
<td>number</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>Fatalities from other causes</td>
<td>number</td>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>

(Source: Eskom, 2010a)

Despite consistent reductions in employee fatalities, Eskom’s lost-time incident rate (LTIR) increased to 0.54 per 200,000 man-hours worked from 0.50 in 2009. The LTIR also remains well above the firm’s internal target of 0.31 per 200,000 man-hours worked (Eskom, 2010a).

**16.5.3 OHS in CTL**

In order to facilitate the benchmarking of Sasol’s health and safety performance with international firms, Sasol uses an international measure for reporting occupational health and safety incidence referred to as the recordable case rate (RCR) reporting standard. Sasol places a high emphasis on health and safety and this is evident in the detailed way in which incidents are reported. Because Sasol operates in a number of areas, they face a number of different health and safety challenges. There was a large variance in RCR rates reported between business units in Sasol’s 2010 Sustainable Development report (Sasol, 2010c). The monthly RCR rate in Sasol’s mining operations (1.19), however, was almost double that of the business unit with the second highest RCR (Technology with a RCR of 0.65).

The figures below show that while Sasol’s over incident rate has reduced significantly since 2001, the average transport incident rate has remained relatively stable since 2002 (with the exception of 2003 which was an outlier in terms of transport incidents) (Sasol, 2010e).

**Figure 48: Selected Sasol health and safety indicators**

(Sasol, 2010c)

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38 The RCR is the “number of fatalities, lost workdays, restricted work cases, medical treatments beyond first-aid cases and accepted illnesses for every 200,000 employee hours worked” (Sasol, 2010a). From 2006 onwards, Sasol’s RCR includes recordable injuries for both employees and service providers and as well as occupational illnesses for employees.
Sasol also provides benchmark data that compares the company with local and international competitors in the chemicals and liquid fuels markets, as well as with South African mining companies. Sasol sets transparent targets with respect to health and safety metrics in a number of areas.

This data suggests that there is still room for improvement before Sasol’s health and safety record will be directly comparable with international competitors in chemicals and liquid fuels. Sasol Mining’s health and performance is, however, on par with that of the best performing local coal mining companies (Sasol, 2010f).

16.5.4 OHS in the metallurgical sector

As early as 2005, the South African Department of Labour had identified the iron and steel industry as one of the high risk industries where workplace health and safety regulations had been disregarded. In 2007, raids by the department revealed how many of the workplaces visited, especially in KwaZulu-Natal, did not comply with state regulations (SAPA, 2007). In 2009, ArcelorMittal reported two separate workplace incidents that resulted in the deaths of five employees. In one case, ArcelorMittal admits that the fatal explosion was caused by flaws in the design of its plant (ArcelorMittal, 2009). During the same period, Evraz Highveld Steel and Vanadium reported 1 fatality and failed to meet its stated safety targets.

Steel foundries are normally equipped with arc furnaces that emit a very fine fume. Metallurgical industry workers in many countries are therefore often exposed to high concentrations of dusts and fumes that result in respiratory problems. Similarly it is suspected that South African steel smelters have high levels of occupational diseases that simply go unreported (Carnie, 2007). Historically high incidences of malignant and non-malignant respiratory diseases associated with occupational hazards have been observed amongst South African foundry workers (Sitas et al., 1989). More recently however, technologies such as closed furnaces have been introduced that are capable of capturing up to 65% of the dust discharged by arc furnaces (Xstrata, 2010b).

16.6 Broad-based Black Economic Empowerment

The MPRDA required that a Mining Charter be developed shortly after the Act was promulgated, in line with the Broad Based Black Economic Empowerment Act, 53 of 2003. Government and industry, with the intention of bringing about widespread socio-economic transformation in the sector, developed the Mining Charter collaboratively. The Charter was ratified in 2002, and identified first phase transformation targets over a five-year period that ended in 2009. These targets were not achieved and the subsequent Amendment (passed in 2010), whilst not increasing the targets, has made the Charter more rigorous through detailing requirements and implications of non-compliance. Significantly, the amendment makes non-compliance with the Charter a contravention of the MPRDA, with companies in breach likely to lose their licences.

16.6.1 BBBEE in the coal mining sector

Black Economic Empowerment (BEE) has significantly changed the face of the coal mining industry in South Africa since the late 1990s. Not only did it lead to a thriving Junior Mining Sector, but all major coal producers had to move to a minimum of 26% BEE shareholding (Steyn, 2009). As a result, there has been a dramatic increase in black economic empowerment. More than 30% of coal production, and 21.76% ownership of the Richards Bay Coal Terminal, is attributed to companies controlled by previously disadvantaged South Africans (Eberhard, 2011). Figure 49 below shows that the coal mining industry is the sub-sector with the largest number of BEE companies within the South African mining industry.

Figure 49: Number of BEE companies by commodity grouping, 2009

(Source: DME, 2009b)
With respect to women-empowerment, the Mining Charter set a goal of women making up 10% of the workforce in the mining sector by 2009 (RSA, 2004). Based on the update of the Sector skills plan for the mining and minerals sector: 2005 – 2010 published in 2009 (MQA, 2009a), it seems that the coal mining industry may have come quite close to meeting this target (see section 0). By 2006, however, the industry was still a way off from meeting the 40% target for previously disadvantaged individuals in management positions, given that only 28% of management posts were held by previously disadvantaged individuals (Chamber of Mines, 2007; RSA, 2004). The coal mining industry was also only half way towards its goal of procuring 70% of goods and services from BEE owned, controlled or influenced firms (Chamber of Mines, 2007).

16.6.2 BBBEE in electricity generation

Eskom has internal transformation guidelines that set targets for gender and race at “managerial” levels. The reason for setting targets for more skilled workers is due to the historical lack of skilled black employees which meant these levels are difficult to transform. Such targets are not required for the lower skilled levels, which are already predominantly black. However, Eskom's transformation guidelines differ from the regulatory definitions of the Employment Equity Act of South Africa which excludes non-permanent employees and foreign nationals. Eskom has thus begun to modify its guidelines to bring them in line with the Act (Eskom, 2010a). NUM and NUMSA have come out publicly in criticism of Eskom claiming that the power utility was employing black foreigners in order to subvert the employment equity requirements as prescribed by the South African government.

Eskom has a 47 year long term coal supply agreement for the new Kusile power station with Anglo Inyosi Coal, which is Anglo Coal South Africa's empowerment subsidiary (Eskom, 2010i).

Eskom’s Development Foundation also runs a contractor academy near the Kusile construction site which aims to build the capacity of 30 selected black contractors in order to increase their ability to render their services to Eskom.

16.6.3 BBBEE in CTL

In 2008, Sasol completed their Sasol Inzalo broad based black economic empowerment initiative in South Africa. The deal led to approximately 300,000 previously disadvantaged South Africans acquiring a 10% stake in Sasol’s listed holding company. Of the shareholding, 4% was reserved for 24,500 South African Sasol employees and 1.5% was reserved for the Inzalo Foundation. The value of this deal was about R 24 billion.

The group also has put in place a number of policies to try and improve its empowerment credentials. Examples include (Sasol, 2010a):

- Sasol has a preferential procurement system for black owned businesses representing more than 30% of Sasol's procurement spend; Sasol has set up a business incubator called ChemCity, and also established the Siyakha Trust which is a supplier development funder that has assisted over 249 companies that employ approximately 2,900 employees to become Sasol suppliers (Sasol, 2010b).
- BEE group Tshwarsisano LFB Investment owns 25% of Sasol Oil’s liquid fuels production, distribution and marketing operations.
- In 2007, Sasol Mining facilitated that Ixia Coal, a company owned by a group of black women, would acquire a 20% stake in Sasol Mining. The transaction was concluded on 29 September 2010 and first dividends flowed on 30 September 2010. Ixia Coal is South Africa’s first black women owned, managed and operated mining company in South Africa.
- During the financial year ending June 2009, 50% of the university bursaries awarded by Sasol were to previously disadvantaged individuals.

16.6.4 BBBEE in the metallurgical sector

The key elements of the Department of Trade and Industry balanced scorecard system for addressing racial transformation include ownership, management control, employment equity, preferential procurement, enterprise development and skills development. As such, Black Economic Empowered programmes in the metallurgy industry have generally followed a multi-pronged approach.

One approach has been to offer shareholding to individuals or consortiums from previously disadvantaged communities. For example, Scaw Metals was a wholly owned division of Anglo American South Africa Limited until 2007 when a 5% equity stake was also sold to an employee trust, and a 21% equity stake was sold to a consortium of three BEE partners and a BEE women's group. The value of the transaction was valued at R 5.3 billion (SAISI, 2007). Another example is the Xstrata-Merafe joint venture that began in 2004 in order to run the Boshoek Smelter. Merafe Resources which is 31% owned by the Royal Bafokeng Resources would control 20.5% of the joint venture (Xstrata, 2010f).

Other approaches that have been adopted by firms in the metallurgy industry have been more broad-based compared to most of the shareholding schemes. These include preferential procurement programmes to support black owned businesses. For example, Evraz Highveld Steel and Vanadium reports that 28.7% of the capital goods, 54.5% of their consumables and 69.9% of the services that they procured in 2009 were from approved BEE vendors (Evraz, 2009). ArcelorMittal’s Vanderbijlpark works has also developed a pilot Preferential Procurement Project for black owned businesses. Under this programme, contracts lasting

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41 Here “managerial” levels refer generically to all the more highly skilled levels (termed M, P and S bands) at Eskom.
a minimum of three years are awarded to black owned companies for them to supply a range of mechanical spares (ArcelorMittal, 2010a).

In 2008, ArcelorMittal set aside a budget of R 250 million for the development or small to medium black owned enterprises that supply ArcelorMittal as well as downstream steel businesses. The funds were allocated to the provision of loan finance, mentorship and management services. ArcelorMittal admits however that little progress has been made in actually disbursing the fund (ArcelorMittal, 2010a).

**Box 7: Mittal Steel's controversial BEE deal**

In 2001 the former state owned iron and steel monopoly Iscor was unbundled into Iscor Steel and Kumba Resources. Iscor Steel (which later became ArcelorMittal) retained a 21.4% mining right to Sishen Mine. Kumba agreed to contract mine Iscor's mining rights on their behalf and supply the iron ore to Iscor for its 21.4% mining right. Iscor would reimburse Kumba the costs of mining the ore and in addition pay a 3% management fee.

In 2009, ArcelorMittal failed to apply for the conversion of its 21.4% old-order right to prospect for iron ore at Sishen mine and the rights were reverted to the state. Although Kumba applied for ArcelorMittal's mining rights to Sishen, the Department of Mineral Resources controversially decided to grant the right to the politically connected empowerment company Imperial Crown Trading (ICT). Subsequently, ArcelorMittal offered to buy ICT for R 800 million and to include the shareholders of ICT in its R 9.1 billion broad based BEE deal. ArcelorMittal's BEE deal included a 5% employee share ownership programme, and a 21%equity share for a consortium of BEE partners.

(Source: ArcelorMittal, 2010c; Kumba, 2010)

**16.7 Wider social impacts of the coal value chain.**

In addition to the indirect impacts mentioned previously in relation to local procurement, public health and education - the coal value chain has additional positive and negative impacts.

Negative impacts include impacts on the road network, and on human health from pollution. Positive impacts include those from electrification. Further impacts, such as those on other sectors such as agriculture and tourism and on the sustainability of new settlements established around power generation, depend on how these are managed. Each of these considerations is discussed further below.

**16.7.1 Community development activities in the mining sector**

The Mining Charter stakeholders, in partnership with the different spheres of government, cooperate in the formulation of integrated development plans for communities where mining takes place as well as for major labour sending areas (Chamber of Mines, 2007). There is a particular focus on the development of infrastructure. The Mineral and Petroleum Resources Development Act further requires that mining companies must file a social and labour plan together with their applications for mining licences that must include detail on planned projects aimed at advancing the socioeconomic welfare of all South Africans and to ensure that mining companies have a positive impact on the socio-economic development of the areas in which they are operate (Chamber of Mines, 2007).

In the coal sector community development activities are coordinated via the Coal Producers’ Community Development Forum which meets on a regular basis. The coal industry has also set up a forum in the Mpumalanga region that includes community development personnel from the coal companies in the area (Chamber of Mines, 2011c).

At present there is very little consolidated information in the public domain regarding community development activities of the coal mining industry in South Africa. This creates the impression (which may not be justified) that there is very little coordination between activities and that the individual mining companies prefer to focus on their individual projects.

**16.7.2 Mine closure considerations**

It is generally accepted that upon the closure of a colliery, in addition to returning land to a state suitable for viable post-mining use (like agriculture) as discussed previously, it is also necessary to assess and manage the socio-economic impacts of mining on local stakeholders (Limpitlaw et al., 2005). The environmental, safety, social and economic risks linked to badly implemented mine closure can not only lead to significant liabilities for mining companies, but can lead to the severe distress for communities as a result of potential economic and social distress (Limpitlaw et al., 2005). These impacts can often reverberate beyond the local communities to have district and even regional implications (Stacey et al., 2010). Because of the wide-ranging potential impact of mine closure, it involves a number of stakeholders in addition to the mining firm. The stakeholders include host communities, mine employees and unions, service providers to the mine, individuals and companies involved in downstream economic activity supported by mining, various levels of government (including local authorities), NGOs and everyone involved in the broader local economy that will be affected by the closure (Stacey et al., 2010).

The potential negative impacts of badly managed mine closure, from a socio-economic perspective assuming that all environmental issues have been adequately addressed, could include, amongst others (Limpitlaw et al., 2005; Stacey et al., 2010):
* Increased poverty and unemployment levels;
* Insufficient or mismatched skills leaves employees unable to find or create alternative employment;
* Insufficient long-term planning leads to issues relating to local infrastructure needs, and infrastructure maintenance and use;
* Social investment projects hampered by closure;
* Local authorities left severely under-resourced and under-capacitated;
* Waves of illegal activity in local community as a result of opportunism, fear or uncertainty, and insufficient stakeholder engagement prior to the roll-out of closure plans;
* Misuse of rehabilitated land by the new owner or lessee.  

Mine closure in South Africa is particularly complicated given the unique socio-economic context and the role that mining has traditionally played within the South African economy. Apartheid era settlement patterns, legislation that is inconsistent and lacking in clarity and detail, and a lack of capacity by various stakeholders to effectively engage around mind closure issues all complicate the issue (Stacey et al., 2010).

In order to address the issue of insufficient effort and focus on mine closure, the coal mining industry has funded the development of detailed guidelines for the socio-economic aspects of closure (see Stacey et al., 2010). The guidelines are built around the following four components (Stacey et al., 2010):

- Guidance on the Socio-Economic Aspects of Closure Policy
- Socio-Economic Closure Activities Mapped Against the Mining Project Life Cycle (a “check status” tool)
- A Process Guide for Mine Closure Planning and Implementation
- Tools in Support of Mine Closure Planning and Implementation

Although the guidelines are relatively new (having only been completed in 2010), and it thus remains to be seen how widely they will be adopted and what impact they will have in practice, early indications are that the coal mining industry believes that the guidelines will lead to more coherent mine closure planning and implementation in future.  

### 16.7.3 Impacts of coal transport on road network and public safety

The transport of coal via road is having a negative impact on the secondary road network in South Africa. Heavy transport on these roads (including the transport of coal) has led to a situation where most of the secondary road system in South Africa has deteriorated to a point where it needs to be reconstructed (Chamber of Mines, 2009a). This has become a particularly serious concern in Mpumalanga as a result of road coal transport (Mpumalanga Provincial Government, undated). This situation is exacerbated under investment in road maintenance by the relevant bodies. Poor road conditions lead to increased vehicle maintenance costs and hence higher logistical costs for the economy as a whole, which could significantly impair economic competitiveness and growth (CSIR, 2009). As a result, the Department of Transport is currently considering legislation to ban trucks with an axle load above a certain limit (8000 kg) from using the secondary road network. In addition, it is considering banning the transport of certain commodities on the primary road network. The intention of this legislation would be to force more heavy freight on to the rail network, which is being upgraded for this purpose.

The current situation, however, is largely a function of inadequate rail freight capacity and an increased demand for coal that cannot be supplied from the mines located adjacent to the power stations (particularly by Eskom). Many coal mines are served by secondary roads and do not have rail links as an alternative source of transport and in some cases the expected remaining life of mine is not sufficient to justify the construction of rail links. The poor quality of service provided by Transnet Freight Rail is an additional factor that leads coal producers to prefer road transport over rail transport.

The security of supply of coal to power stations may thus be jeopardised if the restrictions on road transport are enforced without a concurrent increase in rail freight capacity and quality of service (Chamber of Mines, 2009a).

A related issue is that the large-scale transport of coal by road in South Africa has contributed to heavy vehicle-related accident rates far above international norms. Numerous factors contribute to this situation, including truck overloading, driver fatigue and truck condition (Ryan, 2009). These accidents have also led to a number of public fatalities. In this regard, rail transport is significantly safer than road transport (Crickmay, 2009).
by society as a whole rather than the consumers or sellers of coal. In terms of the cost to society of the pollutants emitted by coal-fired power stations, studies consistently find that the climate change impact is the most significant, followed by the health impacts of outdoor air pollution (Edkins et al., 2010). By some estimates, the cost of the climate externality in coal combustion during electricity generation may be larger than the actual private cost (the cost paid) for the coal input (Blignaut and King, 2002).

As with other large industries, including those along the coal value chain, Sasol’s operations give rise to various pollutants, including SO\textsubscript{2}, NO\textsubscript{x}, particulates, VOC and hydrogen sulphides, all of which potentially have impacts on human health and the environment. As Sasol’s operations are located in heavily industrialised areas, many of which also have high levels of domestic coal use, it is difficult to quantify directly the impacts of their operations on local human health and/or the environment. Furthermore, the Sasol Secunda plant has a buffer zone surrounding the primary production area, which contributes to reducing the impacts of certain pollutants from the CTL operations.

### 16.7.5 Externality costs of pollution associated with coal utilisation

Coal-fired electricity generation is accompanied by the emission of potentially harmful pollutants (such as SO\textsubscript{2}, NO\textsubscript{x}, and particulates) and greenhouse gases like CO\textsubscript{2} which contributes to man-made climate change. These emissions cause damage to human health (in the form of respiratory disease, for example) as well as material (structural degradation as a result of acid rain in areas with high rainfall and dry deposition in areas with lower rainfall) and natural assets (atmospheric deposition of SO\textsubscript{2} and NO\textsubscript{x} have a long-term effects on soil properties in the vicinity of a coal fired power station) (Reid, 2007; Thopil and Pouris, 2010). The potential health effects are difficult to quantify, given the lack of baseline information and confounding factors of poor nutrition, sanitation and hygiene, understanding and levels of health care and domestic coal and wood burning. The health benefits of electrification (associated with replacing sources of indoor air pollution – residential fuel burning) are generally considered to outweigh the health impacts of outdoor air pollution (Scorgie et al., 2005). Under the new emissions standards, new coal fuelled power stations will have to include abatement technologies which drastically reduces the emissions of SO\textsubscript{2}, NO\textsubscript{x}, and particulates.

Given that the cost of these negative impacts are not included in the price of coal, it leads to externality costs that are borne

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44 Energy services denote the “services that energy and energy appliances provide. Such services include lighting, heating for cooking and space heating, power for transport, water pumping, grinding, and numerous other services that fuels, electricity, and mechanical power make possible (World Bank and UNDP, 2005).
access to electricity, a large emphasis is placed on access to grid electricity (and the provision of a free basic allowance) as a means of providing energy services to low income South Africans. Expenditure on extending access to electricity, as one of a number of pro-poor expenditures in South Africa, was one of the factors that led to a significant reduction in poverty in South Africa since the transition to democracy (RSA, 2010). The importance that is placed on access to electricity in improving the lives of low income households in South Africa is evident in the fact that both the “proportion of households with access to free basic electricity” and the “percentage of indigent households receiving free basic services” are included as progress indicators under MDG 1: Eradication of Extreme Poverty in South Africa (RSA, 2010). The South African government has included the target that all South African households should be connected to the national grid by 2014 (RSA, 2010).

<table>
<thead>
<tr>
<th>Box 9: The importance of planning in the creation of sustainable settlements</th>
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| In order to leverage the twin investments in coal mining expansion and power station investment in the Waterberg area, the coal mining industry commissioned the Centre for Sustainability in Mining and Industry (CSMI) to develop a set of settlement scenarios for the Waterberg area (Hermanus et al., 2010). The combined impact of investments in both coal mining (or coal mining expansion) and investment in power stations can provide an important economic stimulus to an area with significant development challenges and backlogs (Bohlwewi, 2006). The likely expansion of the Grootgeluk mine to also supply coal to the new Medupi power station, for instance, is expected to create permanent employment opportunities of a similar magnitude to the 500 permanent jobs that the power station is expected to generate (Bohlwewi, 2006).

The Settlement Scenarios, however, shows that sustainable settlements are unlikely unless there is a structured consultation process, coordinated planning and a high degree of cooperation between all the relevant stakeholders (Hermanus et al., 2010). The Scenarios document provides a number of suggestions on how this outcome can be achieved, which if widely adopted and implemented properly, should assist with the development of sustainable settlements relating to large mining and energy projects in other areas as well (Hermanus et al., 2010).

<table>
<thead>
<tr>
<th>16.7.7 Corporate social responsibility</th>
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<tr>
<td>16.7.7.1 CSR: Eskom</td>
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A subsidiary of Eskom Holdings is the Eskom Development Foundation whose mandate includes responsibility for the coordination and execution of Eskom’s corporate social investments (CSI). Eskom’s CSI are primarily targeted at the communities within which the utility operates, and especially where it is conducting its capital expansion and “new build” programmes. For example, grants were given for the construction of mobile classrooms and science equipment at various schools (Eskom, 2010a).

In 2009/10, the Foundation approved a total of 43 grants worth R 43.4 million. These grants were targeted towards economic and social development projects. Donations to philanthropic and welfare organisations worth R 8.4 million were also approved during the same period. In total 196 organisations and 590,440 individuals benefited (Eskom, 2010a).

In 2010, Eskom committed R 21 million on low cost housing assistance and R 11 million on development projects in Mozambique (Sasol, 2010c).

16.7.7.3 CSR: Metallurgical industry

Since 2000, ArcelorMittal South Africa has invested some R 220 million in social development initiatives. The company’s corporate social investment programme focuses mainly on education and in 2009; ArcelorMittal began a R 250 million project with the state Department of Education to construct 10 schools. The schools would be constructed using new steel technology in all of the country’s 10 provinces over the next few years. The first school – the Meetse-a-Bophelo primary school for 1,200 pupils in Mamelodi Pretoria was completed in 2010 (ArcelorMittal, 2010a).

ArcelorMittal has further committed R 28 million to operate two sciences centres adjacent to its Vanderbijlpark and Saldanha operations. The Sebokeng centre near Vanderbijlpark was launched in 2006 and offers science, mathematics and IT education to over 2,000 pupils at 43 schools in the Vaal Triangle area (ArcelorMittal, 2010a).

The second largest steel producer in South Africa, Evraz Highveld Steel and Vanadium invested R 3.4 million into the community in 2008. As a result of financial constraints this was reduced to R 1.3 million in 2009. From 2010, Highveld made a commitment that its future financial support would be targeted at primary school education. The firm has also set aside a provision for discretionary donations to local communities (Evraz, 2010).
ENVIRONMENTAL IMPACTS ACROSS THE VALUE CHAIN

Historically, coal has not had a good reputation when it comes to environmental performance across the value chain from mining, beneficiation, transportation and utilisation. Environmental impacts from coal extend from land use and transformation, air and water quality to impacts on biodiversity and soils.

However, increasingly the industry is responding to these issues and challenges through careful planning, implementation of effective pollution control strategies, and increased monitoring and management of affected areas. This is in response to increasingly stringent environmental requirements as well as recognition that the industry must improve its environmental performance if it wishes to continue to contribute significantly to economic and social development in South Africa.

This section begins by considering the environmental policy, legislation and institutional context, before describing the environmental impacts of coal across the value chain and the environmental management strategies in place to mitigate these.

17.1 The environmental policy, legislation and institutional context

17.1.1 General

In 1997 the White Paper on Environmental Management Policy was gazetted, representing a paradigm shift in the approach to environmental management in South Africa, away from one of conservation towards one grounded in the concept of sustainable development. The White Paper provides an overarching framework policy, with specific sectoral policies underneath this.

The White Paper policy was translated into legislation in the form of the National Environmental Management Act (NEMA) of 1998, which provides the legislative framework for environmental management in South Africa (DEAT, 2007). There have been three subsequent amendments of NEMA in 2002,4 and 8.

NEMA governs the need for Integrated Environmental Management (IEM) tools, including Environmental Impact Assessments (EIA), Strategic Environmental Assessment (SEA) and Environmental Management Systems (EMS) at specific facilities. All developments that could result in significant pollution or degradation must undertake an EIA, with the other tool being used where appropriate. Under the Act, national departments and other organs of state are given responsibility for preparing an Environmental Implementation Plan and/or an Environmental Management Plan every four years, in order to facilitate the co-ordination and alignment of national environmental policy (NEMA Chapter 3). Compliance with these plans is facilitated through the Committee for Environmental Co-ordination and environmental management frameworks can be formulated for designated geographic areas (Fakir et al., 2005).

The Act enforces sustainability and environmental care. Section 28 of the Act imposes a duty of care and remediation of environmental damage on any person who causes, has caused or may cause significant pollution or degradation of the environment (DEAT, 1998). Workers have the right under the Act to refuse to do environmentally hazardous work, and the Act makes provision for control of emergency incidents. Furthermore, sections 32 and 33 of the Act provide for legal standing to enforce environmental laws, including costs of remediation, and private prosecution respectively.

The suite of legislation under NEMA is specialised to focus on individual issues including air quality, waste management, water and climate change (Fakir et al., 2005). South Africa has a progressive framework for environmental management at a national level, but enforcement and implementation of this presents some challenges (Fakir et al., 2005).

Environmental regulation of the mining sector has traditionally been undertaken by the DMR, however, there is a shift of this environmental function to the DEA, which has provided some uncertainty, particularly in the area of waste (DEA, 2010a).

The MPRDA assumes a cradle to grave approach to mining, including social, environmental and economic costs. Under the Act, a mining applicant is required to make financial provision for the rehabilitation of the mining area, and must manage residue stockpiles and residue deposits according to their environmental management plan or programme. The holder of an authorisation or right remains responsible for the mining site until a closure certificate is issued by the Minister, and can be called upon to implement or finance urgent remedial measures if required.

17.1.2 Air quality

The mining, beneficiation and use of coal have significant air quality implications, and are regulated under the National Environment Management: Air Quality Act (39 of 2004). This Act falls under the ambit of the NEMA, and applies throughout the coal value chain. It replaces the Atmospheric Pollution Prevention Act of 1985, and represents a shift from exclusively source-based air pollution control to “an integrated effects based air quality management” (DEAT, 2007).

Amongst others, the Act provides for:

- The establishment of national, provincial and local ambient air quality and emission standards,
- Air quality plans as components of environmental management plans at provincial and municipal level which will address the effects of emissions from the use of fossil fuels in residential applications; industrial and other sources,
- The identification of emissions sources, controlled emitters, priority air pollutants, classified fuels and priority areas for air quality management,
- Atmospheric emissions licences being required by the identified sources, controlled emitters being subject to
additional standards, priority air pollutants requiring pollution prevention plans and classified fuels being subject to standards and restrictions,

- The appointment of an Emission Control Officer in any company where it is deemed necessary,
- Provision for measures to control dust, noise and offensive odours,
- Ambient air quality standards for ozone, nitrous oxide, nitrogen dioxide, sulphur dioxide, lead, total suspended solids.
- The declaration of priority areas, of which two have been declared, being the Vaal Triangle and Highveld, the latter priority area’s issues being directly related to high levels of coal use.

The 2007 National Framework for Air Quality Management in the Republic of South Africa provides the medium to long term plan for the practical implementation of the Air Quality Act, and was presented as a “work in progress”, establishing numerous projects and programmes within its ambit to advance understanding, measurement and management of atmospheric emissions in the country. Emissions associated with the coal sector are likely to be increasingly affected by the advance of this Framework. In the 2007 Framework, pollutants associated with coal sulphur dioxide (SO₂), Nitrogen dioxide (NO₂) and particulate matter (PM10) are identified as current criteria pollutants. Possible future pollutants include other Volatile Organic Compounds (VOCs) and pollutants controlled by international conventions ratified by SA (including greenhouse gas emissions).

Since the publication of the Framework, National Ambient Air Quality Standards have been published (2009) as has the Listed Activities and Associated Minimum Emission Standards (2010). The Ambient Air Quality Standards identify maximum concentrations of pollutants determined over an averaging period, including sulphur dioxide, nitrogen dioxide and particulate matter. The Listed Activities identify those that are high emitters, and minimum emissions standards, monitoring and reporting requirements against which these activities must comply. Those of relevance to the coal value chain include: combustion installations (electricity, liquid fuel, carbonisation and coal gasification, char, charcoal and carbon black production) for particulate matter, sulphur dioxide, oxides of nitrogen and total volatile organic compounds, hydrogen sulphide, poly aromatic hydrocarbons. Drying and combustion in the metallurgical industry are identified for particulates, sulphur dioxide and oxides of nitrogen. The storage and handling of coal is identified for dustfall. ISO standards, EPA methods and British standards are cited for application. SANS standards 1929 and 69 were both linked to the Act, and define principles of air quality management for South Africa, together with limit values for pollutants. The South African Air Quality Information System enhances the collection of, and access to information on air quality.

The coal sector has a number of responsibilities under the Air Quality Management Act including: compliance with relevant standards for emissions from point sources; compliance with measurement requirements, compliance with standards for controlled emitters; compliance with the requirement for a pollution prevention plan in respect of a substance declared as a priority air pollutant; compliance with a request to submit an atmospheric impact report, to apply for and comply with an atmospheric emissions licence, and to designate and emission control officer if required to.

The Air Quality Act confers decision making power in matters potentially affecting air environment in the case of mining activities to the Minister of Minerals and Energy (now Mineral Resource), but this includes a need to comply with the Act. The 2008 amendment to the MPRDA strengthens emissions controls in the mining sector and includes an obligation to consider the Air Quality Act in environmental management plans.

In addition, the National Framework for Air Quality Management identifies the DMR has having “interest or responsibility” in the following example areas of atmospheric emissions: dust from mine spoil tailings dumps and other mining operations; emissions from the use of fossil fuels; emissions from mining haul roads; dust from open-case mining operations; emissions from fires in coal mines, including abandoned mines. It identifies the Department of Housing as having an interest or responsibility in emissions from coal and wood burning, especially in dense, low-income communities.

Also likely to pertain to the coal industry is that many significant emitters are classified as National Key Points under the National Key Points Act (102 of 1980), which is used to regulate access to information (DEAT, 2007).

17.1.3 Waste

In addition to the White Paper on National Environmental Management (1997), a White Paper on integrated pollution and waste management for South Africa was gazetted in 2000. This White Paper envisions an integrated pollution and waste management system for the effective prevention, minimisation and control of pollution and waste, and as such, marks a turning point for pollution and waste governance in South Africa (DEAT, 2007). It builds on the principles of the National Environmental Management White Paper in its duty-of-care principle: “any institution which generates waste is always accountable for the management and disposal of this waste and will be penalised appropriately for any and every transgression committed” (DWA, 2011), and also in its universal applicability of regulatory instruments within the integrated pollution and waste management system to all sectors and operations in the country.

The National Environmental Management: Waste Act, 2008 provides the legislative framework for waste management in the country, but does not apply to residue deposits and residue stockpiles that are regulated under the MPRDA. Whilst it therefore has limitations in its applicability to the mining of
coal, ash produced in the combustion of coal is identified as a hazardous waste under the Act. The Act also makes provisions for contaminated land which may apply, including provision for remediation and restriction of use types on contaminated land. Under the Act, priority wastes may be declared if there is “persistent non-compliance or failure or inability by a sector or industry to address waste management issues” (DEA, 2010a). Current priority wastes do not implicate the coal sector. Certain waste management activities may require licensing under the Act.

The Act requires the development of a National Waste Management Strategy, which supersedes the 1999 National Waste Management Strategy, developed by the Department of Environmental Affairs and Tourism, and the Department of Water Affairs and Forestry. The new Strategy is to be reviewed every five years, and exists in draft form at the time of writing (DEA, 2010a). Individual Industry Waste Management Plans are also key elements of the Act.

The draft National Waste Management Strategy deals with industrial, power generation and mining waste streams (apart from residue deposits and stockpiles), amongst others. It does not deal with pollution from waste streams, only environmental impact management related to waste, and contaminated land. The draft Strategy follows NEMA in taking a hierarchical approach to waste management, addressing waste avoidance, reduction, re-use, recycling, recovery, treatment, and safe disposal of waste. It elaborates on Industry Waste Management Plans as plans which “describe the waste related issues within an industry, and specify how the industry will address these issues, giving specific actions, targets and timeframes” (DEA, 2010a). The plans could be voluntary, or mandated by the Minister. The draft Strategy identifies four types of plans: sector, company, site and waste stream plans. Included in the plans will be targets and measures for waste minimisation and recycling, monitoring and performance systems. It anticipates that an Industry Waste Management Plan will be required for mining waste within three years. The central purpose of this plan will be to establish waste management guidelines and targets (DEA, 2010a). The draft Strategy identifies that the institutional responsibility for drafting the mining sector plan will lie with the Chamber of Mines, and that the Minister for Environmental Affairs will consult with the Minister of Mineral Resources in approving the plan.

Mining waste is dealt with under the waste requirements of the environmental management plans developed by the DME, which are aligned with the NEMA: Waste Act (DEA, 2010a). The shift in environmental management of mining from DMR to the DEA in accordance with the amendment of the MPRDA (2008) is currently causing some confusion regarding the exact scope and application of the Waste Act (DEA, 2010a). After this shift, residues and stockpiles will fall under DEA. The strategic focus for mining waste is on the safe treatment and disposal of mining waste, although it is acknowledged that opportunities for reuse need to be fully exploited. It is necessary for standards of toxicity for ash to be developed to ensure that any reuse (for example in brick-making) does not pose a risk to health.

The draft Waste Management Strategy purports that fly ash from power stations needs to be better regulated, and in time phased out. In addition, the draft Strategy aims to reduce this waste through treatment, reuse and beneficiation of both fly ash and coarse ash (a waste from the coal to liquids process), with many significant economic uses available. Acceptable uses of ash will be identified as activities not requiring licensing under the Waste Act.

The transportation of hazardous waste is covered by a number of Acts, most important being the National Road Traffic Act (1996) which incorporates SANS Codes pertaining to the transport of hazardous waste, and requires the waste generator to ensure compliance with requirements.

The draft National Waste Management Strategy identifies a number of regulatory mechanisms, including norms and standards (a Waste Classification and Management System is under development), Industry Waste Management Plans. It also makes provision for economic instruments, with the Treasury and DEA to undertake a research programme to develop and refine an appropriate set of instruments for waste management.

### 17.2 Environmental impacts of mining

As noted in the introduction to this section, coal mining can lead to significant environmental impacts, if not properly managed or planned for.

In opencast mining, disruption of the surface is unavoidable and can adversely affect the soil, surface and groundwater and impact on the life-support function, biodiversity and subsequent land use of the local environment. Water coming into contact with overburden, open pits or exposed coal seams, may lead to the formation of acid mine drainage and surface and groundwater contamination. In addition, surface mining is associated with noise, visual intrusion and dust and gas emissions.

Underground mining typically involves less surface disruption, although subsidence may cause considerable land use impacts. The potential for water contamination also exists, with large volumes of groundwater pumped to the surface for the safe continuation of mining. Although appreciable volumes of pumped water may be used, the amount of water that needs to be managed and possibly treated is increased. Groundwater contamination may occur when pumping stops and the aquifer is allowed to return to its normal level. Alternatively, water may be stored in underground, previously mined, compartments, which minimises the risk of contamination. Subsidence may also allow air and water to enter mine workings elevating the potential for acid mine drainage formation and underground fires.

The environmental impacts associated with the particular phases in the mining life cycle are described in Table 45, with the particular environmental impacts and their implications explored more fully in the sections that follow. The environmental impacts associated with underground coal gasification are described in Box 10.
Table 45: Summary of the environmental impacts associated with mining according to phases in the mine life cycle

<table>
<thead>
<tr>
<th>Mining phase</th>
<th>Activities</th>
<th>Potential environmental impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exploration and surveying</strong></td>
<td>• Geochemical, geophysical and aerial surveys</td>
<td>• Vegetation removal, damage and destruction</td>
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<tr>
<td></td>
<td>• Drilling and trenching</td>
<td>• Habitat disturbance due to noise/vibration</td>
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<tr>
<td></td>
<td>• Sinking of exploration shafts</td>
<td>• Disturbance to wildlife and local residents</td>
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<tr>
<td></td>
<td>• Exploration camp housing</td>
<td>• Soil erosion along trenches and transects</td>
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<tr>
<td></td>
<td>• Vehicle and machinery parks, fuel points and service bays</td>
<td>• Disposal of drill cores and waste</td>
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<tr>
<td></td>
<td>• Access road construction</td>
<td>• Demand on local water resources</td>
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<tr>
<td></td>
<td>• Waste disposal (garbage)</td>
<td>• Discharge or spillage of contaminants</td>
</tr>
<tr>
<td></td>
<td>• Camp sanitation systems</td>
<td>• Contamination of local groundwaters by drilling muds and exposed ores</td>
</tr>
<tr>
<td></td>
<td>• Water abstraction and storage</td>
<td>• Restricted public access</td>
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<tr>
<td></td>
<td></td>
<td>• Surface water and soil pollution</td>
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<tr>
<td><strong>Mine development</strong></td>
<td>• Mine construction</td>
<td>• Fauna and flora habitat loss and disturbance</td>
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<tr>
<td><strong>start-up; sourcing</strong></td>
<td>• Mine dewatering</td>
<td>• Reduction in biodiversity on site</td>
</tr>
<tr>
<td>and stockpiling of**</td>
<td>• Blasting at surface mining</td>
<td>• Potential loss of heritage sites</td>
</tr>
<tr>
<td><strong>materials</strong></td>
<td>• Stripping and storing of topsoil</td>
<td>• Decreased aesthetic appeal of site</td>
</tr>
<tr>
<td></td>
<td>• Installation of power lines</td>
<td>• Altered land forms due to construction</td>
</tr>
<tr>
<td></td>
<td>• Surveying and levelling of sites for buildings and plant</td>
<td>• Altered drainage patterns and run-off flows</td>
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<tr>
<td></td>
<td>• Installation of mine and surface water treatment plants</td>
<td>• Altered in-stream flows and dynamics</td>
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<tr>
<td></td>
<td>• Construction of mine facilities, offices and roads</td>
<td>• Increased erosion</td>
</tr>
<tr>
<td></td>
<td>• Construction of beneficiation plant</td>
<td>• Increased siltation of surface waters</td>
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<tr>
<td></td>
<td>• Construction of storage facilities</td>
<td>• Contamination of ground and surface waters by seepage and effluent discharges</td>
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<tr>
<td></td>
<td>• Construction of fine coal and discard facilities</td>
<td>• Acid mine drainage</td>
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<tr>
<td></td>
<td>• Landscaping of site</td>
<td>• Discharge of contaminants via mine dewatering activities</td>
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<tr>
<td></td>
<td>• Construction of staff housing, infrastructure and recreational facilities</td>
<td>• Methane emissions</td>
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<tr>
<td></td>
<td>• Construction of railway lines and sidings</td>
<td>• Contamination from fuel spills and leakages</td>
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<tr>
<td></td>
<td>• Conveyor belts</td>
<td>• Increased demand on local water resources</td>
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<td></td>
<td>• Dam construction</td>
<td>• Increased demand for electrical power</td>
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<tr>
<td></td>
<td>• Stockpiles</td>
<td>• Noise</td>
</tr>
<tr>
<td></td>
<td>• Construction of overland conveyer systems</td>
<td>• Dust</td>
</tr>
<tr>
<td><strong>Open cast mining</strong></td>
<td>• Stripping and storage of overburden</td>
<td>• Land alienation from overburden stockpiles and disposal areas</td>
</tr>
<tr>
<td></td>
<td>• Separate storage of topsoil</td>
<td>• Disturbance from vehicle and machinery noise and site illumination</td>
</tr>
<tr>
<td></td>
<td>• Blasting and drilling</td>
<td>• Formation of acid mine drainage</td>
</tr>
<tr>
<td></td>
<td>• Construction of overburden and waste rock stockpiles</td>
<td>• Spontaneous combustion</td>
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<tr>
<td></td>
<td>• Concurrent rehabilitation</td>
<td>• Increased erosion</td>
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<tr>
<td></td>
<td></td>
<td>• Contamination of surface waters</td>
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<tr>
<td></td>
<td></td>
<td>• Contamination of local groundwaters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Affecting borehole yields</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fauna and flora habitat loss and disturbance</td>
</tr>
<tr>
<td><strong>Underground mining</strong></td>
<td>• Subsidence</td>
<td>• Ground surface disturbance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Dust and fumes from mine vehicles and transportation systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Discharge of contaminated waters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Affecting borehole yields</td>
</tr>
<tr>
<td><strong>Mine closure</strong></td>
<td>• Decommissioning of roads</td>
<td>• Subsidence, slumping and flooding of previously mined areas</td>
</tr>
<tr>
<td></td>
<td>• Dismantling and demolishing of buildings and other infrastructure</td>
<td>• Underground fires in abandoned coal mines</td>
</tr>
<tr>
<td></td>
<td>• Reseeding and planting of disturbed areas</td>
<td>• Acid mine drainage</td>
</tr>
<tr>
<td></td>
<td>• Recontouring pit walls and waste deposits</td>
<td>• Continuing discharge of contaminants to ground and surface waters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Land use change</td>
</tr>
</tbody>
</table>

(Source: Ashton et al., 2001)
Dust or particulate matter is an inevitable consequence of any form of mining and represents one of the most visible, spontaneous combustion of coal and coal wastes exposed to air is one of the most widespread and uncontrolled.

The self-heating tendency of coal depends on its properties, particularly its volatile content, largely unquantifiable, source of greenhouse gas emissions for the industry (GDACE, 2008).

Mitigation strategies for dust include: dust suppression through spraying on roads, stockpiles and conveyors; fitting drills with dust collection systems; and establishment of buffer zones around the mine site (World Coal Institute, 2005). Monitoring of dust levels is an integral part of any mitigation strategy.

17.2.2 Spontaneous combustion

In certain parts of the value chain (either at the coalface, in stock piles, in waste piles or while being transported), coal may be exposed to atmospheric oxygen. The carbon present in coal reacts exothermically, releasing heat. When the temperature of coal particles exceeds approximately 80°C, volatile molecules escape, reacting with oxygen in the atmosphere, and the coal ignites. This is termed spontaneous combustion, and is a significant risk to the safe and environmentally sound operation of a mine or beneficiation plant. Furthermore, once established, these fires are difficult to control and can be extremely costly in economic, environmental and safety terms.

The self-heating tendency of coal depends on its properties, particularly (Carpenter et al., 2003):

- Coal rank: lower-rank coals are more susceptible to spontaneous heating.
• Moisture content: coal with higher moisture content is less prone to spontaneous combustion. However, wetting of dry coal causes heating, so use of water to extinguish coal-pile fires is risky and dust suppression for coals that are prone to self-heating can require the use of chemical suppressants instead.
• Particle size distribution: segregation of particle sizes in a coal heap can enhance air flow into the core of the heap whilst inhibiting heat transfer out, thereby increasing the risk of combustion.
• Mineral content and composition: other coal components can have an influence. For instance, pyrite oxidation can contribute to heat generation.

In South Africa, spontaneous combustion is a specific problem where opencast mining meets old underground bord and pillar mine workings, particularly in the Witbank and Sasolburg coalfields (Coaltech, 2011). Under these circumstances underground pillars from previous mining operations become exposed to air and may start to burn within days. Exposure of old workings to air may also occur through cracks in the overburden and open blast holes.

In accordance with an inventory compiled by the Department of Minerals and Energy (DME, 2001), there has been a marked reduction in fires on coal waste piles over the past decade (6% of dumps burning and 17% partially burned in 2001). Discards from current and future surface mining operations are, however, believed to pose a serious spontaneous combustion problem (Coaltech, 2011). Reports of spontaneous combustion in underground coal mines in South Africa are now rare (Coaltech, 2011). There have also been numerous incidents of damaging fires when coal has been stored in large quantities at shipping ports and on marine vessels (Falcon, 2011). These are mostly due to a combination of coal properties and poor management.

17.2.2.2 Management and control

In many cases, the risks of spontaneous combustion in coal stockpiles, waste piles, mine workings and in transit, can be minimised or avoided through the application of sound management practices and strategies. A number of methods exist to prevent, monitor, control and manage spontaneous combustion in coal stockpiles, waste piles and mine workings, as detailed in a recent Coaltech publication (Coaltech, 2011).

To a large extent, spontaneous combustion can be prevented by limiting contact with oxygen (preventing airflow). In the case of stockpiles and waste dumps this typically involves application of techniques such as cladding with inert material (soil and sand), reducing the effective surface area of the pile exposed to prevailing winds, avoiding high stockpile peaks and the application of stockpile geometry management. Other management strategies found to be effective in preventing spontaneous combustion in stockpiles and dumps include regular monitoring of pile temperature, and reclaiming from stockpiles in a First-In-First-Out schedule.

In the case of surface mining operations, airflow can be prevented or limited by cladding the highwall with sealant, sealing the open bords with soft material, or by collapsing the overburden into the bords by means of buffer blasting. The latter technique is generally considered to be the most effective in the control of spontaneous combustion in old mine workings, and is widely practiced in South Africa. Reducing blast inventory and the amount of coal exposed to the atmosphere prior to processing are also important in controlling spontaneous combustion in “problematic” mines.

As spontaneous combustion is a time-dependent phenomenon, early detection and/or prediction play an important role in its effective prevention and management. Although thermal imaging using infra-red instruments or photography is very effective in the early detection of hot spots, it requires extensive and on-going surveying at the mine to be workable, and is not routinely practiced on South African coal mines. There is also currently no universally accepted method for predicting the likelihood of spontaneous combustion, with predictions relying mainly on intrinsic properties of coal (chemical properties, thermal characteristics and oxygen avidity). These methods are not yet
capable of predicting emission values (i.e. they can warn that a problem may occur but they cannot provide actual emission numbers). Furthermore, emissions from spontaneous combustion are difficult to measure and the mining industry has not reported on incidents in great detail. Spontaneous combustion is sometimes thought to be associated primarily with open cast mining operations and there has thus not been standardisation across the whole sector. In some cases, fires are associated with abandoned mines and waste piles and mitigation might fall to local or national public bodies rather than private mining companies.

17.2.3 Visual impacts and noise

As noted in Table 45, many mining activities can increase noise above ambient environmental levels (GDACE, 2008), which can cause a disturbance to local communities and fauna. Mitigation measures to reduce noise pollution can include equipment selection, insulation, sound enclosures around machinery, as well as the installation of noise and vibration monitoring equipment (World Coal Institute, 2005). Visual impacts associated with coal mining are site specific and depend on the local topography and the proximity to local communities and other developments. Visual impacts may be unavoidable but can be minimised by careful planning and management of the site.

17.2.4 Water consumption and impacts to ground and surface waters in coal mining

Coal mining can have a significant impact on both surface and ground waters if not properly managed as a result of the following (Oelofse, 2008):

- Water consumption during mining,
- Disruption of hydrological pathways,
- Dewatering of active underground and opencast mining operations which result in groundwater drawdown in surrounding areas,
- Seepage of contaminated water from overburden deposits and coal processing wastes into groundwater aquifers,
- Flooding of closed mine voids,
- Possible discharge of untreated mine water into rivers, although this is regulated and strictly controlled.

Water consumption and water quality aspects (including acid mine drainage formation) are explored further below.

17.2.4.1 Water quality impacts

The impact of coal mining on water quality is considered to be the coal mining industry’s most significant environmental impact (McCarthy and Pretorius, 2009; Reddick, 2006). The location of South African coalfields in the sensitive upper reaches of major river systems such as the Vaal, Olifants, Usutu, Komati, Pongola, and Tugela rivers is linked directly to pollution and environmental impacts related to water. It should be noted that mining is only partially responsible for acidification and increased salinisation in these river systems (Oelofse, 2008).

It is the resulting large volumes of low concentration wastewater that are unfit for industrial uses and require treatment, which causes concern. In the Olifants River Catchment, it is estimated that 50 Ml of wastewater from coal mining is discharged into the catchment daily (Maree et al., 2004) and the post-closure decant from defunct mines has been estimated at around 62 Ml for the catchment daily (DWAF, 2004a). Figure 50 shows the deterioration of the quality of water in the Witbank Dam in terms of TDS and sulphate as a result of collective mining operations.

Figure 50: The concentrations of total dissolved solids (TDS) and sulphate (SO₄) have increased steadily in the Witbank Dam over the last four decades as a result of mining operations; similar trend is observed for the Middelburg Dam

(Source: McCarthy and Pretorius, 2009)
The likely sources of surface and groundwater contamination from coal mining are identified in the table below and categorised according to their risk and ease of control.

Table 46: Pollution sources related to coal mining which may affect groundwater

<table>
<thead>
<tr>
<th>Activity</th>
<th>Source type</th>
<th>Risk</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discard dumps</td>
<td>Point</td>
<td>High</td>
<td>Difficult</td>
</tr>
<tr>
<td>Return water dams</td>
<td>Point</td>
<td>Moderate</td>
<td>Easy</td>
</tr>
<tr>
<td>Slimes disposals</td>
<td>Point</td>
<td>High</td>
<td>Easy</td>
</tr>
<tr>
<td>Stockpiling</td>
<td>Point</td>
<td>Moderate</td>
<td>Easy</td>
</tr>
<tr>
<td>Dewatering</td>
<td>Diffuse</td>
<td>Moderate</td>
<td>Easy</td>
</tr>
<tr>
<td>Underground or opencast area</td>
<td>Diffuse</td>
<td>High</td>
<td>Difficult</td>
</tr>
</tbody>
</table>

(Source: Bosman and Kidd, 2009)

17.2.4.2 Acid mine drainage

The most significant problem facing the coal mining and coal processing sector is the formation and control of acid mine drainage (AMD). AMD is the acidic leachate (often as low as pH 2) displaying elevated iron, manganese, aluminium, sulphate and trace metal concentrations that occurs as a result of pyrite oxidation (Evangelou and Zhang, 1995). The environmental impacts of AMD are related to acidity, mobilisation of dissolved metals, mineral precipitation and the accelerated breakdown of gangue minerals. Even neutral drainage can be harmful. Depending on the permeability of rock, mining operations open flow paths for water and AMD and results in the consequent contamination of surface waters and groundwater reserves. Movement of AMD by capillary action through soil layers effects of AMD include extensive land sterilisation and the harming of fauna (Hobbs et al., 2008; McCarthy and Pretorius, 2009).

AMD is one of the most common environmental issues facing the mining industry due to its significant potential for long-term environmental degradation. Once it begins in mining wastes or stockpiles it may persist for tens to hundreds of years and can be difficult and costly to remediate. As such, AMD potentially represents the most serious environmental impact caused by mining, and also the industry’s greatest environmentally related technical challenge (Mitchell, 1999). Apart from potentially being the most significant immediate threat to South Africa’s environment, AMD has the potential to impact significantly on a number of economic sectors like agriculture (grain farming, stock farming, mushroom farming, food processing, etc.) and tourism (Chamber of Mines, 2009a; Naidoo, 2009; Wait, 2010). AMD also carries significant health risk to communities that come into contact with contaminated water, soil or crops. AMD is likely to have an impact on the coal mining industry in the form of higher costs to prevent or address the problem, or potentially as an additional externality cost (Naidoo, 2009).

The generation of AMD from South African opencast and underground mines is described extensively in Vermeulen and Bester (2009).

Box 11: Acid mine drainage mechanisms

Acid mine drainage is caused by exposure of pyrite-containing mined materials to oxygen and water which results in oxidation of the pyrite to ferric sulphate. The aqueous oxidation of pyrite is a heterogeneous surface-controlled process that occurs through a complex series of reactions that includes chemical, biological and electrochemical mechanisms. The rate of reaction is also a function of environmental conditions and waste characteristics. Factors influencing the rate of oxidation include pH, oxygen partial pressure, type of sulphide mineral and crystal morphology, specific surface area of sulphide mineral, temperature, the presence and activity of bacteria (which can increase the rate of reaction by a factor of 1 x106) and presence of clay minerals. Although complex, the overall stoichiometry of pyrite oxidation is often described by the following four reactions:

\[
\begin{align*}
\text{FeS}_2 + \frac{1}{2} \text{O}_2 + \text{H}_2\text{O} & \rightarrow \text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{H}^+ \\
\text{Fe}^{2+} + \frac{1}{2} \text{O}_2 + \text{H}^+ & \rightarrow \text{Fe}^{3+} + \frac{1}{2} \text{H}_2\text{O} \\
\text{Fe}^{3+} + 3\text{H}_2\text{O} & \leftrightarrow \text{Fe(OH)}_3(s) + 3\text{H}^+ \\
\text{FeS}_2 + 14\text{Fe}^{3+} + 8\text{H}_2\text{O} & \rightarrow 15\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 16\text{H}^+
\end{align*}
\]

(Source: Hansen, 2004)

17.2.4.3 AMD management

There are management options for Acid Mine Drainage that aim to minimise the formation of AMD. For pyrite-containing wastes, four categories of control strategies can be identified (Hansen, 2004; Mitchell, 1999; Evangelou, 1995; EA, 1997; Parker and Robinson, 1999):

- Interventions that aim to prevent acid mine drainage generation: the treatment of sulphide mineral (predominantly pyrite) surfaces through various surface coatings and the use of anti-bacterial agents.
- Interventions that prevent oxygen and water ingress into waste deposits thereby limiting pyrite oxidation and acid mine drainage formation. Methods of this type include sub-aqueous deposition, wet covers, dry covers, oxygen consuming covers and the formation of hardpans.
- Interventions that aim to avoid acid mine drainage formation altogether and includes selective handling and macro-encapsulation, in-pit disposal, blending, mixing and co-disposal.
- Interventions that aims to control the migration of leachate (if generated) into groundwater. These strategies centre on the use of liners and leachate collection systems.
The most successful methods for controlling the formation and migration of acid mine drainage involve the segregation of the principal acid generating waste fraction and the use of engineered covers which minimise water and oxygen infiltration (Mitchell, 1999). Diversion of surface water and groundwater away from wastes sites will also limit AMD generation. Many of these strategies involve careful planning and are most effective when they form part of the mining plan. New mine sites have a considerably greater number of options at their disposal to control the formation and migration of acid drainage. At existing sites, however, where AMD is advanced, abatement measures may be limited by economic constraints and the severity of impacts (EA, 1997). Here, treatment strategies are required.

**Box 12: AMD treatment: The Brugspruit water pollution control works**

An initiative by DWAF for protecting Loskop Dam from AMD which decants from abandoned and flooded underground collieries in the Upper Olifants River Catchment is the Brugspruit Water Pollution control works. This works has a design capacity of 10 Ml per day to treat mine water to a quality acceptable for discharge to the aquatic environment. The facility is a DWA initiative and was refurbished in 2008 (Rand Water, undated) after a period of inactivity prior to 2007. This treatment system has been considered to be inadequate in that, despite the activity of the system, the quality of local water sources is continuing to degrade (McCarthy and Pretorius, 2009).

Treatment strategies are commonly categorised into three groups: active, passive and hybrid active-passive treatment systems (Mitchell, 1999). Active treatment systems have the advantage that they require less land area for implementation than passive systems. Operational and chemical costs, however, are usually higher for active treatment systems. Active treatment systems involve neutralisation with alkaline reagents, with limestone and hydrated lime as the most commonly applied reagents. Passive treatment systems neutralise acidity and reduce dissolved metal concentrations through various biological and chemical processes. Examples of hybrid active-passive strategies include microbial mat systems and the use of bioreactors.

Costs for treatment options to remove or neutralise high levels of sulphate in mine water depends on the complexity of the treatment as illustrated below.

**Table 47: Costs of AMD treatment**

<table>
<thead>
<tr>
<th>Treatment process</th>
<th>SO$_4$ level in treated water</th>
<th>Capital cost [R million / (Ml/d)]</th>
<th>Running cost [R/m$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone neutralisation (incl. iron (II) oxidation)</td>
<td>2,500</td>
<td>0.50</td>
<td>0.59</td>
</tr>
<tr>
<td>Lime neutralisation (pH 8)</td>
<td>1,500</td>
<td>0.53</td>
<td>1.36</td>
</tr>
<tr>
<td>Limestone/lime treatment (pH 11) &amp; gypsum crystallisation</td>
<td>1,100</td>
<td>0.88</td>
<td>1.02</td>
</tr>
<tr>
<td>Lime treatment (pH 11.5) &amp; gypsum crystallisation</td>
<td>1,100</td>
<td>0.57</td>
<td>1.61</td>
</tr>
<tr>
<td>Advanced sulphate removal (including neutralisation pre-treatment)</td>
<td>200</td>
<td>4.0 to 10.0</td>
<td>2.0 to 5.0</td>
</tr>
</tbody>
</table>

(Source: van Zyl et al., 2001)

An alternative treatment strategy, which falls outside the categorisation of passive and active treatment involves metal recovery. See the discussion on Eutectic Freeze Crystallisation (EFC) in the research and development section.
The eMalahleni Water Reclamation Plant (EWRP) was established as a joint venture between BHP Billiton Energy Coal South Africa (BECSA), the eMalahleni Municipality and Anglo American to treat excess mine water in the South African Coal Estate (SACE) region. The construction and commissioning of the plant was completed in the final quarter of 2007 and has a treatment capacity of 25 ML/day. The purpose of the facility is to treat acid mine water from underground and opencast coal mining operations in an attempt to achieve several objectives namely, a) to address post-closure environmental liabilities of collieries, b) to protect the environment by preventing decant and seepage of polluted mine water and to c) dewater open-cast and underground reserves to allow safe mining to proceed. A simple flowsheet of the process is as follows:

![Flowsheet of the eMalahleni Water Reclamation Plant](image)

The plant makes use of a three-stage high precipitate reverse osmosis process (HIPRO) and achieves an overall recovery in excess of 99%. The plant produces potable water that meets the South African National drinking water standards (SANAS Class (1)). EWRP supplies the eMalahleni Local Municipality with 16 ML/day of potable water and assists in supplementing their growing demand. Anglo American’s Thermal Coal business unit has taken this once seen liability and has transformed it into a resource in a water-scarce region.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Unit</th>
<th>Raw Water Quality</th>
<th>Product water quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>3.5</td>
<td>5 – 9.5</td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>mS/m</td>
<td>357</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>Acidity</td>
<td>mg/l CaCO₃</td>
<td>240</td>
<td>-</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>mg/l</td>
<td>3,918</td>
<td>&lt; 1000</td>
</tr>
<tr>
<td>Ca</td>
<td>mg/l</td>
<td>420</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>Mg</td>
<td>mg/l</td>
<td>238</td>
<td>&lt; 70</td>
</tr>
<tr>
<td>Na</td>
<td>mg/l</td>
<td>71</td>
<td>&lt; 200</td>
</tr>
<tr>
<td>K</td>
<td>mg/l</td>
<td>7</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>mg/l</td>
<td>3,469</td>
<td>&lt; 400</td>
</tr>
<tr>
<td>Cl</td>
<td>mg/l</td>
<td>35</td>
<td>&lt; 200</td>
</tr>
<tr>
<td>Fe</td>
<td>µg/l</td>
<td>81</td>
<td>&lt; 200</td>
</tr>
<tr>
<td>Mn</td>
<td>m/l</td>
<td>23</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>Al</td>
<td>µg/l</td>
<td>16</td>
<td>&lt; 300</td>
</tr>
</tbody>
</table>

The plant produces approximately 200 tons of solid by-product and 75 m³ of brine per day. The plant aims to achieve zero waste disposal through various research projects. Research into commercial uses of the sludge is being continuously investigated. One of the successes of this research has been the construction of 64 low-cost houses from the gypsum by-product.

(Source: McIntyre, 2011, pers. comm.)
17.2.5 Land use impacts

Coal mining is associated with extreme surface disruption and altered land use function post closure, which affects the soil, fauna, flora and surface water and can result in the loss of biodiversity and degradation of the life support functions. This is due to the presence of final voids, underground workings (which may lead to subsidence) and large solid waste deposit facilities (Figure 51). As there is little flexibility over the location of mineral deposits, the land required for mining can coincide with prime agricultural land (as is the case in areas of Mpumalanga). Thus, mining unavoidably competes with other alternative land uses (MMSD, 2002) and can often result in an irreversible change in land quality.

Figure 51: Aerial view of an open cast coal mine showing the extent of land disruption

Rehabilitation efforts can be successful but it is unlikely that the land will be returned to its former state (GDACE, 2008). Revegetation is a particularly challenging aspect of rehabilitation. Topsoil harvested prior to the commencement of activities is limited and may often be contaminated. Compaction of replaced topsoil, in particular, may hamper revegetation efforts (SACRM Environmental Focus Group, 2010). In addition, finding and establishing suitably hardy plant species that can tolerate the potentially acidic or highly saline conditions is also difficult. The use of soil conditioners to neutralise the acidic conditions (e.g. lime, gypsum etc.) can assist here. Achieving and sustaining ecological diversity in line with surrounding areas on rehabilitated sites is another significant challenge.

17.2.6 Mine closure and rehabilitation

Historically, once mining operations had ceased, waste sites were simply abandoned. In light of the recognition of the severity of long-term impacts, increased legal and financial liability has shifted to operators. This has brought about the development of decommissioning, closure and rehabilitation strategies, which now form an integral part of any waste management plan (ICMM, 2008; Stacey et al., 2010). The objective of these strategies has been extended from an assurance of ecological sustainability to an assurance of environmental security for the next 1000 years (Brown and Lowson, 1999). The socio-economic objectives of mine closure that cover health, safety, social, environmental, legal, governance and human resource considerations are described fully in Stacey et al. (2010) and discussed elsewhere in this report.

It is generally agreed that strategies for decommissioning and closure should be incorporated into the planning and design phase of process development (Stacey et al., 2010; ICMM, 2008; Farrell, 1998). Unfortunately, it is not always possible to develop the most effective strategies during planning and design as not all the variables and complexities are quantifiable at this stage. In fact, it is rare for major operational changes not to be made during the life of a mine (Farrell, 1998). Thus, an effective strategy for decommissioning and closure should be revisited and refined at regular intervals during the mine life cycle: i.e. continuous closure planning (Figure 52).
Another difficulty experienced by operators is determining when decommissioning and closure are complete. Effective closure requires a clear understanding of the endpoints about which there is a large amount of uncertainty (Farrell, 1998). Even if endpoints are well defined, there remains uncertainty regarding the point at which operators are freed from their accountability. According to Laurence (1998), successful decommissioning requires a strategic and systematic approach by owners, managers, operations personnel, communities, regulators and other stakeholders. Such an approach based on general ISO standards and site-specific considerations will ensure the following (Laurence, 1998):

- Overall improvement in environmental performance
- Clearer rules and greater certainty in dealing with regulatory bodies
- Reduced costs and minimum future liabilities
- Avoidance of abandoned sites requiring rehabilitation at public expense
- Improved access for future explorers and miners.

In general, the environmental objective for mine closure is to ensure that the site is rehabilitated to a standard acceptable for subsequent planned land use. It must be noted that this planned land use need not necessarily be the original land use. Other specific criteria include ensuring public health and safety, minimising environmental damage and minimising socio-economic impacts. Public health and safety can be ensured by preventing access to mine workings, pits and waste deposits and by controlling subsidence. Aspects to consider for environmental closure criteria include water quality, potential for dust and leachate formation and migration, site stability and potential for erosion, level of self-sustaining revegetation, biological diversity and aesthetics of rehabilitated landscape (Hansen, 2004). Mine rehabilitation involves the decommissioning and dismantling of redundant surface infrastructure, rehabilitation of the site, which includes plugging mine shafts, recontouring pit walls and waste deposits, reseeding and planting disturbed areas, and removing or isolating potential pollutants (GDACE, 2008; Ashton et al., 2001).

### 17.3 Environmental impacts associated with coal beneficiion

Coal beneficiation wastes are termed discards. According to SANS 10320 (2004) discards and reject coal are defined as: coal or carbonaceous material with or without associated or included stone, that result(s) from mining operations or coal processing operations and with coal quality parameters that fall outside the current saleable product range.

#### 17.3.1 Characteristics of coal beneficiation wastes

There are two types of wastes generated during coal beneficiation, namely discards, from the washing of coarse, small and fine coal, and ultra-fine slurry or slurry tailings. The term “discards” is, however, frequently used in reference to the combination of these two waste streams. In accordance with available statistics approximately 20 – 22% of the ROM coal reports as total discards, of which 4 – 6% is in the form of ultra-fine slurry. Typically in the region of 60 – 65 Mtpa of discards and slurry are generated each year, the typical characteristics of which are summarised in Table 48 (based on a national survey by the Department of Mineral Resources in 2001, which is still the most comprehensive set of data available on discards available).

#### Table 48: Typical characteristics of discard and ultra-fine slurry wastes

<table>
<thead>
<tr>
<th></th>
<th>Discards</th>
<th>Ultra-fine slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value [MJ/kg]</td>
<td>11 – 14</td>
<td>20 – 27</td>
</tr>
<tr>
<td>Ash [%]</td>
<td>30 – 60</td>
<td>10 – 50</td>
</tr>
<tr>
<td>Sulphur [%]</td>
<td>1 – 5</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Volatiles [%]</td>
<td>16 – 24</td>
<td>17 – 27</td>
</tr>
<tr>
<td>Fixed carbon [%]</td>
<td>18 – 24</td>
<td>41 – 56</td>
</tr>
</tbody>
</table>

(Source: DMR, 2001)

The quality of air-dried ultra-fine slurry, largely discarded in South Africa, is roughly equivalent to that of ROM coal, and is (for the most part) of suitable quality for electricity and synthetic fuel production. The propensity of the ultra-fines to adsorb and retain moisture, however, remains possibly the biggest constraints in terms of the down-stream use of this fraction.
The coarser discards, on the other hand, have a relatively low calorific value, with high ash and sulphur values, and would require further upgrading (either through washing or blending) to render them suitable for downstream use.

### 17.3.2 Environmental and health risks

Historically, both discards and ultra-fine slurry have been land-disposed: discards due to their high ash content and slurry due to its high moisture content. The only locally available study on discards estimated that in 2001 an accumulated mass of over 1 billion tonnes of slurry and discards had been dumped over the years, and more than 4,000 hectares of land were occupied by these waste disposal facilities in South Africa (DMR, 2001). The discards are typically disposed on discards dumps; while the slurry is typically disposed of on surface slurry dams together with the discards, underground in old mine workings or in open-cast voids (DMR, 2001).

In accordance with the Department of Mineral Resources (DMR, 2001) “old discard dumps in South Africa are one of the greatest polluters of the environment, polluting the atmosphere, rivers, ground water and the aesthetics of the countryside”. Due to their elevated pyrite content, these facilities are potential causes of acid mine drainage, especially when they are inappropriately located too close to water systems. Discard dumps are also high-risk areas for spontaneous combustion, and associated emission of harmful gaseous pollutants. Furthermore, coal fines that are stockpiled can be blown into the atmosphere, thereby contributing to poor air quality. The fine airborne matter can be carried off-site and therefore poses potential health risks to exposed local communities, and could contaminate surrounding ecosystems.

Apart from degradation of the local environment, these waste facilities also represent a loss in valuable water resources through seepage and evaporation. Significant dissipative water losses occur as a result of the high levels of water entrained in the ultra-fine slurry, as well as the subsequent use of water for dust suppression.

### 17.3.3 Management of disposal facilities

With environmental laws becoming stricter, operations have started to pay greater attention to the methods of discard and slurry disposal. Control over the disposal facilities has improved significantly over the last 25 years, and most modern practices are geared to facilitate future reclamation of both the discards and the ultra-fines.

Free-tipping of coarse discard over the sides of discard dumps has been replaced by spreading of the discard and compaction to eliminate the ingress of air into the dump, thereby greatly reducing the chances of spontaneous combustion of discard on the dump. Discard facilities are now being clad with soil and vegetated to prevent all forms of atmospheric pollution. These rehabilitated dumps are potentially reclaimable, the discarding being kept under non-oxidising conditions. Dumps are now being constructed with run-off paddocks to control storm water run-off from the top and sides of the dump. Seepage from the dumps is now being monitored and collected in paddocks for re-use in the processing plant or gravitated to evaporation dams for evaporation purposes.

Methods of slurry disposal have also changed considerably. Co-disposal, whereby ultra-fine slurry is pumped into the centre of the discard dump and the compacted discard forms a wall around the central slurry impoundment, is now widely practiced. This form of co-disposal will have a marked affect on the discard reclamation. Another disposal method, termed integrated disposal, entails the pumping of ultra-fine slurry onto un-compacted discards, to form a matrix that is non-oxidising. However, this represents a potential waste of a resource as the slurry cannot be easily recovered.

### 17.3.4 Recycling and reclamation

A large number of mines have now realised that their discard dumps and slurry ponds are not just environmental liabilities but also valuable assets. In general, ultra-fine slurry has a quality which will lend itself to beneficiation by froth flotation to produce power station feedstock or even an export product (DMR, 2001). The slurry even has the potential to be utilised in its raw state, provided the moisture content of the initial dried product can be reduced. Although the discards are of a lower quality than the ultra-fines, they can be readily upgraded to saleable coal products. This is now increasingly becoming standard practice in South Africa, with many collieries reprocessing their discard coal (both current arisings and old dumps) to extract a low-grade steam coal, mainly for use in local power stations (de Korte, 2004). If approached in a co-ordinated and strategic fashion, the potential for reclamation could be increased.

In one reclamation venture, a local private company, Waste Energy Recovery and Management (WERM), is using solar energy to recover ultra-fines from slurry dams (Reddick, 2006; Reddick et al., 2007). The dried ultra-fine material is blended with rewashed coarse waste rock and is sold to the Hendrina or Majuba power stations, as other power stations are not equipped to handle the fine material.

### 17.4 Environmental impacts of coal transport

The environmental impacts of coal transport are principally associated with emissions resulting from energy consumption, including greenhouse gas emissions contributing to climate change and locally polluting combustion by-products such as NOx, SO, and particulates. Road transport and diesel-powered rail transport produce these along the route of operation, whilst electrical transport (rail or conveyor) emit these at the point of power generation. Road is more energy-efficient per tonne-km, however, and hence causes lower emissions than road transport (Crickmay, 2009). It is noted that due to the carbon intensive nature of the regional economy, the contribution of transport to GHG emissions is relatively small.

Both road and rail occupy substantial areas of land along their routes, which are often converted from natural areas.
This results in a loss of biodiversity and potential pollution of surrounding areas with fugitive coal dust.

Pipeline transport is relatively energy-efficient, but the large volumes of water required, and the polluted water produced at the destination, represent substantial environmental impacts that would be particularly serious in a water-stressed country like South Africa (Carpenter et al., 2003).

### 17.5 Environmental impacts of coal fired power generation and their management

Environmental impacts of coal fired power generation include greenhouse gas emissions, other atmospheric emissions, water consumption and pollution, and ash generation (with associated land use for disposal). Each of these is considered below, including options for their management.

#### 17.5.1 Greenhouse gas emissions

The most important long-term issue which the coal fired power generation sector has to deal with is that of greenhouse gas emissions. Emissions of greenhouse gases have been linked to anthropogenic climate change, the science and impacts of which are discussed in detail in the section on climate change.

The main greenhouse gas emitted from the South African electricity sector is carbon dioxide (CO₂) which is produced when the coal combusts in the presence of air. In 2010, Eskom reports emitting 224.7 Mt of CO₂, as well as 2,825 t of nitrous oxide (N₂O), a greenhouse gas with a global warming potential of 298 times that of carbon dioxide (Eskom, 2010a). Eskom's emissions intensity is approximately 1.03 kg of CO₂ emissions for every kWh sent out (Eskom, 2010a). The latest national greenhouse gas inventory estimates national emissions for 2000 at 442.5 Mt CO₂e (including land use, land-use change and forestry), which suggests that Eskom contributes roughly 50% of national emissions (DEAT, 2009).

Opportunities for reducing the greenhouse gas emissions associated with coal-fired electricity generation are discussed in detail in the section on climate change mitigation. These include using more efficient power station technologies (such as supercritical, ultrasupercritical and IGCC), co-firing and other renewable augmentation and the use of carbon capture and storage (CCS).

#### 17.5.2 Other emissions to air

Other emissions to air from coal fired power generation include particulates, sulphur dioxide (SO₂) and nitrogen oxide (NOₓ).

In addition to the carbon component which provides its energy value, coal contains mineral constituents which remain as particulate matter after combustion. Their release to the atmosphere is of concern as inhalation can cause respiratory problems, and they cause smog/visibility issues. Various technologies are available for preventing release of particulates from power stations, including electrostatic precipitators (and efficiency enhancers such as sulphur trioxide flue gas conditioning), skew flow technology and modern control systems, retrofitting pulse jet fabric filters and wet scrubbers (which also remove SO₂) (Eskom, 2008a). Although measures are already in place at South African power stations to capture the majority of the particulate residual, Eskom still emitted 88.27 kt of particulate emissions in 2010 (Eskom, 2010a).

While Eskom has made significant reductions to its particulate matter emissions by means of the above technologies, the other significant impacts of the transformation of carbonaceous fossil fuels into electricity and heat are emissions of oxides of sulphur (expressed as sulphur dioxide, SO₂) and nitrogen (NOₓ).

Atmospheric deposition of SO₂ and NOₓ from power stations result in acid deposition, typically as acid rain, and have long-term effects, which include degradation of water and soil resources. Detectable changes in soil chemical properties have been reported, in particular for soil pH which has been found to become more acidic as a result of acid deposition (Scorgie and Kornelius, 2009; Reid, 2007). Even in dry regions, sulphur dioxide emitted from tall stacks is ultimately deposited via dry deposition, as illustrated in Figure 53.

*Figure 53: Conversion paths of atmospheric emissions via dry and wet deposition*

(Source: adapted from IAEA, undated)
Emissions of particulate matter and nitrogen dioxide will reportedly be reduced at Medupi power station, Eskom’s new build project, by means of pulse jet fabric filters and low NOx burners (Singleton, 2010). The two approaches to prevention of sulphur deposition are coal washing to remove sulphur prior to combustion and flue gas desulphurisation (FGD), which removes sulphur post combustion. Coal washing is considered further under beneficiation while FGD is described in the following section. Medupi is required to be “FGD ready” in terms of the financing obtained from the World Bank for its construction, however installation of the FGD technology will be subject to water availability. Indications are that Kusile will have FGD installed.

17.5.2.1 Flue gas desulphurisation

Flue gas desulphurisation is used to remove SO2 emissions after combustion but prior to release into the atmosphere. In fluidised bed combustion (FBC) reactors, sorbents can be injected directly into the combustion chamber for SO2 removal. For SO2 removal from pulvsiere fuel (PF) reactors, those in use in South Africa, additional sorbent systems need to be fitted onto power stations.

The underlying principle of most commercial FGD processes is the removal of SO2 in the flue gas by means of reaction of acidic SO2 with a suitable alkaline substance or sorbent. The most commonly used sorbents are limestone (CaCO3), quicklime (CaO) and hydrated lime (Ca(OH)2); other alkalis used include sodium carbonate, magnesium carbonate and ammonia (DTI UK, 2000).

The production of certain sorbents, in particular lime, comes with a CO2 penalty: the most significant carbon dioxide emission-intensive process in the production of lime (CaO) is calcination of limestone where CaCO3 is decomposed to CaO with the release of gaseous CO2. This can happen either at the mine site or in the power station. Mining operations and transportation are further energy intensive processes and emit CO2 as a result of diesel combustion.

There are several types of FGD technologies, with the major distinction between wet and dry/semi-dry processes. Although water consumption of wet FGD processes is generally higher than dry processes, actual water consumption is site-specific and is dependent on operating conditions (Paton et al., 2006).

The reaction between the SO2 and the alkali occurs either: (DTI UK, 2000)

• in a bulk solution for wet FGD processes where flue gas is contacted with the alkali solution in a spray tower; SO2 gas dissolves into the aqueous medium and reacts with dissolved alkali material, or
• at the wetted surface of the solid alkali material for dry and semi-dry FGD processes. SO2 reacts directly with the porous or finely ground solid to form the corresponding sulphite and sulphate. For semi-dry processes, in order to enhance reaction, flue gas is hydrated to form a liquid film on the particles in which the SO2 dissolves.

A comparison of various FGD technologies is provided in Table 49 below.

<table>
<thead>
<tr>
<th>FGD Technology</th>
<th>SO2 removal capability</th>
<th>Ca/S Molar ratio</th>
<th>Typical water consumption [(l/kWh)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray-Dry Scrubber</td>
<td>70 – 90%</td>
<td>1.01 – 1.05</td>
<td>0.14</td>
</tr>
<tr>
<td>Sorbent Injection Processes</td>
<td>30 – 60%</td>
<td>2 – 4</td>
<td>N/A</td>
</tr>
<tr>
<td>Dry-CFB Scrubber</td>
<td>93 – 97%</td>
<td>1.2 – 1.5</td>
<td>0.14</td>
</tr>
<tr>
<td>Wet Scrubber</td>
<td>90 – 99%</td>
<td>1.1 – 1.6</td>
<td>0.21</td>
</tr>
</tbody>
</table>

(Source: Singleton, 2010)

The Ca/S molar ratio provides an indication of the sorbent requirement on a molar basis. The water requirement of the dry technologies is for the hydration of lime sorbent.

If 0.57 kg coal is burned for every kWh sent out, for a coal with 0.8% sulphur, (Eskom, 2010a), approximately 0.015 to 0.043 kg CaCO3 is required for every kWh of electricity sent out, depending on the FGD technology used.

Limestone-based FGD processes produce a calcium sulphate by-product which produces costly disposal and environmental and post-closure liabilities. Calcium sulphate may be upgraded to gypsum for the building industry and there is thus an opportunity to supply this FGD by-product into the downstream construction industry, if government support is obtained to enable this. Gypsum is quarried in South Africa for the construction and road industry and the demand for gypsum is largely dependent on the strength of this industry (DME, 2004). In South Africa, the source of synthetic gypsum is phosphogypsum which is a by-product from the fertiliser industry. Hence markets do exist which could be explored for this by-product.

Wastewater is also generated at several stages in wet, lime slurry-based FGD. Typically three phases of treatment are involved in the management of these wastewaters (Paton et al., 2006)

• pH adjustment to achieve chemical precipitation of metals into hydroxides and sulphides
• Addition of coagulant to produce a floc in which precipitates suspend
• Sludge settlement (floculation)

Although none of Eskom’s existing power stations employ FGD, Eskom has committed to fit the Kusile power station with FGD technology, and plans to retrofit Medupi with FGD (Eskom, 2010a; Singleton, 2010). Some of the considerations in inclusion of FGD for Medupi are presented in Box 14.
Box 14: Considerations in the use of FGD at Medupi

Notwithstanding the higher water consumption associated with wet FGD compared to similar technologies, Eskom has expressed a preference for wet FGD for Medupi, using limestone as the potential sorbent (Singleton, 2010). Projected input requirements for the Medupi power stations are summarised in Table 50.

Table 50: Input requirements for FGD at Medupi

<table>
<thead>
<tr>
<th>Consumable</th>
<th>Comment</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorbent</td>
<td>Limestone</td>
<td>700,000 t/year</td>
</tr>
<tr>
<td>Water</td>
<td>Raw and softened water</td>
<td>6.5 – 7.2 Mm³/year</td>
</tr>
<tr>
<td>Power</td>
<td>FGD equipment (pumps, motors, fans)</td>
<td>1.5 – 2% per unit</td>
</tr>
</tbody>
</table>

(Source: Hairpersad et al., 2008 in Singleton 2010)

Potential sorbent sources for Medupi have been identified in Limpopo, Mpumalanga and the Free State, as shown in Figure 54, although uncertainty remains around quality and quantity of these mineral resources. Sorbent transport to Medupi is anticipated to be by rail (Singleton, 2010).

Figure 54: Potential sources of sorbent in South Africa

Dolomite (CaMg(CO₃)₂), resources are more abundant than limestone and Eskom is reportedly performing tests to determine the effect of magnesium on FGD in PF power stations (Singleton, 2010).

Given the relatively low sulphur content of South African coals, and the CO₂ penalty associated with calcination of the limestone and transport, the benefits of FGD should be carefully weighed up prior to implementation.
17.5.3 Ash generation

The ash content of coal combusted by Eskom is approximately 30% which, due to its inert nature, is liberated in the production of electricity from coal. Coarse and fly ashes represent the primary components of this solid waste and are collected from furnace chambers to maintain the efficiency of the combustion process.

Coarse ash (approximately 10% of the total ash content of the boiler fuel) represents incombustible components of feed coal which adhere to furnace walls and convection surfaces after combustion of feed coal. Gravity, soot-blowing or load changes dislodge these particles which then gravitate towards the bottom of the combustion chamber and are collected in an ash box or ash hopper.

Fly ash represents approximately 90% of the ash which becomes entrained by the flue gas stream and is removed by hoppers and dust collectors. The ash is taken to ash heaps or ash dams for disposal, although some of the ash is recycled or sold.

For a coal consumption of 122.7 Mt in 2010, Eskom produced approximately 36 Mt ash (Eskom, 2010a).

17.5.3.1 Ash management and reuse

Ash and other coal combustion products are conveyed either in a wet or dry state to land disposal sites or ash dumps. Wet ashing systems rely on hydraulic conveyance as ash is incorporated into a water-based slurry that is pumped along pipelines to the ash dumps. Dry systems convey semi-dry ash on open belt overland conveyor networks to ash heaps. The ash is semi-dry in that sufficient moisture is added to the ash to suppress dust from blowing off the conveyors.

Effluent water and wastewater (resulting from the water reuse circuits employed at power stations) are used as dust suppressant or slurring medium for dry and wet applications respectively. Seepage or leachate from ash dams collects in sub-soil drains and is returned to the plant where it is recycled for ashing purposes. The composition of leachate generated from ash dumps is characterised by high dissolved salt contents, elevated trace metal concentrations and extreme pH (Hansen et al., 2002). Upon contact with ash leachate, water pH and elemental concentrations of natural water bodies are altered and secondary effects include increases in electrical conductivity, turbidity and water temperature (Carlson and Adriano, 1993).

The water balances for ash dumps are illustrated in Figure 55, and ash system water flows relative to other streams at the power plant in Figure 56 below.

**Figure 55: Schematic of water flows at dry and wet ash dumps**

**Figure 56: Schematic of power station water network including the ash disposal system**

(Source: Hansen et al., 2002)
Incorporating ash into other applications such as road bases, admixtures for concrete production and others reduces the volumes of this waste only marginally. Approximately 1.2 Mt (or 3% of all ash produced by Eskom) of ash is sold annually by Eskom (Eskom, 2010j). Fly ash is used in brick-making, dam building and cement manufacture for which ash acts as an extender due to its pozzolanic characteristics. Around 250 Mt of ash was exported from Eskom’s Lethabo power station to Lesotho for the Latse Dam project (Eskom, 2010j).

Large-scale use of ash for back-filling of coal mines may represent a more effective waste management route. South African experience with back-filling of coal mines with ash commenced in 1963, and successful large-scale backfilling operations followed, notably at Grootvlei power station and also for the stabilisation of a major national road (Ward et al., 2006). Today, the design of modern backfill distribution systems in South Africa is supported by advanced computer models and a well developed understanding of the backfill rheology (Ward et al., 2006). The synergy between power stations and coal mines in the backfilling of coal mines potentially may result in several benefits in terms of compliance with environmental laws and the controlled disposal of waste (Ilgen, 2000). The two main factors which inhibit wide scale use of back-fill are the cost to backfill and the perceived risk of environmental pollution.

Given the acidity of coal mine water and the alkaline nature of ash, the process of mine water treatment with ash appears attractive. However, the potential for long-term solubilisation of salts from ash and the leakage into groundwater bodies remains poorly understood. Furthermore, the carbonate minerals in some South African coal have been found to provide only temporary buffering capacity (Pinetown et al., 2007).

In the attempt to collectively address the accumulation of ash wastes as well as salts and water balance problems, pilot scale research has been conducted on the co-disposal of ash and saline wastewater by means of pasting at Eskom power stations and Sasol’s CTL plant at Secunda. Seemingly apparent chemical and mineralogical interaction between brines and ash has prompted interest in salts and water binding processes, and experimentation with lysimetry is ongoing at Sasol (Moitsheki et al., 2010), at academic institutions (Muntingh et al., 2009; Gitari et al., 2008a; Gitari et al., 2008b) and its progress has been presented at several conferences (Mooketsi et al., 2007; Roux, 2006; Mahlaba and Pretorius, 2006; Gitari et al., 2009). Similar studies have been performed in Australia (Ward et al., 2006; Jewell et al., 2002) and the United States of America (Joshi et al., 1994).

17.5.4 Water impacts from power generation

17.5.4.1 Wastewater

Wastewater sources from coal-fired power stations include steam cycle drainage and blowdown, makeup water treatment plant effluent, and cooling tower blowdown (Paton et al., 2006). Desalination of cooling water blowdown has been proposed as a means for reducing raw water requirements and alleviating problematic water balances collieries (Buhrman et al., 1999).

Eskom’s wastewater management policy endorses a “Zero Liquid Effluent Discharge” (ZLED) policy, which aims to prevent pollution of water resources through the establishment of a “hierarchy of water uses based on quality” (Pater, 2004). The ZLED principle is as follows: water is cascaded according to decreasing quality to facilitate re-use until all pollutants are finally captured in the ash dams; the objective is to dispose of the maximum mass of salts with the smallest possible volume of water without compromising the ability of the ash to encapsulate the salt load imposed (Eskom, 2010c). Water loss through evaporation is the only water loss aimed for and this system attempts to prevent “deliberate discharge of pollutants to a water resource” (Pater, 2004). While the aim of the ZLED policy is to reduce the negative environmental impacts on surface and ground waters, it may place stringent constraints on the water balance of the power station. This occurs when the moisture retentive capacity of water sinks (ash conditioning and dust suppression) is exceeded by excess water accumulated in dams (stormwater run-off and excess effluent) even after recovery (as boiler feed water) or re-use (as cooling water) according to ZLED. Expansion plans to the water treatment plant at Tutuka power station has recently been proposed to address a similar problem related to the disposal of excess reject brine from the cooling and mine water treatment unit (Corbett and West, 2010).

As described below, the potential for ash dumps to act as sinks for problematic wastewater has been the focus of recent research work by the two largest ash generating companies in South Africa, Sasol and Eskom.

17.5.4.2 Salinity

Saline wastewater results from large volumes of fresh water which are evaporated in wet cooling columns at coal fired power stations. Saline wastewater sources include drainage and blowdown from the boiler water/steam circuit of the steam cycle, raw- and makeup water treatment plant effluent, and cooling tower blow down (Paton et al., 2006). Given the large volume reduction associated with evaporative cooling, cooling tower blow down is characterised by high TDS. A further source of large amounts of salinated liquid wastes results from the freshwater treatment required prior to use in steam applications, in particular for power generation and CTL. Wastewater streams produced from water treatment units thus contain both treatment chemicals and raw water salts.

Management options for saline mine water include: pollution prevention at source, volume reduction through reuse and recycling prior to treatment, treatment of effluents if
production is not preventable, reuse and recycling and finally discharge of treated effluent as the least preferable option (Pulles, 2006; Annandale et al., 2009).

Eskom’s mine water desalination initiative in collaboration with adjacent coal mines is demonstrated at its Tutuka and Lethabo power stations. A spiral reverse osmosis (SRO) plant was established in 1998 at Tutuka for the daily desalination of a combined stream of 12 ML consisting of equal splits of cooling water blowdown and mine water in support of the colliery supplying the power station (Buhrmann et al., 1999). A recovery of 87% was reported for the first two years of operation (van der Walt and Wessels, 2001). Today, around 15 ML mine water is desalinated daily.

**Figure 57: Existing water circuit at Tutuka**

Recently water balance problems at the power station have necessitated the need to recover more water from waste streams. Expansion plans include the construction of a brine concentration plant situated near the existing RO works to treat 3 ML/d and a groundwater treatment works situated on rehabilitated ash dump to treat 1 ML/d of groundwater (Corbett and West, 2010; Corbett and Lawson 2010). The feed for the first plant will be the brine reject from the existing RO plant and it is anticipated that around 2 ML can be reclaimed from this for reuse in the power station. As illustrated below, the concentrated brine from the new installation will be disposed of at the tied colliery, New Denmark.

**Figure 58: Expansion on the existing water reclamation plant at Tutuka**

Lethabo power station also successfully incorporates mine water into its water circuit at cooling water makeup clarification (Eskom, 2010i).
17.5.5 Other environmental issues

Coal-fired power stations have a number of environmental impacts that go beyond the release of pollutants into the air and water. The construction of power plants and transmission lines can impact on land use and ecosystems stability, which, if not managed properly, can in turn impact on local populations that rely on the land and ecosystem services for their livelihoods (Eskom, 2010a).

Coal-fired power plants also impact on the aesthetics of an area (through factors like noise pollution and reduced visibility), which in turn impacts on the wellbeing of residents and the economic viability of other sectors (like tourism) (Thopil and Pouris, 2010).

**Box 15: Reducing the social cost of coal-fired electricity generation - environmental management**

Although the construction of the Kusile site includes the clearing of 5,200 hectares of agricultural land, the Environmental Management Plan for the construction period was approved by the Department of Environmental Affairs and Tourism (DEAT). In an effort to retain some of the site’s ecosystems, the integrity of the wetlands shall be preserved, and topsoil from the site shall be removed and conserved for the rehabilitation of the site when construction is complete. In addition to this, only indigenous trees and plants shall be replanted on the site.

Source: Eskom (2010)

17.6 Environmental impacts of CTL

The primary environmental impact associated with coal-to-liquids is the generation of greenhouse gas emissions

17.6.1 Greenhouse gas emissions and emissions to air

The most significant environmental issue for CTL in South Africa is the high level of greenhouse gas (GHG) emissions associated with the CTL technology. In 2010, GHG emissions from Sasol’s South African operations were to the order of 60 Mt, with a large proportion of this attributed to the CTL process at Secunda (Sasol, 2010a). Figure 59 below illustrates the contributions of the various stages in the CTL process to Sasol’s CO₂ emissions. The impacts of climate change, and potential mitigation technologies, are covered in the section on climate change.

*Figure 59: Sources of CO₂ emissions from the CTL process*

In addition to the GHG emissions, other atmospheric pollutants from the CTL process include:

- Particulate matter from ash dumps and emitted by power stations
- Sulphurous and nitrogenous gases (SOₓ, H₂S and NOₓ)
- Volatile organic compounds (VOCs) or non-methane hydrocarbons

Table 51 reflects emissions of local air pollution for the entire Sasol group, with main contributions arising from Secunda and Sasolburg operations.

**Table 51: Sasol’s airborne emissions of non-GHG**

<table>
<thead>
<tr>
<th>Air pollutants (kt per annum)</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen oxides (NOₓ)</td>
<td>162</td>
<td>166</td>
<td>160</td>
<td>165</td>
</tr>
<tr>
<td>Sulphur oxides (SOₓ)</td>
<td>219</td>
<td>225</td>
<td>233</td>
<td>241</td>
</tr>
<tr>
<td>VOC</td>
<td>-</td>
<td>-</td>
<td>46.9</td>
<td>46.8</td>
</tr>
<tr>
<td>Particulates (fly ash)</td>
<td>7.59</td>
<td>8.45</td>
<td>9.39</td>
<td>11.38</td>
</tr>
</tbody>
</table>

(Source: Sasol, 2010a)

(Source: adapted from Mulder, 2009)
Box 16: Examples of Sasol’s initiatives towards addressing environmental impacts

Sasol’s “strategic commitment to promote sustainable development” has initiated monitoring and reporting of environmental performance indicators such as water consumption, mine water, energy efficiency and greenhouse gas emissions.

Atmospheric emissions of H2S and VOCs have been addressed by means of a sulphuric acid plant which was commissioned at Secunda. This addition has also contributed to the overall energy efficiency of the Synfuels process, while the closure of Sasol Nitro has resulted in a reduced production of phosphor-gypsum waste. A gas conversion project at Sasolburg has reduced the amount of tar and oil waste and ash at that facility.

As a step towards addressing the water scarcity challenge experienced by Sasol, it is a signatory of the UN Global Compact CEO Water Mandate, a public-private initiative launched in 2007 to “assist companies in the development, implementation and disclosure of water sustainability policies and practices”. This requires it to reduce the water intensity of its facilities.

Negatively affected land and loss of biodiversity of areas on which existing operations are located are compensated for by the conservation of land elsewhere and are managed according to environmental management programmes. New projects are subjected to environmental impact assessments.

(Sasol, 2010a; Meyer, 2009)

17.7 Environmental impacts from iron and steel

It is suggested that the iron and steel industry is the largest contributor to industrial process greenhouse gas emissions in South Africa, followed closely by the cement industry (Letete et al., 2010; Figure 60). In absolute terms however, the contributions of these two industries have remained largely constant for the last three decades. More recently, the contribution of other metallurgical industries such as the production of ferroalloys has increase markedly (see Figure 60).

Figure 60: South African GHG emissions from industrial processes

The majority of greenhouse gas emissions are the direct process and fuel-combustion emissions, primarily from the BF/BOF process. Iron and steel process emissions were suggested to be approximately 18 Mt CO₂e in 1994, and indirect energy emissions, 19.2 Mt CO₂e. These figures, making up nearly 10% of South Africa’s greenhouse gas emissions, exclude emissions from coke ovens (DEAT, 2009).

(Source: Letete, et al., 2010)
Other gaseous emissions from coke production and its use include particulate matter, volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs), NO, and sulphur oxides (SOx). Tars and bitumens are also produced as a by-product of coke production. These are disposed of to ponds where they potentially present an environmental hazard.

Wastewater with a high organic, dissolved solids, cyanide, fluoride and heavy metal loading is also generated from this sector, as is slag with high Cr(VI) loadings which can impact on groundwater quality. These are, however, not directly related to the coal use per se and so are not considered further here.

**Box 17: Efforts to reduce pollution - recycling in the iron and steel industry**

Collect-a-can is a joint venture between ArcelorMittal and Nampak which began in 1993. The objective of the initiative is to promote the recovery and recycling of used beverage cans and other steel packaging. The joint venture currently operates from 6 sites in South Africa and purchases R 25 – R 30million annually, mainly from small to medium enterprises. From 1993 to 2006, approximately 750,000 tonnes of used cans were recovered in Southern Africa. In 2010, Collect-a-can estimated that it had a recovery rate of approximately 72%.

(Source: ArcelorMittal, 2010b)
WATER DEMAND AND SUPPLY

18.1 Water demand across the value chain

This section considers demand for water in relation to the major sectors of the coal value chain in South Africa, being coal mining and beneficiation, electricity production and liquid fuels production. Competing demand for water is briefly considered thereafter.

18.1.1 Coal mining and beneficiation

Water is used in coal mining, beneficiation and sometimes in the transportation of the mineral product to end-users. Water use per tonne of coal depends on the mining method used, the type of equipment and the availability of water in the region (Mavis, 2003). In underground coal mining water is required as a coolant for cutting surfaces and for prevention of fires and explosions which may result from ignition of coal fines and gas during mining (Mavis, 2003). In surface mining the main water use is for dust suppression (Bradford and Salmon, 2008). It has been estimated that dust control consumes around 20 litres of water per tonne of coal produced from a surface mine (Mavis, 2003). Calcium chloride and magnesium chloride are frequently introduced to reduce water used in dust suppression as their hygroscopic properties help to retain water and promote dust suppression.

Coal preparation is performed either at the mine where stone and shale can be separated out or at a post-mine facility where raw coal undergoes pretreatment and cleaning/washing (see the beneficiation section for more detail). Aside from picking tables and air tables, almost all other beneficiation techniques involve the use of water, and the subsequent dewatering of the beneficiated coal. Slurries from the cells in jig table washing, scrubbers and coal dewatering stages are conveyed to water clarification plants where thickening and settling operations remove suspended minerals and clay particles. The underflow is discarded and water is returned to the beneficiation plant for reuse (Hand and Wiseman, 2009). Slimes dam return water is a major water input stream for beneficiation plants.

Coal mining (without beneficiation) in South Africa was reported to have consumed on average 130 litres of water per tonne of coal mined in 2001 (Pulles et al., 2001). Beneficiation can more than triple this consumption figure. More detailed and up-to-date information on water use in the coal mining industry is not available.

18.1.2 Electricity production

Most of Eskom’s coal-fired power stations are located in two water management areas (WMAs), namely the Olifants River WMA and the Upper Vaal River WMA (Eskom, 2008b). In addition, Matimba power station is located in the Limpopo WMA, where a further station (Medupi) is currently under construction. Eskom consumes approximately 1.5% of the total fresh water available annually in South Africa (Eskom, 2010a). The total water use by the group was 316,202 Ml for 2010 (Eskom, 2010a) with specific water consumption for various technologies detailed below.

Primary water inputs at a coal-fired power station are as ultra pure quality water for boilers and water of softened quality for cooling water. Water is further used for dust suppression and ash handling.

18.1.2.1 Boiler water

Thermal power stations generate electricity through burning coal to produce steam which is used to drive turbine blades coupled to generators. The steam is generated from boiler feed water. Boiler feed water requires extensive treatment prior to use for the removal of suspended particles, hardness and other dissolved solids which can damage the boilers. The required water quality is typically achieved by means of pretreatment and ion exchange which produces water of ultra pure quality. Developments in membrane processes are allowing Reverse Osmosis technology to advance into the use for pretreatment, thus replacing clarification and filtration (Paton et al., 2006).

A saline wastewater results from chemicals intense ion exchange and is used for ash handling as described below. After use, boiler water is condensed and returned but requires a small feed makeup which is provided from surface water bodies.

18.1.2.2 Cooling

Coal fired power stations produce excess heat which, for inland locations remote from large water bodies, has traditionally been removed to the atmosphere with cooling water. Cooling water obtained from surface water bodies is typically treated to inhibit fouling of the cooling system as a result of growth of bio-organisms (Paton et al., 2006).

Dry cooling, a technique which was pioneered in South Africa, is in use at several of South Africa’s power stations, most notably Matimba, Kendal and Majuba – the largest dry cooled power stations presently in operation globally (Eskom, 2010i). The new Medupi plant will also use dry cooling. Dry cooling reduces the water consumption for electricity generation and increases flexibility in power plant siting, but results in a penalty on power plant performance efficiency of the order of 2% (annual average for an optimised system) (EPRI, 2007). Given the reliance on the ambient dry bulb temperature (which is more variable than the ambient wet bulb temperature which wet cooling systems rely on), dry cooling systems may fluctuate in capacity and performance over short periods of time (Paton et al., 2006). The energy efficiency penalty may rise to more than 20% for extended periods on extremely hot days, thus requiring more fuel and increasing greenhouse gas emissions (EPRI, 2007). Further, energy requirements of fans (see Figure 63 below) further affect energy efficiency of the power station.

Two different configurations of wet cooling systems are shown in Figure 61 and Figure 62, and a dry or air cooled system in Figure 63.
The cooling technologies in place at the various Eskom power stations are shown in Table 52.

### Table 52: Cooling technologies at Eskom power stations

<table>
<thead>
<tr>
<th>Power station</th>
<th>Cooling method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnot</td>
<td>Wet</td>
</tr>
<tr>
<td>Tutuka</td>
<td>Wet</td>
</tr>
<tr>
<td>Matla</td>
<td>Wet</td>
</tr>
<tr>
<td>Duvha</td>
<td>Wet</td>
</tr>
<tr>
<td>Kendal</td>
<td>Dry</td>
</tr>
<tr>
<td>Kriel</td>
<td>Wet</td>
</tr>
<tr>
<td>Camden</td>
<td>Wet</td>
</tr>
<tr>
<td>Lethabo</td>
<td>Wet</td>
</tr>
<tr>
<td>Hendrina</td>
<td>Wet</td>
</tr>
<tr>
<td>Matimba</td>
<td>Dry</td>
</tr>
<tr>
<td>Majuba</td>
<td>Dry and wet</td>
</tr>
<tr>
<td>Komati</td>
<td>Wet</td>
</tr>
<tr>
<td>Grootvlei</td>
<td>Wet</td>
</tr>
</tbody>
</table>

Water consumption for dry-cooled generation is 0.1 l/kWh, and 1.9 l/kWh for wet. Eskom’s water use for dry and wet cooled power stations is estimated at 3,500 Ml and 50,000 Ml per annum respectively (Eskom, 2008c).

Specific water consumptions of the different cooling technologies employed by Eskom power stations are summarised in Table 53.
Table 53: Specific freshwater requirements of cooling technologies at power stations

<table>
<thead>
<tr>
<th>Type of power station</th>
<th>Specific water consumption (litre per kWh sent out)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet cooled coal-fired</td>
<td>1.9 – 2.1</td>
</tr>
<tr>
<td>Dry cooled coal-fired</td>
<td>0.12 – 0.16</td>
</tr>
<tr>
<td>Dry cooled with FGd* (CCS)**</td>
<td>0.37 – 0.41 (0.52)</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*FGd: flue gas desulphurisation, **CCS: carbon capture and storage. Note that this is for future technologies.

(Source: Eskom, 2008c)

18.1.3 Liquid fuels production

Sasol’s coal to liquids facilities at Secunda obtain water from the Vaal River system which is characterised by erratic run-off and by the low conversion of rainfall to usable water (Sasol, 2008; Meyer, 2009; DWA, 2009). Large volumes of water are transferred from the Usutu to Mhlatuze and Thukela WMAs and from Lesotho into the catchment areas above the Vaal Dam (DWAF 2004a). The Usutu-Vaal Scheme routes water to the Grootdraai Dam, from which the Secunda CTL facilities draw raw water (Sasol, 2008). The Sasol Sasolburg facility, producing chemicals from natural gas, consumes 20 million m$^3$ of water per year, whilst Sasol 2 and 3 in Secunda jointly consume some 90 million m$^3$ per year (DWA, 2009).

Sasol consumes water directly for the generation of electricity onsite (water of a polished quality is used) and for process requirements (steam), boiler feed water, cooling water and ash handling. Process water is used in the liquefaction process and is thus a reagent in the chemical reactions (Mulder, 2009).

The Secunda plant’s water balance for 2009 was 260 Ml/d of fresh, raw water input, 240 Ml/d evaporative losses and 20 Ml/d in effluent discharges; as well as a 200 Ml/d recycle stream that treated and reused (Meyer, 2009). Sources of wastewater include saline cooling water blowdown from evaporative water losses at cooling towers, concentrated brine streams resulting from raw water treatment (reverse osmosis and ion exchange) and the salts which remain after saline mine water reclamation at the Secunda plant (Sasol, 2010a; von Gottberg et al., 2005).

Despite extensive wastewater recovery at Sasol’s Secunda plant, fresh water consumption and wastewater generation remain an environmental concern.

The use of mine water as a substitute for using fresh water to perform cooling has been studied at Sasol’s facility at Sasolburg on pilot scale (Swart and Engelbrecht, 2004).

Although reportedly chemicals cost associated with mine water (MW) use is similar to that of conventional cooling, the variability of MW quality over time was deemed to be problematic in the treatment of feed. Also, although low scaling and corrosion rates were reportedly found during the trials, it was anticipated that elevated sulphate levels would compromise the cooling infrastructure in the long term.

Sasol Secunda’s Project Landlord addresses the problem of saline blow down, a liquid waste stream which placed additional pressure on the already problematic water balance and was discharged into a river system (Grant, 2006). The plant treats cooling tower blowdown water through a sequence of clarification, softening and membrane processes and concludes with polishing by means of ion exchange to achieve the polished and condensate water qualities required by downstream units (Grant, 2006). Water conservation has been achieved through the recovery of cooling water blowdown which has enabled the group a saving of 18 Ml/d at Sasol Secunda (Meyer, 2009; Grant, 2006).

18.1.4 Other water demand

The scarcity of water in South Africa leads to inevitable competition between industry, mining, agriculture and the requirements for maintenance of ecosystems. The relative consumption of water by different sectors of the South African economy in 2000 is shown in Figure 64. This needs to be supplied without infringing on the minimum water flows required to maintain ecosystems and basic human health. Estimates place the national average requirement for ecological reserves at approximately 20% of total river flow (DWAF, 2004b), although this varies between 12% and 30% for individual river systems.

Figure 64: Percentage water requirements by sector in South Africa in 2000

Although reported chemical cooling water represent the most significant water loss through evaporation.

(Sources: StatsSA, 2006)
It is noteworthy that whilst mining and heavy industry are significant among water users, agriculture is by far the greatest consumer. Even on the local scale of the Olifants WMA, where many coal mines are situated, mining and bulk industrial operations make up only 10% of local water requirements whilst agriculture accounts for 58% (DWAF, 2004b).

18.2 Water supply

South Africa’s average annual rainfall is just 450 mm/year, well below the international country average of 860 mm/year (DWAF, 2004b). In combination with high rates of evaporation and uneven water distribution, this leads to severe constraints on the country’s water resources, and water availability is recognised to be among the critical risks facing the coal value chain in the future. This section explores the broader issues related to the status quo and future evolution of water supply and the required infrastructure, and broader considerations related to water demand. Water issues related to individual value chain elements, including consumption and pollution issues, are discussed in the relevant sections.

The discussion on water supply considers two key factors affecting water provision: the availability of water resources and the infrastructure to deliver these to the point of demand.

18.2.1 Availability

There is a strong spatial variability in water availability and demand across South Africa, which are frequently mis-aligned. Furthermore, conversion of precipitation to usable runoff is generally low. For example, although the Limpopo River Catchment and Orange River Catchment together sustain about 70% of total national economy, only 5.1% of the total rainfall there is captured in dams, with the rest evaporating (Figure 65) (Turton, 2011). Inter-basin transfers of water are built to manage water supply and mitigate the uneven distribution of water across the country. South Africa’s water management areas (WMAs) and major inter-basin transfers of water are illustrated in Figure 66 below.

Figure 65: Water runoff distribution across South Africa

![Figure 65: Water runoff distribution across South Africa](image_url)

(DEAT, 1999)
Table 54 provides a summary of the water balances for freshwater resources in each of the WMAs presented in Figure 66. This reflects the minimum flows required to sustain ecosystems and basic human needs, as well as showing withdrawals for local demand and the strong influence of transfers (including river flows in the case of Vaal and Orange systems).

Table 54: Water Management Areas (all flows expressed in Mm$^3$/year)

<table>
<thead>
<tr>
<th>Water management area</th>
<th>Ecological reserve</th>
<th>Local yield</th>
<th>Local demand</th>
<th>Transfer in</th>
<th>Transfer out</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berg</td>
<td>217</td>
<td>505</td>
<td>704</td>
<td>194</td>
<td>0</td>
<td>-5</td>
</tr>
<tr>
<td>Breede</td>
<td>384</td>
<td>866</td>
<td>633</td>
<td>1</td>
<td>196</td>
<td>38</td>
</tr>
<tr>
<td>Crocodile (West) and Marico</td>
<td>164</td>
<td>716</td>
<td>1,184</td>
<td>519</td>
<td>10</td>
<td>41</td>
</tr>
<tr>
<td>Fish to Tsitsikamma</td>
<td>243</td>
<td>418</td>
<td>898</td>
<td>575</td>
<td>0</td>
<td>95</td>
</tr>
<tr>
<td>Gouritz</td>
<td>325</td>
<td>275</td>
<td>337</td>
<td>0</td>
<td>1</td>
<td>-63</td>
</tr>
<tr>
<td>Inkomati</td>
<td>1,008</td>
<td>897</td>
<td>844</td>
<td>0</td>
<td>311</td>
<td>-258</td>
</tr>
<tr>
<td>Limpopo</td>
<td>156</td>
<td>281</td>
<td>322</td>
<td>18</td>
<td>0</td>
<td>-23</td>
</tr>
<tr>
<td>Lower Orange</td>
<td>69</td>
<td>-962</td>
<td>1,028</td>
<td>2,035</td>
<td>54</td>
<td>-9</td>
</tr>
<tr>
<td>Lower Vaal</td>
<td>49</td>
<td>126</td>
<td>643</td>
<td>548</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>Luvulvu and Letaba</td>
<td>224</td>
<td>310</td>
<td>333</td>
<td>0</td>
<td>13</td>
<td>-36</td>
</tr>
<tr>
<td>Middle Vaal</td>
<td>109</td>
<td>50</td>
<td>369</td>
<td>829</td>
<td>502</td>
<td>8</td>
</tr>
<tr>
<td>Mvoti to Umzimkulu</td>
<td>1,160</td>
<td>523</td>
<td>798</td>
<td>34</td>
<td>0</td>
<td>-241</td>
</tr>
<tr>
<td>Mzimvubu to Keiskamma</td>
<td>1,122</td>
<td>854</td>
<td>374</td>
<td>0</td>
<td>0</td>
<td>480</td>
</tr>
<tr>
<td>Olifants</td>
<td>460</td>
<td>609</td>
<td>967</td>
<td>172</td>
<td>8</td>
<td>-194</td>
</tr>
<tr>
<td>Olifants/Doorn</td>
<td>156</td>
<td>335</td>
<td>373</td>
<td>3</td>
<td>0</td>
<td>-35</td>
</tr>
<tr>
<td>Thukela</td>
<td>859</td>
<td>737</td>
<td>334</td>
<td>0</td>
<td>506</td>
<td>103</td>
</tr>
<tr>
<td>Upper Orange</td>
<td>1,349</td>
<td>4,447</td>
<td>968</td>
<td>2</td>
<td>3,149</td>
<td>332</td>
</tr>
<tr>
<td>Upper Vaal</td>
<td>299</td>
<td>1,130</td>
<td>1,045</td>
<td>1,311</td>
<td>1,379</td>
<td>17</td>
</tr>
<tr>
<td>Usutu to Mhluzuze</td>
<td>1,192</td>
<td>1,110</td>
<td>717</td>
<td>40</td>
<td>114</td>
<td>319</td>
</tr>
</tbody>
</table>

(Source, DWAF, 2004, cited in Cessford and Burke, 2005)
1. Surpluses in the Vaal and Orange WMAs are shown in the most upstream WMA they become available.

2. Transfers of water may include transfers between WMAs by river or artificial transfer scheme, as well as to or from neighbouring countries. Yields transferred from one WMA to another may also not be numerically the same in the source and recipient WMA. For this reason, the addition of transfers into and out of WMAs does not necessarily correspond to the country total. The transfer of water from Lesotho to South Africa is reflected in the table as being from the Upper Orange WMA.

3. The yield takes into account the volume required for the ecological component of the Reserve, river losses, alien vegetation, rainfed sugar and urban runoff.

The major coal mining areas of the Witbank and Highveld coalfields fall largely within the Olifants and Upper Vaal WMAs shown in Table 54, and their small or negative balances indicate that water consumption is already nearing or exceeding sustainable water availability, despite existing water transfer schemes. The Waterberg coalfield, where future mining development is expected, is located in the Limpopo WMA. In 2004, this WMA was also consuming water at a rate that depleted the WMAs ecological reserve, although this is no longer the case due to the augmentation of water supplies from various sources through the Mokolo and Crocodile Water Augmentation Project (MCWAP) (See discussion below).

18.2.2 Infrastructure

As a result of water scarcity and uneven distribution in South Africa, the most important water-related infrastructure is that for water transport and storage. These are the inter-basin water transfer schemes with their associated dams, weirs, pumps, pipelines and canals, and the major storage dams. As shown in Figure 66, the large-scale transfer of water is widespread in South Africa, and only the areas of particular relevance to coal will be discussed here in detail.

Many of South Africa’s coal mines and Eskom’s major coal-fired power stations are located in the Mpumalanga Highveld. This region is water scarce and, as such, many industrial activities are almost entirely reliant on water from other areas. The area receives major water transfers from the Inkomati, Usutu and Upper Vaal catchments, but the water availability in the Vaal is itself augmented by further transfers from the Usutu and Thukela WMAs and Lesotho (DWAF, 2004c). Once the water has been transferred across watersheds through pipelines and pumping stations, several dams are important for storage, including Grootdraai, Jericho, Morgenstond, Westoe, Heyshop, Zaaihoek, and Witbank dams. Eskom’s coal-fired power stations use substantial volumes of cooling water in the region, for which critical water infrastructure is detailed in Table 55.

**Table 55: Water consumption and water source for the existing Eskom coal power stations**

<table>
<thead>
<tr>
<th>Power station</th>
<th>Water source</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnot</td>
<td>Komati Water Scheme, Nooitgedacht Dam</td>
<td>Basson et al. (2010)</td>
</tr>
<tr>
<td>Tutuka</td>
<td>Grootdraai Dam via the Usutu River Scheme</td>
<td>DWA (2011)</td>
</tr>
<tr>
<td>Matla</td>
<td>Usutu River Scheme, Jericho dam, Upper Vaal, Grootdraai Dam</td>
<td>Basson et al. (2010)</td>
</tr>
<tr>
<td>Duvha</td>
<td>Komati Water Scheme, Nooitgedacht Dam</td>
<td>Basson et al. (2010)</td>
</tr>
<tr>
<td>Kendal</td>
<td>Usutu River Scheme, Jericho Dam or Grootdraai dam</td>
<td>Basson et al. (2010)</td>
</tr>
<tr>
<td>Kriel</td>
<td>Usutu River Scheme, Grootdraai/Jericho dam</td>
<td>Basson et al. (2010); DWA (2011)</td>
</tr>
<tr>
<td>Camden</td>
<td>Usutu Scheme</td>
<td>Du Preez (2010)</td>
</tr>
<tr>
<td>Lethabo</td>
<td>Lethabo intake</td>
<td>Holman (2008)</td>
</tr>
<tr>
<td>Hendrina</td>
<td>Komati Water Scheme, Nooitgedacht Dam</td>
<td>Basson et al. (2010)</td>
</tr>
<tr>
<td>Matimba</td>
<td>Mokolo dam</td>
<td>Eskom (2010k)</td>
</tr>
<tr>
<td>Majuba</td>
<td>Zaaihoek Dam, Buffalo Catchment</td>
<td>WISA (2011)</td>
</tr>
<tr>
<td>Komati</td>
<td>Komati Water Scheme</td>
<td>Basson et al. (2010)</td>
</tr>
<tr>
<td>Grootvlei</td>
<td>Vaal Dam</td>
<td>Jackson (2011)</td>
</tr>
</tbody>
</table>
An extensive network of transfer and storage infrastructure provides water for Sasol's coal to liquids and chemicals facilities at Sasolburg and Secunda, including the Usutu-Vaal Scheme that routes water from the Usutu-Mhlatuzi WMA to the Grootdraai Dam (Sasol, 2008) and the Vaal River Eastern Subsystem Augmentation Project (VRESAP) which transfers from the Vaal Dam to supply Sasol's Secunda facilities (DWA, 2009).

Water resources in the Limpopo WMA, in which the Waterberg coalfield is located, have been developed too close to their limit. The aridity and flat topography of the area limit opportunities for further major dam construction, and would be further complicated by the Limpopo River being shared with neighbouring countries (DWAF, 2004c). There could, however, be possibilities for expanding interbasin transfers into the area. The Mokolo dam, south of Lephalale, is by far the largest dam in the Limpopo WMA with a capacity of 146 Mm³ (more than three times greater than the next largest), and total allocations\(^{47}\) of 39 Mm³/year (SAWEF, 2011).

18.2.3 Non-conventional sources of water

It has been generally assumed that because of water scarcity in the Waterberg region, only dry cooling for power generation can be considered. However, a factor that has changed in recent years is the cost of desalinating water, which with reverse osmosis membranes is in the region of R 6-10/m³ or less in some circumstances\(^{48}\). This raises the possibility of treating coal acid mine drainage from sources that are at present liabilities, and pumping treated water to other areas where it could be required, such as the Waterberg.

18.2.4 Policy and Legislation affecting water

The White Paper on a National Water Policy for South Africa (1997) provides the overarching policy for water for the country. The policy establishes the government as the custodian of the nation’s water, treated as a common resource, and exercising these powers as a public trust. The Paper guarantees the water required to “meet basic human needs and maintain environmental sustainability”, the water “Reserve”, as a right, with other water uses being recognised only if these uses are beneficial to public interest. The Paper stipulates that water is to be managed through both allocations and pricing mechanisms, with a move towards full cost pricing of water. Allocations are to take into consideration the investments made by the user in water infrastructure, and being limited to a certain time period. All major water use sectors are required to develop a water use, conservation and protection policy.

The White Paper was translated into legislation in the National Water Act (36 of 1998) and the Water Services Act of 1997 and amendment of 2004, and together these provide the legislative environment for water conservation and demand management in the country (DWAF, 2004b, d, e). The Water Act established an institutional framework for water management consisting of 19 Catchment Management Agencies who have devolved responsibility and authority for managing water resources (Fakir et al., 2005), and who are required to develop a catchment management strategy, including an allocation plan, for the resources under their jurisdiction. Water User Associations are established under the Act to represent local resource users. The Water Services Act established Water Services Authorities which are required to undertake Water Services Development Plans.

The National Water Act establishes a system of licensing for all water use apart from that identified in Schedule 1 of the Act, which encompasses individual use, or those governed by specific authorisations. In particular, a licence is required to draw water directly from a water resource, and licenses are by their nature temporary. Water charging is undertaken to cover the cost of managing the water resources, and is done according to a use and polluter pays principle.

Specific activities are identified for regulation under the National Water Act, and include stream reductant activities, irrigation using waste or water containing waste from certain sources, modification of atmospheric precipitation, altering the flow regime of a water resource as a result of power generation, and aquifer recharge using waste or water containing waste. In terms of water pollution, the Act identifies the person who owns, controls, occupies or uses land as being responsible for remediying any pollution of water resources, and in the case of emergency incidents, the person responsible for the incident is liable for it. Industrial users who draw their water directly from a resource have to submit a water management programme as part of the their environmental management plan. The National Water Act recognises power generation as a strategic use of water (DWAF, 2004e).

A National Water Resource Strategy was developed under the National Water Act in 2004, and identifies how the country aims to achieve integrated water resources management, and co-ordination and collaboration amongst all government departments on issues related to water. The Strategy is to be reviewed every five years.

Under the National Water Resources Strategy lie the National Water Conservation and Water Demand Management Strategy. The objective of this strategy is to promote a culture of water conservation and demand management throughout the country, and to facilitate and implement water conservation and demand management activities as an efficient way of managing South Africa’s water resources. Three Water Management and Water Demand Management sectoral strategies fall under this general strategy: industry, mining and power generation sectors, the water services sector, and agriculture. The sector level strategies have the objective of pursing and implementing opportunities for water efficiency and water demand management at a sectoral level, with the industry, mining and power generation document being most pertinent to the coal value chain. Opportunities identified by

\(^{47}\) This is expressed as the equivalent volume at 99.5% assurance of supply.

\(^{48}\) Gunter Renken, Veolia Water Solutions & Technologies South Africa (Pty) Ltd
this Strategy include: new water efficient technologies, close circuit re-use of water within an industry or mine, re-use of water form other sectors, pollution abatement technologies within an industry, and self regulation through standards set by the international market. The industry, mining and power generation sector has the following strategic outputs identified under the Strategy: carry out ongoing water audit and water balance; benchmark as far as possible water use for various activities, monitor performance against these benchmarks, implement a water conservation programme and undertake marketing and publicise water conservation. The Strategy identifies that pricing of water resources for waste discharge has shown to be an effective way of achieving desired levels of pollution internationally, but that South African industry may not yet be ready for a waste discharge charge system. The basis of water management at mines is the wastewater hierarchy (pollution prevention; water re-use or reclamation; water treatment; discharge). This requires an integrated water management system at each mine.

18.3 Likely evolution of water demand and supply

The previous discussion outlines the status quo with respect to water supply and demand issues in the mining sector. Consideration is now given to some of the water-related issues moving into the future. In particular, any expansion of mining activities within the Waterberg coalfield district will result in significantly increased demand, both from the coal value chain itself and from associated development in the region. The Waterberg coalfields fall within the Limpopo WMA which will require augmentation by means of inter-basin transfers to support these developments. The discussion first focuses on the Waterberg, and then looks at the remainder of the country.

Given that South Africa in general (and the Waterberg region in particular) is classified as water scarce, coal mining and related industries will need to deploy more water-efficient technologies. Technologies for reducing water consumption are presented along with the discussion on the individual value chain elements.

18.3.1 The Waterberg

In 2006, an estimated 87% of water use in the water catchment of the Waterberg was dedicated to agricultural applications (van Vuuren, 2006). However, water demand for coal mining, beneficiation and processing purposes is anticipated to escalate steadily as a result of investments by Eskom and major coal mining companies (Jeffrey, 2005; Basson et al., 2010). Exxaro is expanding its existing operation at the Grootgeluk colliery in the Waterberg to supply coal to Eskom’s Medupi power station, which is currently under construction. Medupi is planned to be commissioned in nine-month stages from 2012 to 2015 (Eskom, 2010b).

Water demand for the full operation of the first three units of Medupi without flue gas desulphurisation will be met by unused allocation to Matimba power station from the Mokolo Dam (2.9 Mm³/year). The licence for this allocation to Medupi Power Station was issued in February 2009. The additional water requirement to operate all six dry-cooled units of Medupi power station is 6 Mm³/year once the plant is fully operational without FGD and 14 Mm³/year when FGD is online (SAWEF, 2011). FGD is anticipated to be completed towards 2018 (Eskom, 2010a).

In addition to Medupi, there is the potential for further power station build in the Waterberg. The promulgated IRP2010 suggests 1 GW of FBC by IPPs in 2014-15, and a further allocation of 5.25 GW of coal-fired generation in the period 2019-2030 from PF, FBC, import and own build. Although the location of new build remains flexible, some of this will certainly be in the Waterberg. Furthermore, there is considerable interest in additional mining operations, as well as the possibility of Mafutha, a further Sasol coal-to-liquids plant, being established in the area. Mafutha is at the pre-feasibility stage, with the study including an ongoing assessment of water availability (Sasol, 2010a). Even assuming greater water efficiency than existing plants, it is expected to require in the order of 40 Mm³/a of water (von Ketelhodt, 2011).

As illustrated in Figure 67 below, a high demand scenario used in the in planning for the construction of a transfer pipeline indicates that future water requirement in the Lephalale district cannot be met by the Mokolo dam yield alone. Any significant future development in the Waterberg area will require large volumes of water to be imported from other catchments.

---

49 Accounting for water needs by 5 power stations, new coal mines and the Sasol CTL plant as well as secondary and tertiary developments
Several options for the augmentation of water supplies have been evaluated (Basson et al., 2010). These include (van den Berg, O., 2011):

- **Mokolo Dam (Existing supply):** a switch from irrigation to game and cattle farming in the catchment has resulted in significant increase in yield;
- **Return Flows in Crocodile West River (Future supply indirectly imported via Vaal River system);**
- **Augmentation from the Vaal River;**
- **Further options (important but limited):** Groundwater, water conservation and demand management, re-use of local return flows.

The Mokolo and Crocodile Water Augmentation Project (MCWAP), illustrated in Figure 68, is planned to deliver water from the Crocodile (West) & Marico WMA to the Mokolo dam, which will supply Medupi (Eskom, 2010a) amongst other water needs in the area. The first phase of MCWAP streamlines the use of Mokolo dam’s current water supply through upgrading and building new pipelines (Neville Bews and Assoc., 2010), and will result in sufficient water delivery in 2013 for all water requirements associated with Medupi excluding water for flue gas desulphurisation (Eskom, 2009b). Medupi’s FGD facility is planned to be completed by end 2018 (Eskom, 2010a), making use of water from the second phase of the MCWAP which will see the transfer of water from the Crocodile West River to the Mokolo dam. Return flows from wastewater treatment works of Johannesburg and Pretoria (water which originates from the Vaal River system but is discharged into the Crocodile River) will contribute to the volumes transferred to the Waterberg (SAWEF, 2011).

**Figure 68: Proposed Mokolo water scheme**

(Source: Govender 2009)
A feasibility study on the necessary infrastructure to enable the transfers (pipelines, pumping stations and reservoirs) is underway. However, the Crocodile River system will not be sufficient to provide for all the proposed development of the Waterberg coalfields. Water deficit in the region is to be supplied by further phases of MCWAP or other sources such as municipal return flows and groundwater (SAWEF, 2011). An option under consideration is the northward re-routing of municipal effluent from the south of Johannesburg, which currently discharges into the Vaal, into the Crocodile system (DWA, 2009).

The timing and capacity of Phase II of the MCWAP is subject to the requirement for additional water in the Waterberg (e.g. further coal mining activity, any shortfall on Medupi’s FGD requirements, and associated town and other developments), although indications are that all is technically ready for 110 Mm³/year of water at R 18/m³ (total cost) (van den Berg, O., 2011). The execution of Phase II is reliant on the up-front commitment of users in terms of the National Water Pricing Strategy (SAWEF, 2011).

In the long term, extensive development in the Waterberg would rely on water sourced at much higher cost from further afield (Basson et al., 2010).

### 18.3.2 The Mpumalanga coalfields

As active mining relocates to new areas, substantial redistribution of the mining industry’s water demand is expected. The current water requirement for mining in the water scarce region of the upper Olifants River catchment, where many of the Mpumalanga coal mines are located, is anticipated to drop from 68 Ml/day (2001 level) to 27 Ml/day in 2020 (Table 56).

**Table 56: Current and projected water usage in the upper Olifants River catchment**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
<td>211</td>
<td>211</td>
<td>0</td>
</tr>
<tr>
<td>Stock watering</td>
<td></td>
<td>16</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Urban and industrial</td>
<td></td>
<td>173</td>
<td>504</td>
<td>331</td>
</tr>
<tr>
<td>Mining</td>
<td></td>
<td>68</td>
<td>27</td>
<td>-41</td>
</tr>
<tr>
<td>Power station*</td>
<td></td>
<td>479</td>
<td>625</td>
<td>146</td>
</tr>
<tr>
<td>Total (excluding power station)</td>
<td></td>
<td>468</td>
<td>761</td>
<td>237</td>
</tr>
<tr>
<td>Total (including power station)</td>
<td></td>
<td>947</td>
<td>1,385</td>
<td>483</td>
</tr>
<tr>
<td>Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine water decant</td>
<td></td>
<td>44</td>
<td>131</td>
<td>87</td>
</tr>
</tbody>
</table>

(Source: van Zyl et al., 2001)

Note, however, that overall demand in the upper Olifants River catchment will have increased substantially to 1,385 Ml/day by 2020, and hence mines in the area can expect greater water stress in the future, despite their lowered aggregate demand. Balancing supply with demand in 2020 will require optimised use of water resources, including reclamation of mine water and transfer of water from other catchments (van Zyl et al., 2001). Eskom’s older return-to-service stations will contribute significantly to water demand in the region, including Komati, Grootvlei and Camden which make use of wet cooling and ashing (Eskom, 2010a). Among the key water supply infrastructure which will deliver water to Eskom is the Komati Water Scheme Augmentation Project (KWSAP) (Eskom, 2010a).

### 18.3.3 Other regions

It has been predicted that the future water needs of all major urban and industrial centres in South Africa can be met by increasingly interconnected and interdependent networks, but that water costs will see steep increases in most regions (Basson et al., 2010). Total water supply cannot be extended significantly through new schemes as in the past. In general, water supply in South Africa will need to be managed in more efficient ways through extensive planning of supply for existing demand as well as for new development centres (SAICE, 2009).

Table 57 provides a summary of the current and planned “Mega Infrastructure Projects”, their capacities, estimated completion dates and budgets (DWAF, 2010; Basson et al., 2010).

**Table 57: Major water infrastructure projects**

<table>
<thead>
<tr>
<th>Project description</th>
<th>Capacity [Mm³/year]</th>
<th>Completion period</th>
<th>Budget [Rand]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmentation of Eastern Vaal Subsystem (VRESAP pipeline) (Gauteng/ Mpumalanga)</td>
<td>172</td>
<td>2010</td>
<td>2.6 billion</td>
</tr>
<tr>
<td>Luuvhu River GWS: Nandoni Water treatment works (Limpopo) Bulk Distribution Works (Limpopo)</td>
<td></td>
<td>2010</td>
<td>405 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012</td>
<td>787 million</td>
</tr>
<tr>
<td>Olifants River Water Resources Development Project Phase 1: De Hoop Dam (Limpopo)</td>
<td>80</td>
<td>2012</td>
<td>2.6 million</td>
</tr>
<tr>
<td>Sabie River GWSL Inyaka Water Treatment Works (Mpumalanga) Inyaka PH 3 Comp Inyaka PH 3 Comp</td>
<td></td>
<td>2012</td>
<td>424 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>290 million</td>
</tr>
<tr>
<td>Hihihule Regional water bulk distribution project</td>
<td></td>
<td>2012</td>
<td>290 million</td>
</tr>
<tr>
<td>Nwamitwa Dam</td>
<td>14</td>
<td>2015</td>
<td>1.032 billion</td>
</tr>
<tr>
<td>Raising of Clanwilliam Dam wall</td>
<td></td>
<td>2015</td>
<td>1.173 billion</td>
</tr>
<tr>
<td>Dam Safety Rehabilitation Programme projects</td>
<td></td>
<td>2010</td>
<td>414.5 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>440.8 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012</td>
<td>288.8 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2013</td>
<td>72.2 million</td>
</tr>
</tbody>
</table>

(Sources: DWAF, 2010 and Basson et al., 2010)
A summary of potential water resource development options for various WMAs is provided below in Figure 69.

**Figure 69: Progress in potential water development projects as at March 2010**

- **Reconnaissance Phase**
  - **Vaal**
  - **Orange**
  - **Lephalale**
  - **KZN Coastal**
  - **Groundwater**
  - **Surface water**
  - **Re-use of water**
  - **Acid mine drainage**
  - **Importation of water**
  - **Desalination of seawater**
  - **Capacity (million m$^3$/a)**
    - Vaal: 660+ million m$^3$/a
    - Orange: 3110+ million m$^3$/a
    - Lephalale: 1900+ million m$^3$/a
    - KZN Coastal: 770 million m$^3$/a
    - Groundwater: 190 million m$^3$/a
    - Surface water: 880 million m$^3$/a
    - Re-use of water: 110 million m$^3$/a
    - Acid mine drainage: 250 million m$^3$/a
    - Importation of water: 370 million m$^3$/a
    - Desalination of seawater: 2790+ million m$^3$/a

- **Pre-feasibility Phase**
  - **Vaal**
  - **Orange**
  - **Lephalale**
  - **KZN Coastal**
  - **Groundwater**
  - **Surface water**
  - **Re-use of water**
  - **Acid mine drainage**
  - **Importation of water**
  - **Desalination of seawater**
  - **Capacity (million m$^3$/a)**
    - Vaal: 200+ million m$^3$/a
    - Orange: 200+ million m$^3$/a
    - Lephalale: 50+ million m$^3$/a
    - KZN Coastal: 218 million m$^3$/a
    - Groundwater: 53 million m$^3$/a
    - Surface water: 13 million m$^3$/a
    - Re-use of water: 14 million m$^3$/a
    - Acid mine drainage: 14 million m$^3$/a
    - Importation of water: 111 million m$^3$/a
    - Desalination of seawater: 55 million m$^3$/a

- **Feasibility Phase**
  - **Vaal**
  - **Orange**
  - **Lephalale**
  - **KZN Coastal**
  - **Groundwater**
  - **Surface water**
  - **Re-use of water**
  - **Acid mine drainage**
  - **Importation of water**
  - **Desalination of seawater**
  - **Capacity (million m$^3$/a)**
    - Vaal: 100+ million m$^3$/a
    - Orange: 50+ million m$^3$/a
    - Lephalale: 60+ million m$^3$/a
    - KZN Coastal: 126 million m$^3$/a
    - Groundwater: 32 million m$^3$/a
    - Surface water: 110 million m$^3$/a
    - Re-use of water: 18 million m$^3$/a
    - Acid mine drainage: 110 million m$^3$/a
    - Importation of water: 80 million m$^3$/a
    - Desalination of seawater: 33 million m$^3$/a

- **Decision Support Phase**
  - **Vaal**
  - **Orange**
  - **Lephalale**
  - **KZN Coastal**
  - **Groundwater**
  - **Surface water**
  - **Re-use of water**
  - **Acid mine drainage**
  - **Importation of water**
  - **Desalination of seawater**
  - **Capacity (million m$^3$/a)**
    - Vaal: 250 million m$^3$/a
    - Orange: 100 million m$^3$/a
    - Lephalale: 30 million m$^3$/a
    - KZN Coastal: 190 million m$^3$/a
    - Groundwater: 16 million m$^3$/a
    - Surface water: 300 million m$^3$/a
    - Re-use of water: 13 million m$^3$/a
    - Acid mine drainage: 190 million m$^3$/a
    - Importation of water: 80 million m$^3$/a
    - Desalination of seawater: 55 million m$^3$/a

- **Design/Documentation Phase**
  - **Vaal**
  - **Orange**
  - **Lephalale**
  - **KZN Coastal**
  - **Groundwater**
  - **Surface water**
  - **Re-use of water**
  - **Acid mine drainage**
  - **Importation of water**
  - **Desalination of seawater**
  - **Capacity (million m$^3$/a)**
    - Vaal: 200+ million m$^3$/a
    - Orange: 100+ million m$^3$/a
    - Lephalale: 50+ million m$^3$/a
    - KZN Coastal: 218 million m$^3$/a
    - Groundwater: 53 million m$^3$/a
    - Surface water: 13 million m$^3$/a
    - Re-use of water: 14 million m$^3$/a
    - Acid mine drainage: 14 million m$^3$/a
    - Importation of water: 111 million m$^3$/a
    - Desalination of seawater: 55 million m$^3$/a

- **Construction Implementation Phase**
  - **Vaal**
  - **Orange**
  - **Lephalale**
  - **KZN Coastal**
  - **Groundwater**
  - **Surface water**
  - **Re-use of water**
  - **Acid mine drainage**
  - **Importation of water**
  - **Desalination of seawater**
  - **Capacity (million m$^3$/a)**
    - Vaal: 100+ million m$^3$/a
    - Orange: 50+ million m$^3$/a
    - Lephalale: 60+ million m$^3$/a
    - KZN Coastal: 126 million m$^3$/a
    - Groundwater: 32 million m$^3$/a
    - Surface water: 110 million m$^3$/a
    - Re-use of water: 18 million m$^3$/a
    - Acid mine drainage: 110 million m$^3$/a
    - Importation of water: 80 million m$^3$/a
    - Desalination of seawater: 33 million m$^3$/a

- **Overall Progress**
  - Vaal: 3110+ million m$^3$/a
  - Orange: 200+ million m$^3$/a
  - Lephalale: 50+ million m$^3$/a
  - KZN Coastal: 218 million m$^3$/a
  - Groundwater: 53 million m$^3$/a
  - Surface water: 13 million m$^3$/a
  - Re-use of water: 14 million m$^3$/a
  - Acid mine drainage: 14 million m$^3$/a
  - Importation of water: 111 million m$^3$/a
  - Desalination of seawater: 55 million m$^3$/a

*Details of water development projects are as follows:*

- **Surface water projects**:
  - Zambezi transfer
  - Vaal water transfer
  - Olifants Dam
  - KZN Coastal

- **Groundwater projects**:
  - Mzimvubu-Vaal transfer
  - Lower Sundays River RF
  - West Coast Aquifer
  - Cape Flats Aquifer
  - Cape Flats Augment
  - Mokolo Crocodile Augment
  - Re-use of wastewater

- **Desalination projects**:
  - Lower Thukela-Mhlatuze Transfer
  - Desalination
  - Re-use of water

- **Acid mine drainage projects**:
  - Thukela-Vaal (Jana)
  - Thukela-Vaal (Mielietuin)

- **Other projects**:
  - Use of acid mine drainage
  - Importation of water
  - Desalination of seawater
  - Use of effluent from Vaal
  - Re-use of water
  - Acid mine drainage

*Phases of development:

- **Reconnaissance Phase**: 660+ million m$^3$/a
- **Pre-feasibility Phase**: 200+ million m$^3$/a
- **Feasibility Phase**: 100+ million m$^3$/a
- **Decision Support Phase**: 250 million m$^3$/a
- **Design/Documentation Phase**: 200+ million m$^3$/a
- **Construction Implementation Phase**: 250 million m$^3$/a
18.3.4 The ecological and energy cost of future water demand

Whilst bulk water transfers ease water scarcity in the receiving catchments, their true costs extend beyond volumetric flows alone. Inter-catchment transfers cause significant ecosystem disturbance through alien species introductions, altered flow regimes and changes to physico-chemical characteristics. They have been associated with mass fish mortality, enhanced erosion, groundwater changes including salinisation of surrounding lands and the transfer of pest organisms to new territories (Slabbert, 2007). It should also be borne in mind that whilst transfers typically ease water stress, they reduce water availability in the catchment of origin.

Besides the potential ecological cost, it has been projected that in order to deliver water from various new infrastructure developments around the country, about 1,000 MW will be required by 2050, as is indicated for the various regions in Figure 70 below (Basson et al., 2010). The future pumping of water to the Vaal River system and the desalination of seawater for supply to the Western Cape are predicted as the main contributors to this additional energy requirement.

Figure 70: Energy requirements for projected future water developments

(Source: Basson et al., 2010)
19.1 What is climate change and what is causing it?

Scientific evidence has demonstrated that levels of greenhouse gases (GHGs) in the atmosphere are increasing, and that these increases are linked to increased industrialisation, human activity and population. The concentration of GHGs has increased from pre-industrial revolution concentrations of 280 parts per million (ppm) carbon dioxide equivalent (CO$_2$e) to about 391 ppm CO$_2$e in January 2010. Current levels are higher now than at any time in 650,000 years (Forster et al., 2007; ESRL, 2011; IPCC, 2011).

Evidence also exists that this increase in levels of greenhouse gases is already contributing to changes in the planet’s climate. Examples include increases in global average air and ocean temperatures, melting of snow and ice, rising global mean sea level, rainfall changes, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and intensity of tropical cyclones. As discussed further below, it is anticipated that the frequency of these climate change events will continue to increase, and will be catastrophic for life on the planet – not necessarily affecting everyone in the same way, and not at the same time.

The evidence on which these statements are based originates from thousands of international academic and other studies. The Intergovernmental Panel on Climate Change (IPCC) is a scientific body, which collates evidence from these studies to provide decision-makers and other stakeholders with an objective source of climate change information. The most comprehensive analyses are contained in the IPCCs Assessment Reports, of which the fourth was completed in 2007, and the fifth is underway at the time of writing (IPCC, 2011).

The so-called “greenhouse effect” works as follows. The GHGs act as a blanket that traps heat from the sun, which would otherwise be reflected back from the earth’s surface into the atmosphere (see the Figure below). A certain level of GHGs is necessary, otherwise the planet would be too cold and uninhabitable. Too much heat being trapped in the atmosphere results in a rise in temperature and a series of knock on effects, collectively known as climate change.

The United Nations Framework Convention on Climate Change (UNFCCC) recognises six priority greenhouse gases, although others also exist:

- carbon dioxide (CO$_2$);
- methane (CH$_4$);
- nitrous oxide (N$_2$O);
- perfluorocarbons (PFCs);
- hydrofluorocarbons (HFCs); and
- sulphur hexafluoride (SF$_6$).

These gases differ in the extent to which they reflect heat, otherwise known as their radiative forcing. This is often expressed relative to that of CO$_2$. It has become convention to express GHGs as carbon dioxide equivalents (CO$_2$e) by multiplying by their radiative forcing or global warming potential (GWP). The relative radiative forcing of the different greenhouse gases which are covered under the Kyoto Protocol is shown in Table 58. It is noted that the IPCC updates these at various times; the values below are the most recent at the time of writing.

---

**Figure 71: The greenhouse effect**

(Source: adapted from University of Oregon, 2009)

Note that hydrofluorocarbons and perfluorocarbons are families of gases, each with different GWPs.
Aerosols, which occur due to anthropogenic activities and natural events such as volcanic eruptions, also have an impact on global warming and hence climate change. However, these result in a cooling rather than a heating effect, thus countering some of the warming effects of anthropogenic greenhouse gases (IPCC, 2007).

### 19.2 Likely impacts of climate change

Changes in climate have already been observed in South and Southern Africa\(^5\). These include (Midgley et al., 2007; DST, 2010):

- Air temperatures over the past thirty years have increased and higher maximum temperatures have been recorded for the western and southern half of the country, and the north-west region. There are fewer frost days, particularly on the inland plateau.

- No strong trends have been detected in the amount of rainfall over the century. There is, however, some evidence of drying in the north-west, and wetting in the north-east since the 1950s.

- Significant increases in the intensity of extreme rainfall events have been identified over more than two thirds of the country.

The extent of climate change impacts going into the future cannot be stated with certainty, due to uncertainties in the degree by which emissions will continue to grow, and those around the potential feedback mechanisms associated with climate change – certain effects may cause a reinforcement of other effects. To account for the uncertainty surrounding climate change, scenario analysis is used to map out the full extent of possible impacts (Boko et al., 2007; Midgley et al., 2007).

Global circulation models (GCMs) have become the primary tools for the projection of climate change impacts. These mathematical models, which are based on the laws of physics, are used to estimate the changes in the structure of the atmosphere that may take place in response to the effects illustrated in Figure 71, under different scenarios (DST, 2010). Six scenarios are considered in the IPCC reports, with the temperature rises being seen in three of the likely scenarios being as follows (IPCC, 2007):

- In the scenario which considers global convergence on climate change and a move towards a more information and service economy (the so-called B1 scenario), and the CO\(_2\)e of the combined radiative forcing of greenhouse gases and aerosols in the atmosphere reaches 600 ppm by 2100. This results in a “best estimate” of the temperature increase of 1.8°C by 2090-2099, with a range of 1.1 to 2.9°C.

- Scenario A1B considers a future in which there is a balance between fossil and non-fossil sources of energy globally, and thus the CO\(_2\)e of the combined radiative forcing of greenhouse gases and aerosols in the atmosphere is higher, at 850 ppm. This scenario results in an estimated 2.8°C rise in temperature by 2090 – 2099, with a range of anywhere from 1.7 to 4.4°C.

- The A1F1 scenario, that of a fossil and greenhouse gas intensive future, results in CO\(_2\)e levels equivalent to 1,550 ppm, and a temperature increase of between 2.4 and 6.4°C, with a best estimate of 4°C.

Some examples of the predicted impacts of such increase in global temperature are shown in Figure 72. Note that here the black lines link the different impacts while the broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of the impact.

It is clear from this figure that many of the impacts start at below 1°C rise in temperature. With a 2°C rise in temperature, considered to be inevitable unless drastic mitigation action is taken, climate change will impact the planet significantly (IPCC, 2007).

\(^5\) Southern Africa includes Botswana, Angola, Zambia, etc.
Various studies have explored the predictions of likely future climate change impacts and vulnerabilities for South Africa. These include (DST, 2010; Midgley et al., 2007):

- Temperature increases of between about 1°C and 3°C across the country over the next three to five decades, and 2°C to 4°C across South Africa over the next six to nine decades. The greatest increases in temperature will be in the interior, with coastal areas being at the bottom of the indicated range.

- Summer rainfall regions are suggested to become drier in spring and autumn, although summer rainfall totals are likely to increase. There is a likely decrease in rainfall over the winter rainfall region of South Africa and the western margins of Southern Africa.

- The impacts of climate change on the intensity and frequency of rainfall events remain uncertain. Some models suggest possible increases in rainfall intensity and drought duration, and an increased risk of flood damage in extreme rainfall events, particularly in urban areas, which in turn will impact on urban infrastructure such as roads and stormwater drains, and disaster management costs.

- Evapotranspiration will increase by between 5 and 15% throughout the region by about 2050, primarily as a result of increased temperatures. This will result directly in a reduction in water in rivers and groundwater bodies.

- Heat stress will reduce the productivity of some crops and livestock. Irrigation requirements for crops in the summer rainfall region are projected to increase between by between 10 and 30% throughout southern Africa by about 2050. A reduction in soil moisture levels resulting from climate change could result in changed runoff generation and dryland agriculture, although this effect will interplay with uncertain rainfall changes.

- More frequent fires are expected in dominant ecosystems, such as Fynbos, Grasslands and Savanna.

- Gauteng's grassland biome will become more favourable for tree growth due to higher temperatures, and possibly due to elevated CO₂. The grassland biome is one of the most endangered biomes in South Africa (Scholes et al., 2000).

---

**Figure 72: Examples of global impacts of a rise in temperature**

<table>
<thead>
<tr>
<th>WATER</th>
<th>Increased availability in moist tropics and high latitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes</td>
</tr>
<tr>
<td></td>
<td>Hundreds of millions of people exposed to increased water stress</td>
</tr>
<tr>
<td></td>
<td>Up to 30% of species at increasing risk of extinction</td>
</tr>
<tr>
<td></td>
<td>Significant extinctions around the globe</td>
</tr>
<tr>
<td></td>
<td>Increased coral bleaching</td>
</tr>
<tr>
<td></td>
<td>Most corals bleached</td>
</tr>
<tr>
<td></td>
<td>Widespread coral mortality</td>
</tr>
<tr>
<td></td>
<td>Terrestrial biosphere tends toward a net carbon source as:</td>
</tr>
<tr>
<td></td>
<td>-15%</td>
</tr>
<tr>
<td></td>
<td>-40% of ecosystems affected</td>
</tr>
<tr>
<td></td>
<td>Increasing species range shifts and wildfire risk</td>
</tr>
<tr>
<td></td>
<td>Ecosystem changes due to weakening of the meridional overturning circulation</td>
</tr>
<tr>
<td>FOOD</td>
<td>Complex, localised negative impacts on small holders, subsistence farmers and fishers</td>
</tr>
<tr>
<td></td>
<td>Tendencies for cereal productivity to decrease in low latitudes</td>
</tr>
<tr>
<td></td>
<td>Productivity of all cereals decrease in low latitudes</td>
</tr>
<tr>
<td></td>
<td>Tendencies for some cereal productivity to increase at mid- to high latitudes</td>
</tr>
<tr>
<td></td>
<td>Cereal productivity to decrease in some regions</td>
</tr>
<tr>
<td>COASTS</td>
<td>Increased damage from floods and storms</td>
</tr>
<tr>
<td></td>
<td>About 30% of global coastal wetlands lost</td>
</tr>
<tr>
<td></td>
<td>Millions more people could experience coastal flooding each year</td>
</tr>
<tr>
<td>HEALTH</td>
<td>Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases</td>
</tr>
<tr>
<td></td>
<td>Increased morbidity and mortality from heat waves, floods and droughts</td>
</tr>
<tr>
<td></td>
<td>Change distribution of some disease vectors</td>
</tr>
<tr>
<td></td>
<td>Substantial burden on health services</td>
</tr>
</tbody>
</table>

† Significant is defined here as more than 40% §Based on average rate of sea level rise of 4.2mm/year from 2000 to 2080.
In addition to the impacts on the biophysical environment, climate change is likely to have knock-on impacts on society and the economy. Such implications for South Africa include:

- Health impacts will arise due to changes in mean and extreme temperatures, droughts and floods, air pollution, diseases and indirectly through impact on rural livelihoods. Increasing extreme rainfall events and rising temperature favour expansion of diseases such as malaria.
- Production and income activities and other livelihood activities are likely to be affected by climate change and variability by ~ 2050, particularly in rural areas where rainfall affects agriculture and natural resources.
- The possibility exists of environmental migrants and refugees, seeking opportunities, which could impact further on the environment and the economy.
- South Africa’s economic competitiveness is at risk due to the emissions intensity of our economy. If other countries impose border tax adjustments on imports from South Africa to take into account the embedded carbon in products, this could impact significantly on the local economy.

19.3 South Africa’s greenhouse gas emissions

The last official greenhouse gas inventory, which quantifies the sources of sources of emissions, was conducted for the year 2000 (DEAT, 2009). The total emissions in that year, including land use, land use change and forestry were 442.5 Mt CO₂e. Of this, 78.9% was associated with energy supply and consumption.

19.4 Reducing greenhouse gas emissions: Greenhouse gas mitigation

Greenhouse gas mitigation refers to technological and other interventions that serve to reduce GHG emissions associated with human activities, through technological and behavioural/societal changes.

19.4.1 International and local commitments to reducing greenhouse gas emissions

With increased awareness of the likely impacts of climate change, governments globally are setting targets for the reduction of emissions. The United Nations Framework Convention on Climate Change was established by international treaty to explore what could be done to reduce global warming and cope with the impacts thereof. The Kyoto Protocol was included as an addition to the treaty under which signatories in developed countries were required to reduce emissions to, on average, 5% below 1990 levels to be achieved between 2008 and 2012. Developing countries who are signatories, including South Africa, do not have emission reduction commitments in this period, but can partner developed countries in emission reduction projects. The primary mechanism for doing so is the Clean Development Mechanism or CDM (UNFCCC, 2011a).

By the end of the first commitment period in 2012, a new international framework needs to have been negotiated and ratified. Progress towards agreement on this framework has been challenging, with a number of sticking points on burden sharing being encountered.

The South African government has been proactive in preparing for the eventuality that it will have emission reduction targets in a future commitment period. In December 2009, just prior to the United Nations climate negotiations in Copenhagen, the Presidency pledged that South Africa would undertake mitigation actions, which will reduce carbon emissions to below a business as usual trajectory by 34% by 2020 and by 42% by 2025. This pledge is conditional on financial, technological and capacity building support from developed countries, and a fair, effective and binding multilateral agreement to enable delivery of this support.

The South African pledge was included in the Copenhagen Accord, where 138 developed and developing countries accounting for 87% of global emissions have listed GHG emissions reduction pledges within a single document, demonstrating that there is a broad commitment within the international community to fight climate change. It was later made more formal in the Cancun Agreements.

Finally, South Africa is also actively involved in negotiations and discussions with the BASICs and BRICS countries around allocation of climate mitigation effort sharing.

The Copenhagen pledges along with other climate change mitigation activities in South Africa including the proposed carbon tax, and discussions with alliances such as BASICs and BRICS, and globally, have a number of implications for industry. Firstly, emission reduction targets are likely to be placed on the largest GHG emitting sectors of the economy – most notably the energy sector being the largest contributor to the country’s emissions. Secondly, if a carbon tax is implemented, (see the discussion below) there could be financial implications. Finally, export markets could be affected if foreign demand, particularly in the Northern Hemisphere, moves away from coal and carbon-intensive products. There have also been indications that certain developed country governments could move to introduce carbon taxes on carbon-intensive imported products (known as “border tax adjustments”).

Eskom and Sasol have recognised the relevance of climate change for their businesses, and are actively pursuing climate change response strategies, including support for the development of carbon capture and storage (CCS), discussed below. The response of the mining industry is represented in Box 18.
A survey conducted in 2010 to gauge the mining industry’s response to climate change (for the industry as a whole and not just coal) found the following:

- Generally, mining organisations are adopting a “wait and see” approach to actions involving climate change.
- Less than 20 percent of respondents stated that climate change is a significant driver for new initiatives in their organisation.
- Almost 50 percent of the respondents said that their organisation has not quantified the potential cost of climate change on their business.
- Approximately 60 percent of the respondents said that their organisation has not implemented structural changes to address climate change issues.
- Over 60 percent of the organisations, according to respondents, have not measured their carbon footprint and do not include climate change in dealings with suppliers and customers.
- The lack of progress is not from scepticism about climate change but from the difficulties of building a quantifiable business case for addressing climate change.
- There is a diversity of opinion among senior executives about climate change and the best strategies for dealing with sustainability and regulatory compliance.

(Source: KPMG, 2010)

19.4.2 Local policy and legislation related to climate change

The Department of Environment is leading the country’s climate change policy response, with a National Climate Change Response Green Paper out for comment at the time of writing. It is anticipated that this will lead to a White Paper within the year. However, given the extent and reach of the issue, many other departments and government bodies are impacted by climate change, and are therefore including climate change in emerging policy.

For the decade prior to the release of the Green Paper, a series of white papers, research reports and other documents on climate change were developed and populate the climate policy space. These include:

- First (DEAT, 2000) and Second (under development) National Communications to the United Nations Framework Convention on Climate Change (UNFCCC, 2011b),
- 2004 Climate Change Response Strategy (DEAT, 2004),
- 2005 Technology Needs Assessment (DST, 2007),
- Long Term Mitigation Scenarios (LTMS) process (SBT, 2007),
- African National Congress’s 2007 Polokwane Resolution on Climate Change (ANC, 2007),
- 2008 Cabinet Response to the LTMS, outlining a strategic mitigation vision based on a “Peak, Plateau and Decline” trajectory (van Schalkwyk, 2008),
- International pledges to reduce emissions by 34% and 42% from business as usual by 2020 and 2025 subject to international financial and technical assistance, made at the 2009 Copenhagen Conference of the Parties to the Kyoto Protocol (South African Office of the Presidency, 2009).

The Green Paper considers both climate change mitigation and adaptation. In the introduction to the paper, the government acknowledges the need for an “efficient international implementation of an effective and binding global agreement on, among others, greenhouse gas emission reductions”, and that South Africa is committed to reducing its greenhouse gas emissions in order to secure such an agreement (DEA, 2010b). The paper therefore presents a vision of a “climate resilient and low-carbon economy and society” (DEA, 2010b). A number of principles guide the achievement of this vision, including both the precautionary principle which advocates a risk-averse and cautious approach, and the polluter pays principle, which determines that those responsible for harming the environment must pay for the costs of remedying this damage.

From the perspective of mitigation, the Paper confirms a peak, plateau and decline trajectory, with the peak being characterised by the Copenhagen pledges, a plateau until 2035, and a decline in real terms from 2036. This trajectory has been described as a shift “from an energy-intensive to a climate-friendly path as part of a pro-growth, pro-development and pro-jobs strategy” (van Schalkwyk, 2008). The business as usual baseline which accompanies the Copenhagen pledges is not specifically defined (DEA, 2011), resulting in a degree of ambiguity in these near term targets which the Green Paper does not clarify. The energy, transport and industrial sectors will be prioritised for mitigation interventions, and those which support job creation, poverty alleviation and have other positive economic impacts will further be prioritised.
In the energy sector, the Green Paper states that in future continued reliance on coal may jeopardise the country’s international competitiveness, and that limited availability of finance for large scale fossil fuel infrastructure is emerging as “a potential risk to new coal fired power stations” (DEA, 2010b). The paper identifies energy efficiency, renewables and nuclear as playing key roles in South Africa’s future low carbon economy, but defers more detail on the nature of the transition to the White Paper. The intention is to align this with other economic policies such as the New Growth Path and the Industrial Policy Action Plan. Certain response policy approaches are identified though. A carbon constraint will be integrated into energy planning tools, and that the peak, plateau and decline trajectory will be accounted for. Diversification of the energy mix will be supported, with policy, legal and regulatory frameworks established for renewables, nuclear and carbon capture and storage. Where coal power stations are still built, more stringent thermal efficiency and emissions standards will be applied, and investment in clean and efficient coal technologies will be supported. Energy efficiency will be supported through mandatory targets, scale up of existing mechanisms, education, standards, technology replacement and energy management systems. A web-based greenhouse gas information management system will be developed as part of the National Atmospheric Emissions Inventory component of the South African Air Quality System, and mandatory emissions reporting will be implemented by 2013.

Other policies, legislation, discussion papers and initiatives that are supportive of a low carbon energy transition include:

- The Renewable Energy Feed in Tariff
- The South African Renewables Initiative (SARI) (under development)
- National nuclear energy policy
- The 2,5c/kWh tax on electricity generated from non-renewable sources (SARS, 2008)
- Exemption of Certified Emission Reduction certificates of the Clean Development Mechanism from normal income tax (Newman, 2009)

With regard to industry, the Green Paper identifies the intention to develop a climate change response action plan for the commercial and manufacturing sector by 2012. Section 29 (1) of the Air Quality Act will be used to manage greenhouse gas emissions from sources in line with approved mitigation plans prepared at plant or sector level. The role of mining in contributing to employment in South Africa is acknowledged, and so too is the role of coal mining in the country’s greenhouse gas emissions profile. The Paper identifies an intention, by 2015, to implement a strategy and action plan to reduce fugitive methane emissions by 42% from coal mining business as usual by 2025 and also by 2015, to implement an action plan for the national roll out of appropriate coal-bed gasification projects.

The Green Paper indicates that regulation and economic instruments will be used to promote mitigation, including an escalating CO₂ tax. Treasury has developed a discussion paper for public comment on the carbon tax option (National Treasury, 2010). It proposes the use of a low and escalating upstream carbon proxy tax on fossil fuel inputs as a way of pricing the carbon externality. The paper does not advocate exemptions or earmarking of tax revenues, but Treasury confirms that revenue neutrality is a policy objective. Treasury has identified the 2012 Budget to announce the introduction of the tax (National Treasury, 2011). However the DEA Green Paper acknowledges that time and support must be given for the transition of high carbon sectors, particularly in the event of other countries adopting trade measures against the export of carbon intensive products. Treasury received 79 responses to this discussion paper document, and there was much debate at a public stakeholder workshop where concerns were raised about its design and implications of implementation.

With respect to adaptation, water is argued to be the “primary medium whereby climate change impacts will be felt by people, ecosystems and economies” (DEA, 2010b). The Green Paper proposes a number of policy approaches to water. These include implementation of cost reflective water and water-use pricing.

The National Planning Commission has identified that climate change and the transition to a low carbon and climate resilient economy are long term planning issues, and will be covered in its work (Treasury, 2011).

The climate change policy framework is still in early stages of development, and therefore there is little specific legislation in place that impacts the coal value chain. However, this is an area which is anticipated to have a significant impact going forward. The Air Quality Act makes provision for the regulation of greenhouse gas emissions, although this has yet to be elaborated on (for example the Listed Activities and Associated Emissions Standards does not currently include greenhouse gases).

19.5 Approaches to greenhouse gas mitigation

A variety of interventions are available which are able to achieve reductions in emissions to the atmosphere. A selection of the more relevant ones to the coal value chain is presented below. It is pertinent to note that given the scale of the emissions reductions challenge, it has been repeatedly emphasised that all of the available mitigation options will be required.
19.5.1 Energy efficiency in operations

Energy has historically been very inefficiently used, and reducing energy consumption per unit of service at all stages of the coal value chain can result in a reduction of the greenhouse gas footprint of the value chain. Whilst the relative greenhouse gas emissions reduction potential of energy efficiency along the value chain is small compared to, for example that of CCS (discussed below), this mitigation option is still important. The coal industry has been diligent at picking this up and assessing available energy efficiency technologies and installing these as appropriate.

A variety of energy efficiency opportunities for mining are identified in Genesis Analytics (2010). Those relevant to coal mining specifically are shown in Table 59. Under the (previous) DME’s Energy Efficiency Accord, mining companies pledged a 15% decline in total (direct and indirect) energy demand from the 2000 baseline to 2015.

**Table 59: Energy efficiency options in mining**

<table>
<thead>
<tr>
<th>Low cost options</th>
<th>Moderate cost options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Underground mining</strong></td>
<td></td>
</tr>
<tr>
<td>Increasing energy efficiency on fans, cooling and ventilation systems. Air handling equipment for maintaining adequate air quality and temperature underground is required, representing a significant energy requirement and hence greenhouse emissions. Electricity savings of 30% or more are possible through efficient compressed air systems and installation of variable speed drives</td>
<td>Shifting from diesel to electric transport vehicles and motors in underground operations, as electric vehicles are, in general, more efficient in terms of greenhouse emissions. This shift is often motivated by the associated improvements in air quality.</td>
</tr>
<tr>
<td>Installation of variable speed or more energy efficient drives on pumping systems for water, slurries etc.</td>
<td>Installing turbines on shaft infrastructure</td>
</tr>
<tr>
<td>Improving drilling efficiency</td>
<td>Switching from pneumatic to hydraulic equipment</td>
</tr>
<tr>
<td>Reducing consumption due to lighting through energy efficient light bulbs and switching off lights in areas of the mine which are not in use</td>
<td>Improving efficiencies of compressed air systems</td>
</tr>
<tr>
<td><strong>Open cast mining</strong></td>
<td></td>
</tr>
<tr>
<td>There is considerable potential to reduce diesel use through more efficient diesel motors and through improved driving practices, such as switching off engines when not moving</td>
<td>Where trucks are used to remove coal there is potential to reduce diesel consumption by utilising electric power on the up-ramps (i.e. by connecting to overhead power cables). This generally results in significant cost savings for the mine and lower energy emissions overall. There is also the potential to switch other heavy machinery to electric power wherever feasible</td>
</tr>
<tr>
<td>Installation of variable speed or more energy efficient drives on pumping systems for water, slurries etc.</td>
<td>Greater and more efficient use of conveyors running on electricity rather than trucks for haulage</td>
</tr>
<tr>
<td>Install day/night switches on lighting circuits, and installation of more efficient lighting systems</td>
<td>Increased use of draglines in preference to diesel trucks for haulage of material in open cast mining (where mine conditions are suited).</td>
</tr>
<tr>
<td>Switching off unused equipment</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Genesis Analytics, 2010)

In terms of industrial operations including Sasol, metallurgical processing and other industrial users, the energy efficiency opportunities with the greatest potential include the following (Winkler, 2007; Genesis Analytics, 2010). For some of the options potential efficiency improvements, and payback periods on investments, are indicated, both of which will clearly depend on the operation:

- Thermal savings, including savings in the steam system, in addition to improved efficiency of steam use. Savings in the steam system can be achieved through steam trap maintenance, improved boiler efficiency, isolating steam from unused lines, repairing steam leaks, optimising condensate return, minimising vented steam and other measures. An estimated 20% improvement in steam system efficiency could be achieved, with an average payback period of 1.4 years.
  - Further thermal savings can be achieved through utilisation of waste heat to generate additional steam and power.
  - Compressed air savings can be realised at the compressors as well as in the ducting system. In terms of the ducting system, fixing leaks in compressed air pipes, closing pipes that are not needed and reducing elbows all result in savings with minimal capital expense. Sequencing compressors to meet demand so that they run at full load or using more compressors of smaller size, as well as using cool intake air and waste heat recovery are low cost measures for savings at the compressors.
Typically these measures have a payback period of less than a year and achieve a saving to the order of 20%.

- Lighting efficiency can be improved by switching to more efficient lamps and fixtures, including replacing magnetic ballasts with electronic ballasts and improved lighting design. Experience through DSM lighting programmes in South Africa has shown that between 30 and 60% savings in lighting in factories are achievable. Additional savings can be achieved by making use of daylight through skylighting, or using sensors to switch lights off in areas where they are not needed continuously. The average payback period on interventions is 3.6 years. Anglo American Thermal Coal switched to CFLs in 2010 which resulted in a saving of 10 MW.

- Motor efficiency savings can be achieved through the correct sizing of motors and the use of high efficiency motors. A payback period of 6 years is estimated for these measures, with a saving of 5%.

- Variable speed drives, also called variable frequency drives, achieve savings by regulating the speed of the motor to meet the requirements at that point in time. Variable speed drives can achieve savings of between 5 and 10% depending on the application, with a payback period to the order of 7 years.

The above energy efficiency opportunities are also relevant in power stations. Further opportunities exist in power stations in reducing fouling of heat exchangers, improved operational control, training of operators, improving boiler and turbine efficiencies and maintaining an adequate quality of coal. Eskom is actively pursuing opportunities for improving power station efficiency (Eskom, 2010a).

19.5.2 Implementing cogeneration opportunities

Cogeneration, or combined heat and power (CHP), refers to the simultaneous generation of electricity and useful thermal energy (heat) from a single energy source in a single piece of equipment. After generation of electricity, the waste heat is then used either as steam or heat, or for mechanical work such as shaft power. The mitigation potential of cogeneration relates to the ability to recover greater useful energy from the energy source such as coal. Many companies, including Exxaro, Sasol, Anglo American and Xstrata, as well as other industries such as pulp and paper and sugar production, have or are considering cogeneration opportunities, with Eskom stating an intention to add between 1,000 MW and 1,500 MW of cogeneration capacity up to 2013 and suggesting an overall potential of 4,000 MW.

19.5.3 Substituting coal with biomass

As discussed in detail in the section which explores alternatives to coal, biomass can be used as a partial replacement for coal in power stations and industrial boilers, and as a reductant in metallurgical processes. The potential also exists for the production of liquid fuels and chemicals through a biomass-to-liquids process which parallels the existing CTL/GTL process used by Sasol. Substitution of coal with biomass results in a concurrent reduction in CO₂ emissions.

19.5.4 Managing spontaneous combustion

Spontaneous combustion, discussed in detail elsewhere, refers to a burning or smouldering coal seam, coal storage pile or coal waste pile. Spontaneous combustion or coal fires occur because adsorption of oxygen to the coal results in an exothermic oxidation reaction, which leads to an increase in temperature within the coal seam or stockpile. If the temperature gets high enough (approximately 80°C) the coal can ignite and start to burn. Greenhouse gases, primarily CO₂, are released into the atmosphere.

Approaches to mitigating fires involve cladding the combustible material under at least a metre of soil to prevent oxygen reaching the coal. In certain cases, such as on steep slopes, the material may be excavated and trucked to a suitable water body where it is submerged. Underground fires are more challenging and can be managed by injecting a water-mud slurry into cracks created by subsurface burning or by drilling a series of holes pumping in the slurry to smoulder the flames. The surface is then covered with a substantial layer of soil to prevent oxygen from restarting the fire (Stracher and Taylor, 2004; Genesis Analytics, 2010).

19.5.5 Management of Coal Bed Methane (CBM)

Coal Bed Methane is covered in detail elsewhere in this report. Although South African coals have relatively low methane levels compared to elsewhere in the world (such as Australia), release of methane from coal beds should be limited as far as possible, particularly given that the global warming potential associated with methane is 25 times greater than that of carbon dioxide (see Table 58).

Approaches to reducing the impacts thereof, provided the methane is available at sufficient concentrations which is not always the case in South Africa, include capture for energy recovery, and flaring which converts the methane into CO₂ with the associated lower global warming impact.

19.5.6 Carbon capture and storage (CCS)

Carbon capture and storage (CCS), otherwise known as carbon capture and storage, refers to the capture of CO₂ emissions from point sources including power stations, coal-to-liquid plants and other large-scale industrial processes such as cement manufacture, and storing the CO₂ so that it does not enter the atmosphere. In a number of futures scenarios, including those conducted by the International Energy Agency (IEA, 2010a; IEA 2010b), CCS is identified to have a critical role to play in achieving the emissions reductions required to contribute to climate change mitigation. In the so-called Blue scenario, which is explores ambitious CO₂ emission reductions, CCS makes up 19% of the required reductions. In the absence of CCS under this scenario, the cost of abatement rises substantially under these scenarios.
In geological CCS, CO₂ emissions are captured, compressed to a high density [supercritical state] stream, transported (sometimes long distances) through pipelines to injection sites and pumped underground at depths greater than 800m, for permanent storage (Figure 73). Other options for CCS include:

- Enhanced Coal Bed Methane recovery (ECBM), the pumping of CO₂ to displace coal bed methane, which is then recovered for its energy value, is also being considered globally although has not yet been implemented at full scale. In South Africa, there are some deeper unmineable seams with methane which could theoretically be used for storage of CO₂ with an estimated storage potential of 277 to 1,386 Mt. However this capacity is highly dispersed amongst smaller storage basins (Council for Geoscience, 2010b).

- Mineral sequestration, in which the CO₂ is reacted above ground with magnesium and calcium containing minerals to form a stable solid carbonate compound, is being explored. Box 19 provides further information on developments in this area.

- Algal sequestration, in which the CO₂ is pumped into a pond and is used by algae for growth. The algae can be harvested and used as biomass for co-firing into power stations, for biodiesel extraction and/or as animal feed. The challenges here are the land area required for algal ponds for sequestering the large volumes of CO₂ produced by a power station or liquid fuels plant, as well as maintaining the required algal growth rates. Pilot trials are underway in Australia with Anglo American as cornerstone investor. An algal project sponsored by Eskom has been underway for the past 4 years. This involves algal farms for the purpose of (a) CO₂ capture and use, (b) co-firing coal with algal waste, and (c) support of three major industrial developments arising from this complex of which fisheries, food/chemicals and biodiesel are only a part of the development. Although this process has the net effect of decreasing CO₂ emissions, this, however, is more of a renewable energy project as the carbon sequestered in the biomass may eventually be released to the atmosphere when the biomass is harvested for its energy content.

- Enhanced oil recovery.

Only geological CCS is considered further in detail here, as this is the technology being most actively pursued in South Africa today, evidenced through the activities of the South African Centre for Carbon Capture and Sequestration (SACCCS), the development of the CCS Atlas, and sourcing of finance for a local pilot demonstration. Other technologies should not be dismissed, however, as they potentially have significant potential and overcome some of the limitations of geological CCS.

Box 19: Carbon capture and storage by mineral carbonation

Mineral carbonation is the process by which rocks weather and age through uptake of atmospheric CO₂, giving rise to a spectrum of carbonate mineral products. This reaction is irreversible and permanent, and its products are benign. Most importantly, the reaction is a net overall producer of energy52. The abundance of silicate minerals in the Earth’s crust53, such as serpentine and olivines, not to mention the plethora of waste materials and other “difficult-to-treat” minerals (such as asbestos minerals and wastes) which are available for reaction on a global scale, suggest that mineral carbonation is worthy of serious consideration as an option for carbon capture and storage. These sorptive minerals are often located close to major coal deposits (including those in South Africa).

The main challenge is how to accelerate the reaction rate. This acceleration of the reaction rate requires energy. Research and development over the last 20 years or so has shown that this acceleration is not only possible but practicable; and, that through energy integration techniques, it is possible to conceive of a range of prospects for entire industrial complexes which benefit from having mineral carbonation at their core (Brent et al., 2011). These include the potential for production of a range of by-products (including iron oxides and other metallics). These findings should challenge the IPCC’s original reticence towards mineral carbonation.

In comparing the cost of geo-sequestration with mineral sequestration, a common basis for comparison is required. Putting aside the possible synergies between capture processes and mineral carbonation, it has been suggested that mineral carbonation sequestration is achievable (at large scale) at a price of USD 10 – 20 per tonne of CO₂ sequestered, based on 2008 figures (Brent and Petrie, 2008). This does not include CO₂ capture costs, which would be similar to those for geo-sequestration process. Nor does it factor into consideration any energy optimisation potential. Other estimates (Zevenhoven et al., 2011) put the total cost of mineral carbonation in the range USD 50 – 100/tonne CO₂ net mineralised (including capture and transport). However, these figures exclude energy integration synergies or sales of by-products (including hematite). Full-scale plant costs could be reasonably estimated to be somewhat lower.

An advantage of mineral carbonation technologies are that they are based on existing minerals processing technologies, all of which have been deployed at commercial scale; and that South Africa has an existing technical capability to develop these technologies. Mineral carbonation thus represents a potentially viable “carbon solution”

52 Albany Research Centre, USA (various publications)
53 The USA has sufficient mineral deposits to permanently sequester that country’s total annual anthropogenic CO₂ (about 7 Gt/a) for more than 500 years. Oman, in the Gulf, possesses one single deposit of olivine-containing rock which could fix all CO₂ that might be produced from combustion of all the coal present on Earth (Zevenhoven et al. 2011). A more focused study in Australia confirms that deposits of serpentinite minerals in NSW and Queensland alone can cope with those states’ coal-fired electricity emissions beyond the extent of those coal deposits (Brent and Petrie, 2008).
19.5.6.1 Requirements for geological CCS

The first requirement for geological storage of CO$_2$ is the selection of suitable sites. Such sites typically have a porous and permeable rock structure for injection and storage, overlain by impermeable rock. These include geological reservoirs such as depleted oil and gas fields, unmineable coal seams and deep saline aquifers. Whilst geological CCS is a relatively new technology, the principle has been used for decades for enhanced oil recovery. Already there is one CCS plant in the world operating on a commercial basis – namely Sliepner in Norway, which is economic on the basis of the carbon tax imposed by the Norwegian government. The technology is otherwise not in wide scale use world wide, but there have been demonstration/pilot plants in countries including Germany, Norway, the United States and Australia (McKinsey, 2008), and CO$_2$ storage has been undertaken commercially in applications such as enhanced oil recovery (Garnaut, 2011).

Geological CCS is lowest cost for point sources with concentrated CO$_2$ streams, as is the case of some of the streams generated by the CTL industry. The streams from power stations require concentration before injecting underground.

In addition to suitable sites and streams of CO$_2$, infrastructure requirements include those for capture and compression, transport, injection and monitoring and verification.

Capture technologies include (World Coal Association, 2011d):

- Post-combustion: The most commonly used process for post-combustion CO$_2$ capture is to bubble the CO$_2$ rich gas stream through an amine solution. The CO$_2$ bonds with the amines while other gases continue up through the flue. The CO$_2$ is separated from the amines, ready for storage and the amines can be recycled. Whilst post-combustion CO$_2$ capture has been proven technically for coal-fired power plants, it has not yet been implemented commercially for large-scale CO$_2$ removal. Separating the CO$_2$ from the amines requires energy and hence, power plants will incur a significant energy penalty to undertake this process.

- Pre-combustion capture involves separating CO$_2$ before the fuel is burned. The fuel is first gasified at high temperatures with a controlled amount of oxygen. Gasification produces two gases, hydrogen and carbon monoxide (CO). The CO is converted to CO$_2$ and removed, and the hydrogen is be burned to produce electricity or used for another purpose. The CO$_2$ is compressed and transported for geological storage.

- Oxyfuel combustion or oxyfiring involves combustion of coal in pure oxygen, rather than air, for use in a steam turbine. By avoiding nitrogen in the combustion chamber, the CO$_2$ in the power station exhaust stream is greatly concentrated, making it less costly to capture and compress. One of the advantages of oxy-fuel combustion is the resultant high temperatures that [when materials science/engineering makes available] would enable higher efficiency conversion from fossil fuel to say electricity – thus decreasing CO$_2$ emissions.

Transport of high pressure gases, including CO$_2$, is well established, and does not represent a technological challenge. However, there are aspects the need to be addressed, such as corrosion and the high density state of the CO$_2$. Typically the transport of high volumes of CO$_2$ over relatively short distances is in pipelines.
One of the issues that need to be determined is the extent of leakage which can be expected from injection sites. Monitoring and evaluation, thus represents a critical component of CCS implementation and one which needs to be established from the outset with the initial project design and not included as an afterthought later in the process.

19.5.6.2 Cost implications of CCS

Factors that affect costs include infrastructure requirements (capture, injection and monitoring wells and retrofitting facilities, especially in offshore environments), the volumes to be injected, injection depth and hydrocarbon economics. Pumping costs depend on the distances to injection sites. As identified below, the cost of capture is suggested to dominate the costs of CCS.

McKinsey (2008) suggests early demonstration plants will have an abatement cost of €60 to €90 per tonne, dropping to €30 to €45 per tonne by 2030. The IEA (2008) suggests costs to the order of USD 40 to USD 90 per tonne of CO₂ emissions avoided at coal fired power stations, depending on the fuel and the power plant technology. The IPCC (2005) provides a breakdown of costs associated with different components of the different CCS technologies (Table 60).

Table 60: Cost components of different CCS technologies

<table>
<thead>
<tr>
<th>CCS system components</th>
<th>Cost range [USD/tCO₂]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture from a coal- or gas-fired power plant</td>
<td>15 – 75 net captured</td>
<td>Net costs of captured CO₂ compared to the same plant without capture</td>
</tr>
<tr>
<td>Capture from hydrogen and ammonia production or gas</td>
<td>5 – 55 net captured</td>
<td>Applies to high purity sources requiring simple drying and compression</td>
</tr>
<tr>
<td>Capture from other industrial sources</td>
<td>25 – 115 net captured</td>
<td>Range reflects use of a number of different technologies and fuels</td>
</tr>
<tr>
<td>Transport</td>
<td>1 – 8 transported</td>
<td>Per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) MtCO₂/yr</td>
</tr>
<tr>
<td>Geological storage</td>
<td>0.5 – 8 net injected</td>
<td>Excluding potential revenues from EOR or ECBM</td>
</tr>
<tr>
<td>Geological storage: monitoring and verification</td>
<td>0.1 - 0.3 net injected</td>
<td>This covers pre-injection, injection and post injection monitoring and depends on the regulatory requirements</td>
</tr>
<tr>
<td>Ocean storage</td>
<td>5 – 30 net injected</td>
<td>including offshore transportation of 100 - 500 km, excluding monitoring and verification</td>
</tr>
<tr>
<td>Mineral carbonation</td>
<td>5 – 100 net mineralised</td>
<td>Range for the best case studied, includes additional energy use for carbonation</td>
</tr>
</tbody>
</table>

(Source: IPCC, 2005)

As indicated above, the likely cost implications for adding CCS to a CTL or GTL plant are thus much lower than for electricity generation, as capture is not required. It is estimated that the cost of adding CO₂ purification to a CTL/GTL plant range from USD 3 to USD 5 per barrel of oil produced (IEA, 2010b).

In terms of the impact on electricity price of CCS attached to coal fired power generation, Figure 74 presents one comparison between the cost of electricity generated by different technologies in 2020, 2030 and 2040. While this analysis was done for Australia, and calculation and interpretation of results depends on a number of underlying assumptions, the important observations from this figure are that CCS adds significantly to the cost of generation, and that other technologies, including renewables, become more competitive. The differential between technologies is likely to be even greater in South Africa, due to the remote location of potential CCS storage sites.
Figure 74: Levelised cost of electricity for 2020, 2030 and 2040 for various technologies

In addition to the direct process costs of CO\(_2\) capture, compression and pumping, CCS also implies a cost and thermal efficiency penalty for power stations. Power plants with CCS use more fuel than those without (i.e. have lower efficiencies with an energy penalty of approximately 30%) and are estimated to only be able to sequester to the order of 90% of the CO\(_2\) emitted (GCCSI, 2011). The remaining 10% is still released into the atmosphere.

19.5.6.3 CCS potential in South Africa

The CCS Atlas (Council for Geoscience, 2010b) presents a comprehensive study on the potential for geological sequestration of CO\(_2\) in South Africa. The study has identified an estimated storage capacity of 150,000 Mt of CO\(_2\) with almost all of this capacity (~98%) being located offshore. Figure 75 shows the location of these sites, along with an indication of the capacity at each. Although this capacity may sound high (providing sufficient storage for over 500 years of the combined total Sasol and Eskom emissions at 2009 levels), the geographical distribution, technological challenges and cost of off-shore CCS imply that utilising these sites may be restrictively challenging and expensive. In addition, given the expected demand for CCS technology globally, the ability to secure qualified personnel to build and operate the technology may represent a significant challenge.
The CCS Atlas plots a roadmap for CCS in South Africa, with a test injection being planned by the South African Centre for Carbon Capture and Storage for 2016, a demonstration plant (sequestering in the order of hundreds of thousand tonnes of CO₂) by 2020 and commercial operation by 2025 (Council for Geoscience, 2010b).

19.6 Climate change adaptation

Adaptation in the climate change context refers to changing approaches to doing business to ensure that it can cope with the effects of climate change. Two main types of adaptation are defined, being “resilience-type” adaptation which addresses the potentially damaging effects of changing climate extremes, and “acclimation-type” adaptation, which address strategies to cope with gradual changes in background climate such as slow rates of warming and reduced water availability.

Requirements for adaptation are highly site and activity specific. Resilience type adaptation for the coal value chain include planning for extreme weather events such as floods, fires and heat waves and planning for severe water shortages, depending on the location of operations.

It is suggested that the different players in the coal value chain are investing surprisingly little in exploring adaptation needs and measures, as suggested by Box 18 and a survey of the open literature. There have been some case studies published in Canada for the mining sector more broadly (although none for coal) (Pearce et al., 2009), and CSIRO in Australia has established a climate adaptation flagship which has produced a limited number of more general publications relating adaptation in the mining sector (CSIRO, 2011).
COAL CHARACTERISTICS AND THE ROLE OF SAMPLING AND CHARACTERISATION

20.1 Coal characteristics

There are a number of classifications for coal types and other characteristics that are considered important. These reflect different aspects of coal quality and affect the range of feasible uses.

20.1.1 Coal rank

The most common differentiation of coals is between lignite, sub-bituminous, bituminous and anthracite. These divisions are based on, inter alia, the coal ranks and reflect, in this order, a combination of increased age and exposure to elevated temperatures and pressures. These give rise to a corresponding increase in calorific value and reduction in moisture content and volatile content (non-moisture mass lost when heated in the absence of air - a measure of mass loss during coking) which imply a generally higher quality coal (Figure 76). Increasing rank is also correlated to an increase in vitrinite reflectance, which is used as a standardised quantitative measure of coal rank (SABS, 2004). It is important to note that such a coal classification system is not appropriate for commercial or trade purposes. Normal trade practices make use of many coal properties at levels of appraisal best met by using analysis and test data directly.

Figure 76: Coal ranks with proportion of world reserves and major uses

<table>
<thead>
<tr>
<th>Coal Type</th>
<th>% of World Reserves</th>
<th>Major Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>17%</td>
<td>Large power generation</td>
</tr>
<tr>
<td>Sub-Bituminous</td>
<td>30%</td>
<td>Power generation Cement manufacture</td>
</tr>
<tr>
<td>Bituminous</td>
<td>52%</td>
<td>Power generation Industrial uses</td>
</tr>
<tr>
<td>Anthracite</td>
<td>1%</td>
<td>Manufacture of iron and steel</td>
</tr>
</tbody>
</table>

(Source: adapted from World Coal Institute, 2005)

20.1.2 Coal constituents

The chemical make-up of coal is variable across all coal classifications, being largely dependent on the origin of the organic material and geological conditions. The chemical, physical or petrographic characteristics of coal are an integral consideration in the trade and end-use (utilisation) of the coal product, whether it is raw coal or beneficiated coal. The most important considerations are (Anon., 2008):

- **Fixed carbon:** The fixed carbon content of coal provides the energy and metallurgical reductant ability for which coal is valued, with the higher the fixed carbon the higher the calorific value. Carbon increases with increasing coal rank.
  - **Total carbon:** Total carbon is the amount of fixed carbon plus any carbon present as volatile constituents (e.g. carbon monoxide, methane, hydrocarbons, etc.). Total carbon is always greater than fixed carbon and calorific value increases with increasing total carbon.
  - **Ash:** Ash is the total of non-combustible minerals contained within the coal. Presence of ash reduces its calorific value and presents handling problems. Ash originates from several sources, including the minerals.
contained in the original plant matter, mineral matter laid down with the plant matter, or minerals infiltrated into the peat.

- **Hydrogen**: Hydrogen in coal is associated with the volatile matter. In metallurgical coals, the greater the \( \text{H}_2 \) content, the greater the yield of NH\(_3\), in the coke oven gas, which is then used in fertiliser production. Hydrogen content generally increases the calorific value of coal, but is not related to coal rank, with hydrogen content ranging from 4.5% to 6.5% from peats to bituminous coal.

- **Moisture**: A high moisture content in coal is associated with a lower calorific value.

- **Sulphur**: Sulphur can occur in coal in three forms: sulphide minerals (such as pyrite), organic sulphur and sulphate minerals. While sulphides increase the calorific value of the coal, the presence of sulphur is undesirable in the use of coal as a fuel. The oxidation products of sulphur can result in corrosion of equipment and their release leads to local air pollution and acidification effects. Sulphur is also undesirable in metallurgical applications, causing cracking when the steel is forged or rolled at elevated temperatures. Sulphur content is not related to coal rank.

- **Oxygen**: The oxygen content of a coal reduces its calorific value. The lower the oxygen content, the greater the rank.

- **Nitrogen**: Appears in coals at between 1 and 3%. The presence of inert nitrogen reduces the calorific value of the coal, but does not relate to coal rank.

- **Phosphorus**: Phosphorus is a coal constituent that is problematic for metallurgical applications of coal as it reduces the ductility of steel, causing cracking at low temperatures.

South African coals are generally relatively low in sulphur content and high in ash content, requiring washing (beneficiation) to remove these undesirable constituents for export (World Energy Council, 2007). During beneficiation, only the pyritic sulphur can be reduced significantly.

The most common chemical analyses undertaken and properties of coal include: proximate analysis, heat value, sulphur compounds, ultimate or elemental analysis, ash constituent analysis and trace element/minor constituent analysis. The physical properties of the coal are also important parameters to consider as they determine the behaviour of coal products during combustion, and conversion.

### 20.1.3 Coal macerals

Examination of the microscopically visible organic constituents of the coal (coal macerals) forms an important part of coal petrology. Macerals are constituent grains in coal, which are relatively homogenous and analogous to mineral forms in the study of rocks. Three groups of macerals are commonly identified (Petrakis and Grady, 1980):

- **Liptinite**: Originates from the remains of spores, resins, algae and plant cuticles. Liptinite macerals display relatively low reflectance of light. Liptinite macerals are less present in coals of higher rank.

- **Vitrinite**: These macerals originate from wood and bark, and show greater reflectance than liptinite. The reflectance of its vitrinite macerals is held to be among the most generally applicable measures of a coal’s rank.

- **Inertinite**: Named for their limited reactivity on coking, the materials that formed these macerals were subject to oxidation early during coal formation and have the highest levels of reflectance. Inertinite macerals are relatively abundant in South African coals.

### 20.1.4 Washability

It is often economically viable to beneficiate raw coal prior to sale. This typically involves preliminary crushing followed by washing to reduce the sulphur and ash content of the final product, thereby increasing its value. The ease with which the undesirable components can be removed depends on their form, how intimately they are embedded into the coal matrix, and how readily they break free during crushing (liberation). The achievable quality and yield of product is therefore an important characteristic of a coal resource, which is often measured as its washability. This is a measure of the percentage yield that can be achieved from washing the coal to a given final quality. Washability curves can be constructed which plot the ash content of the product against the percent yield achieved when washing to this level (Couch, 2003; de Korte, 2006).

### 20.1.5 Other coal terms

- **Brown coal**: Low rank coals ( lignite and sometimes sub-bituminous coals) (UNStats, 2010).

- **Black coal**: A general term for coals of sub-bituminous, bituminous or anthracite rank.

- **Hard coal**: High rank coals (bituminous and anthracite). Hard coal can be either coking coal or thermal/steam coal (UNStats, 2010).

- **Metallurgical coal/coking coal**: Coal of suitable quality for carbonisation to produce blast furnace coke, generally high-rank bituminous. The coke is principally used in smelting iron ore. Important properties include mechanical properties at high temperature that give rise to good caking and coking behaviour (fluidity, crucible swelling number, etc.); low ash; low moisture; low sulphur and phosphorus (Evolution Markets, 2010).

- **Steam/thermal coal**: Coal used for steam generation for heating or electricity generation.

### 20.2 Sampling and characterisation

As identified previously, coals, and in particular South African coals, are highly heterogeneous, and differ in a number of different ways. These include:
- type of coal (bright, dull, mixed, banded carbonaceous, shaley and torbanitic, etc.),
- grade of coal (ranging from high to low grade as determined by mineral matter/ash content and types of ash),
- rank (important for determining whether coals have been burnt by local sills and dykes or achieved maturity through deep burial and geothermal gradients),
- vitrinite reflectance (indicates the true level of maturity of a coal and possible blending by rank)
- condition (refers to the oxidised or inherently heated/burnt nature of the coals),
- tendency to gain or lose moisture (which affects calorific value) and
- oxidation when exposed to the environment (relevant when coals are stockpiled for a length of time or when hallow seams that have been oxidised are mined).

These considerations have implications along the whole value chain including geological evaluation, plant engineering design, efficiency predictions in use and environmental control. Given that Eskom and many other smaller industries in SA are increasingly using types and grades of coal that no other country in the world is using, South African coal users are now having to re-examine and improve the specifications of their coals and, at the same time, re-consider the technologies they employ. Many are now looking to bring in new technologies in order to improve their efficiencies. This is for two reasons: firstly, the qualities of the future mining areas are, in most cases, inferior to the conventional seams that have been mined to date, and secondly because SA is exporting more and more of the best-to-middlings qualities of coal, thereby leaving even lower grades of coal for local consumption.

A further consideration is that South African coal qualities have to be understood in far greater depth than the norm both organically and inorganically in order to ensure efficient use and reduced GHG emissions.

It is within this context that consideration is given in this section to available coal characterisation and sampling approaches, as well as further trends and challenges in characterisation.

### 20.3 Conventional coal characterisation and sampling approaches

Historically, coal analysis was mainly conducted for purposes of product quality control, estimation and evaluation of coal deposits and, to some extent, monitoring and predicting performance during conventional processing (coal cleaning) and use (combustion). A full list of standard coal characterisation methods are summarised in Table 61 and include:

- Chemical analysis: includes proximate analysis (moisture, ash, volatile matter and fixed carbon); ultimate analysis (carbon, hydrogen, sulphur, nitrogen), calorific value, total sulphur and sulphur speciation, ash fusion temperature determination, ash elemental oxide composition, Sisher assay (water, tar, gas and char), minor and trace elements (by for example XRF analysis).
- Physical analysis: density, grindability, swelling index, Roga index spontaneous combustion liability, abrasiveness, porosity, particle size distribution and mechanical stability.
- Petrographic analysis: Coal petrography is a mineralogical technique which determines the proportions of macerals and to some extent the comportment of mineral matter in coal seams. Petrography is typically used to classify coal in accordance with rank and type. This information, in turn, provides an indication of key combustion properties (ignition temperature; burn-out rates). Petrography is also used to evaluate potential use or marketability of key coal types geological exploration, to diagnose problems in mining (e.g. anomalies in pick wear) and beneficiation (e.g. anomalous grades at key RDs, etc.), to establish reasons for anomalous behaviour in combustion and gasification processes, to evaluate potential and identify causes for many self heating/spontaneous combustion cases (been used in many arbitrations locally and abroad) and in the prediction and evaluation of coals for coke making, coke blending and PCI use.
- Behavioural analysis: Standard techniques to predict/monitor performance during coal preparation and combustion include grindability, washability (float/sink tests), and coking tests.
### Table 6:1 Standard characterisation techniques

<table>
<thead>
<tr>
<th>Method</th>
<th>Example of standards</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling Procedures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample preparation</td>
<td>ISO 1988</td>
<td></td>
</tr>
<tr>
<td>Sample of dumps</td>
<td>ISO 2309</td>
<td></td>
</tr>
<tr>
<td>Sampling of coal seams</td>
<td>ISO/SANS 14180 (1998)</td>
<td></td>
</tr>
<tr>
<td>Sampling of slurries</td>
<td>ISO/SANS 20904 (2007)</td>
<td></td>
</tr>
<tr>
<td><strong>General Tests: Analyses used to define exploration core, in-seam quality control &amp; coal shipment values</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inherent moisture</td>
<td>ISO/SANS11722</td>
<td>Moisture held within coal itself</td>
</tr>
<tr>
<td>Total ash content</td>
<td>ISO 1171, ASTM D3174; SANS 131 (1997)</td>
<td>Non-combustible inorganic residue that remains after coal is combusted</td>
</tr>
<tr>
<td>Ash composition by XRF</td>
<td>SANS 408 (2007)</td>
<td>Standard major - minor element suite for high rank coal &amp; coke ash</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>ISO/SANS 562; ASTM D3175</td>
<td>All coal constituents which are release upon heating in the absence of air:</td>
</tr>
<tr>
<td>Proximate analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inherent moisture; ash content; volatile matter, fixed carbon</td>
<td>SANS 17246 ; ASTM D3175</td>
<td>Used routinely to define exploration core, in-seam quality control sampling &amp; coal shipment values</td>
</tr>
<tr>
<td>Ultimate analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon, hydrogen, oxygen &amp; nitrogen</td>
<td>ISO/SANS 17247</td>
<td>Used to complement proximate analysis</td>
</tr>
<tr>
<td>Calorific value (CV)</td>
<td>ISO 1928</td>
<td>Number of heat units measured when coal is combusted under standard conditions</td>
</tr>
<tr>
<td>Ash fusion temperature (AFT)</td>
<td>ISO 540</td>
<td>Measure of the 4 critical temperature which coal/coke ash pass through when heated in oxidising atmosphere</td>
</tr>
<tr>
<td>Nitrogen by semi-micro Kjedal method</td>
<td>ISO/SANS 333</td>
<td></td>
</tr>
<tr>
<td>Total sulphur</td>
<td>ISO 3348351; ASTM D4239</td>
<td></td>
</tr>
<tr>
<td>Forms of sulphur</td>
<td>ISO 157; SANS 402</td>
<td>Mineral (pyritic and sulphate sulphur)</td>
</tr>
<tr>
<td><strong>Other standard characterisation methods for inorganic matter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major &amp; minor elements in coal and coke by FAAS</td>
<td>SANS 414 (2006)</td>
<td>For high rank coal and coke</td>
</tr>
<tr>
<td>Chlorine in coal</td>
<td>ASTM D4208</td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>Example of standards</td>
<td>Additional information</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>----------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Phosphorus in coal</td>
<td>ISO 622</td>
<td>Quality criterion</td>
</tr>
<tr>
<td>Phosphorus in ash</td>
<td>ASTM D2795; BS 1016</td>
<td></td>
</tr>
<tr>
<td>SO3 in coal</td>
<td>ASTM D5016</td>
<td>Environmental criterion</td>
</tr>
<tr>
<td>Boron in coal &amp; coke</td>
<td>SANS 412 (2006)</td>
<td>ICP-AES method</td>
</tr>
<tr>
<td>MnO2</td>
<td>ISO 942</td>
<td></td>
</tr>
</tbody>
</table>

### Physical and mechanical properties: Used to test/predict coal preparation/beneficiation plant efficiency

<table>
<thead>
<tr>
<th>Property</th>
<th>Example of standards</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative density</td>
<td>ISO/SANS 5072 (2005)</td>
<td></td>
</tr>
<tr>
<td>Hardgrove grindability index</td>
<td>ISO 5974: ASTM D3402 ISO/SANS 5074 for hard coal (1994)</td>
<td>Grindability-used to estimate the capacity and power consumption as a function of particle size</td>
</tr>
<tr>
<td>Abrasion index</td>
<td>Eskom method</td>
<td>Hardness of coal and influence on wear and tear of a plant</td>
</tr>
<tr>
<td>Magnetite</td>
<td>ISO/SANS 8833 (1989)</td>
<td>Sizing and non-magnetics</td>
</tr>
<tr>
<td>Moisture holding capacity</td>
<td>ISO 1018/SANS 403 (2005)</td>
<td></td>
</tr>
<tr>
<td>Drop shatter</td>
<td>ASTM D440/SANS 401</td>
<td>Ability to withstand breakage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Principles &amp; conventions for flowsheets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coal cleaning equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dust/moisture relationships for coal</td>
</tr>
</tbody>
</table>

### Coking tests: Used to determine the suitability of coal for coke production

<table>
<thead>
<tr>
<th>Property</th>
<th>Example of standards</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determination of caking power</td>
<td>SANS 881 IS0/SANS 15585 (2007) IS0/SANS 502 (1982)</td>
<td>Mechanical strength of the coke</td>
</tr>
<tr>
<td>Roga index</td>
<td>SANS 881 IS0/SANS 15585 (2007) IS0/SANS 502 (1982)</td>
<td></td>
</tr>
<tr>
<td>Hard coal caking index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gray-King coke test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dilatation</td>
<td>SANS 6072 (2009)</td>
<td>Measure of volume change during coking</td>
</tr>
<tr>
<td>Ruhr dilatometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low temperature distillation tests:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>SANS 6073 (1984) IS9/SANS 647 (1974)</td>
<td>Yield the nature and yields of various products when coal is carbonised (coke, gas, tar, ammonia)</td>
</tr>
<tr>
<td>Brown coals and lignites</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Coal characterisation and classification protocols

- South African guide to the systematic evaluation of coal resources and reserves: SANS 10324 (2004)
- Classification of coals: ISO/SANS 11760 (2007)
Standard methods for many of these analyses have been described and published by the American Society for Testing Materials (ASTM), British National (BS) Institute, the International Standards Organisation (ISO) and, locally, the South African National Bureau of Standards (SABS). Many of these standard analytical procedures and methods have been updated as analytical methodologies have advanced, with instrumental methods replacing some of the more time-consuming wet chemical methods.

Standards are also provided for taking and preparing representative samples, which is of utmost importance particularly in cases where instrumental methods are applied due to the sample size of samples used (see Table 61). The purpose of establishing and utilising of standards in the South African context is to facilitate international trade which is facilitated by standards and harmonised conformity assessment practices. A number of coal projects have failed due to poor sampling, which is then followed by inapplicable analyses on incorrect samples of coal. In some cases this has been ascribed to inadequate training and lack of understanding of coals in non-conventional coalfields.

20.4 Current trends and challenges in sampling and characterisation

The standard chemical and mineralogical techniques outlined above are all relatively inexpensive and readily available. However they all have inherent limitations, and are not generally considered to provide the full particle and mineralogical characterisation required to address current and future pressures and demands facing the industry sector. In particular there is currently a major shift towards cost effective and clean coal technologies (CCTs), improved productivity and product quality, and enhanced safety and environmental performance. At the same time coal grades are declining and are no longer in line with original boiler and gasifier design specifications. Increasingly it is being recognised that the success of both existing and emerging technologies (e.g. specialised fluidised bed combustion and IGCC) requires a better understanding of coal properties and behaviour than that provided by conventional analytical methods.

Current trends are thus towards the development and application of methods to provide more detailed information on the concentration, mode of occurrence and association of coal components and their subsequent deportment across all stages in the coal extraction, processing and utilisation chain. Classification of inorganic mineral matter is relevant in that it accounts for many of the techno-economic and environmental problems associated with coal processing and utilisation. More detailed analysis and understanding of the inorganic matter in coal can provide valuable information to assist mining, processing, combustion and environmental engineers in the prediction and reduction of technological (e.g. fouling and slagging, corrosion, abrasion) environmental (e.g. AMD, gaseous emissions) and health problems associated with coal mining, processing and utilisation.

The organic (maceral) matter is also significant in this regard as it determines coal performance in technologies across the coal value chain. A number of cases have been identified where coal utilisation equipment that has been brought into this country has not worked due to the proportions and properties of the organic (maceral/petrographic) matter contents in coal. The problems that arise cannot be predicted or diagnosed by conventional chemical or physical analyses. Some of the problems that have been solved, predicted or diagnosed by petrographic analyses include boiler plant that could not ignite coal; coal that does not burn out, thus leading to low combustion efficiencies and, in turn, high CO₂ emissions; high thermal shattering of coals reducing optimum combustion or gasification; huge misplaced fireballs in the free board leading in turn to misplaced thermal transfer; melting of water tubes, chain grates, etc. due to excessively high inherent combustion temperatures (up to 1750°C proven); huge slagging deposits in fluidised beds through the high temperature combustion of specific types of low grade coals (irrespective of the temperatures being held below 900°C); and high NOx production in low N coals due to the conversion of atmospheric N into NOx at high temperatures (Falcon, 2011).

Recent advances in technology have provided a more definitive basis for the reliable characterisation of coals, particularly in terms of the abundance and associations of different minerals in quantitative terms. Such advances include:

- Rietveld-based XRD and computer-controlled scanning electron microscopy (CCSEM) and related techniques, such as QEMSCAN and MLA for the advanced characterisation of mineral matter.
- Laser ablation ICP-MS is another technique that provides in coal research, with capable of analysing trace elements of whole coal (detection limits down to ppb levels and spatial resolution as low as 10 microns), as well as individual minerals and macerals.
- Energy dispersive XRF (EDP-XRF) is another cost effective and rapid method for simultaneously analysing over 60 elements down to ppm levels.
- Abnormal Condition Analysis (ACA) considers features not typically characterised during routine petrographic analysis, providing a measure of extent of coal weathering, which has been shown to have a significant effect on coal combustion properties.
- Approaches to predicting the potential for spontaneous combustion

These and other non-standard coal characterisation methods are summarised in Table 62.
### Table 62: Non-standard coal characterisation methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element concentrations</strong></td>
<td></td>
</tr>
<tr>
<td>- ICP-AES</td>
<td>Detection limit in ppm range</td>
</tr>
<tr>
<td>- ICP-MS</td>
<td>Detection limit in ppb range</td>
</tr>
<tr>
<td>- Laser ablation coupled ICP-MS</td>
<td>Whole coal analysis of elements down to ppb levels</td>
</tr>
<tr>
<td><strong>Mineralogy</strong></td>
<td></td>
</tr>
<tr>
<td>- XRD/ Rietveld-based XRD</td>
<td>Provides quantitative information in mineral concentrations</td>
</tr>
<tr>
<td>- Scanning electron microscopy (e.g. QEMSCAN)</td>
<td>Provides quantitative data on the mineral compositions and texture</td>
</tr>
<tr>
<td>- X-ray adsorption fine structure spectroscopy (XAFS)</td>
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</tr>
<tr>
<td><strong>Leach tests to determine chemical properties</strong></td>
<td></td>
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<tr>
<td>- Sequential chemical extraction (SCE) tests</td>
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<td>- Acid generating potential tests</td>
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</tr>
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<td><strong>Combustion behaviour</strong></td>
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<td>Drop tube furnace and Eskom’s Combustion Test Rigs (PF and FBC)</td>
<td>Assessment of the behaviour of coal during combustion</td>
</tr>
<tr>
<td>Abnormal condition analysis</td>
<td>Petrographically-based method to determine degree of weathering</td>
</tr>
</tbody>
</table>
RESEARCH AND DEVELOPMENT ACTIVITIES AND NEEDS

Locally and internationally research needs in the coal industry focus on the continued use of coal, which thus necessitates a consideration of improved efficiencies, management and control of CO₂ emissions and minimisation of other environmental and human health impacts along the value chain (MIT, 2007). This section provides an overview of the research and development activities and needs across the coal value chain. A comprehensive, but by no means exhaustive, summary table of local research activities is provided at the conclusion.

Enhanced effort into the following areas will greatly assist the coal research:

- Clean coal technologies
- Carbon capture, storage and sequestration.
- Coal reserve utilisation
- Methane utilisation from current mine workings

21.1 Research and development needs and local facilities for coal characterisation

Characterisation techniques and protocols are required across the coal value chain, and a selection of the research needs in this area is presented here. Also presented is a list of local facilities for coal characterisation.

21.1.1 Advanced systematic characterisation protocols

Whilst recent advances in analytical techniques have resulted in more detailed and accurate characterisation of coal, it is equally important that these technologies are effectively incorporated into advanced coal characterisation programmes, which integrate organic petrology, inorganic analytical techniques and coal chemistry as a function of cleaning and utilisation processes. Such programmes would necessarily take the form of systematic characterisation protocols. These protocols will aid in the selection of appropriate analytical techniques based on consideration of the coal types and where they will be used across the value chain; data requirements in terms of accuracy and detail; and the inherent strengths and limitations of the available techniques.

21.1.2 Meaningful coal classification models

Following on from the above, the data and information obtained through the advanced characterisation protocols could be used to develop a coal classification model which identifies and quantifies the essential or key characteristics common to various types or ranks of coal in a generic manner, such that variabilities in origin, processes and uses can be accommodated. It is noted that little detailed information and data on the characteristics of local coal deposits and extraction, processing and utilisation outputs is available in the published literature; and the quality of that which is available generally poor (in terms of detail and accuracy). Although it is recognised that each major coal mining company in SA has developed and uses its own in-house derived method for logging, sampling and characterising coals, and storing the data on qualities and quantities in their reserve resource database, and hence much information may be contained in in-house (and largely confidential) reports; it is likely that adequate inventory data pertaining to the coal sector will remain largely incomplete and inconsistent.

Within this context, it is noted that there are numerous well researched models for characterising coals, from simple to advanced levels, but these are not used. For example, the US and UK used to have coded systems to categorise coals into between 3 and 8 levels of quality groupings using technical specifications. In the past international organisations called for a common international system of classification using 6 or more analytical parameters in order to be able to achieve consistency between coal producing and using countries’ systems. Producing countries (South Africa and Australia) fought hard to abandon this system. It is not used commercially today. The petrographic classification of rank using vitrinite reflectance is the only legally valid system for rank identification within South Africa and when comparing coals internationally. Such models could be revisited should this be a path worth pursuing in South Africa.

21.1.3 Development and application of automated, in-situ or on-line analysers

There is also a need for techniques that provide rapid on-line and continuous monitoring of coal quality and process control, in a manner that is cost effective and avoids subjective judgments. Rapid and reliable quality feedback will enable mines to optimise quality control and produce well blended coal stockpiles that meet customer specifications. Current on-line methods are currently largely limited to moisture content and size analysis.

21.2 Research in the mining industry

Research activities in the mining sector are spread across various academic institutions and research laboratories in the country. Key focus areas in mining and extraction research and development include:

- geotechnical modelling of mine structural stability
- thin coal seam mining techniques
- continuous mining methods, and mine automation
- coal seam degassing techniques with methane capture or abatement in preparation for mining
- underground coal gasification modelling and experimental studies
- ash backfill studies and beneficiation of the fine coal and coal slimes
In addition, much research focuses on preventing, controlling and treating acid mine drainage and on post closure management of mines, in order to reduce the impact of mining on the environment.

The Water Research Commission (WRC) has acid mine drainage as a key topic for ongoing research (Burgess, 2009). The WRC also has commissioned specific projects into the study of inter mine flow and decant points to help locate and size AMD treatment plants as well as developing water treatment technologies to integrate and elevate experience from research projects into pilot and operational scale trials.

The Crystallisation and Precipitation research group at the Department of Chemical Engineering, University of Cape Town conducts ongoing research into the application of Eutectic Freeze Crystallisation (EFC) for the treatment of multi-component brines and mine water. While the capital costs associated with this “new” technology are as yet unfavourable, operating costs for an EFC facility have been determined to be approximately nine times lower than that for evaporative crystallisation (Lewis et al., 2009). Other favourable findings from thermodynamic modelling and successful laboratory scale investigations have propelled this research to the level of a pilot study which is presently in the planning phase (Randall, 2010).

21.3 Research into spontaneous combustion

Various aspects of spontaneous combustion have featured on Coaltech’s R&D agenda since 1999. Much of this work has been assimilated in the recently published best practice guidelines document, compiled by the School of Mining Engineering at the University of Witwatersrand and endorsed by Coaltech (Coaltech, 2011). Whilst mainly directed towards surface mining, this guideline also covers underground mines, coal stockpiles and waste dumps, and is aimed at assisting mine managers, blasting engineers, planners and operators to implement standard procedures in the areas of prediction, prevention, detection, monitoring, control and management. The document also includes a comprehensive literature review into the causes and control of spontaneous combustion in coal mining and coal storage.

A further field of study relates to the application of computational fluid dynamics (CFD) for predicting potential spontaneous combustion in coal stockpiles (Siyakatshana, 2010).

21.4 Coal processing and beneficiation research

Research and development in coal preparation and beneficiation focuses on the following aspects:

21.4.1 Dry coal processing

Although not as effective as conventional wet processing, dry processing consumes less water and produces a drier product. Recent research has indicated that South African coal can be successfully upgraded through dry processing. A number of research and development projects are currently investigating aspects such as optical sorting, dry-air jiggng, dry screening (de Korte, 2008) and dry dense medium separation. The use of jiggng techniques has been found to particularly effective in de-stoning large volumes of low-grade ROM ores, in preparation for further processing. The application of an octagonal rotary triboelectrostatic separator achieved removal of ash from around 30% to 14% and total sulphur from 1.7% to 0.5% (Bada et al., 2010). In collaboration with Technical University of Delft the dry sorting technique “dual energy x-ray transmission” has recently been developed for “on-line determination of ash content and particle size distribution of bituminous coal” (Von Ketelhodt and Bergman, 2010).

21.4.2 Simultaneous washing of coarse and small coal

Large-diameter cyclones can be used to process a wide range of raw coal and simplify the lay-out and operation of plants. This process is already in application at Twistdraai, South Witbank (de Korte, 2004).

21.4.3 Desliming and upgrading of fines

As discussed previously the quantity of fines in the ROM coal to preparation plants is increasing due to mechanised mining techniques. Dense medium cyclones offer a potentially superior alternative to spirals, but require efficient desliming to be effective. Wet screening using Kroosh screening technology has been found to be effective in some cases for desliming fine coal at 100 micron (de Korte, 2003). However, this technology was abandoned, for example, at Anglo American’s Goedehoop colliery as the screens disintegrated very quickly.

21.4.4 Agglomeration of ultra-fine coal

Agglomeration of ultra-fine coal after beneficiation and thermal drying has been found to reduce handling problems and prevent the ultra-fines from re-adsorbing moisture. Various kinds of agglomeration are available, including pelleting, extrusion, binder and binderless briquetting. The latter is reported to be the most economically viable (England, 2000).

21.4.5 Upgrading and/or utilisation of ultra-fines

A number of potential options for the beneficiation and/or utilisation of ultra-fines have been outlined by Reddick et al. (2007). These include:

- Beneficiation and thermal drying: in accordance with Reddick et al. (2007), the combination of flotation and thermal drying can result in a 75% conversion of the ultra-fines to a valuable product, depending on the quality of the coal
- Solar drying of ultra-fines. A similar process to that used to reclaim slurry from dams is proposed for current arisings.
• Solubilising the ultra-fines to produce methane and polymers.
• Producing a coal-water slurry from the ultra-fines for power generation
• Use as a low-smoke fuel in the domestic sector, using agglomeration
• Combusting the ultra-fines in a fluidised bed combustor: A project at the CSIR has established that it is technically feasible to combust ultra-fine coal slurries of 63% moisture in a fluidised bed combustion boiler

21.5 Research priorities for Eskom

Eskom presently generates 88% of its electricity from coal. This predominance will decrease, with the introduction of alternative energy carriers to mitigate the impact of the continued usage of coal. Coal will however remain a predominant, albeit reducing primary energy carrier for electricity generation for the foreseeable future in South Africa. Eskom has therefore been running a comprehensive Clean Coal Technology research and development program for several decades, to explore, identify and demonstrate solutions for continued coal usage.

The focus of the clean coal technology research has been primarily in the following areas:
• Improved efficiencies on conventional sub-critical pulverised coal plants
• Supercritical pulverised coal plants
• Ultra-supercritical pulverised coal plants
• Fluidised bed combustion for electricity generation
• Conventional and advanced emissions control on new and existing plants
• Surface gasifier technology related to integrated gasification combine cycle (IGCC) plants
• Carbon capture and storage
• Underground coal gasification related to co-firing with coal and IGCC.

An overview of the coal research programme is shown below:

Figure 77: Overview of Eskom’s coal research programme
The coal research forms part of Eskom's consolidated technical research programme that has a budget of R231 million of the financial year 2001/12. The primary focus areas for the overall research programme are as follows:

- Air Quality
- Applied Chemistry and Microbiology
- Asset Management
- Clean Coal and Fuel Resources
- Climate Change & Sustainability
- Decision Support Sciences and Statistics
- Distribution Technology
- Generation Plant Integrity and Performance
- Integrated Demand Management
- Renewable Energy
- Safety, Health, Environment & Quality
- Smart Grid - Control & Optimisation Solutions
- Transmission Technology
- Water Resources

### 21.6 Research and Development in coal to liquids and coal chemicals

Sasol has a strong culture of R&D, as is evident from the regular presence of its researchers at local and international conferences. Research primarily focuses on reducing the severity of the process conditions, increasing the yield of valuable products and reducing overall costs (Sasol, 2010c). Significant attention has also been given to the issue of Carbon Capture and Storage due to the 90 to 98% pure CO₂ stream produced in the Sasol process, which specifically lends itself to this technology (Mwakasonda and Winkler, 2005).

Collaborative research with Eskom and tertiary institutions into “paste technology” or the co-disposal of ash and brine (both significant problems to Sasol and Eskom) has been ongoing (Menghistu, 2010; Muntigh et al., 2009; Mahlaba and Pretorius, 2006).

Sasol research and innovation projects include (Sasol, 2010a)

- Recovery and processing of solvents, waxes, phenolics
- Base-metal catalysts for FT synthesis processes
- Coal exploration and innovation; performance enhancing techniques
- Fuel research: quality and standards, current and future motors
- Sasol New Energy Holdings investigating lower carbon energy options
- Development of synthetic jet fuel

Combined with generally high-energy requirements of the CTL process, the production of hydrogen (H₂) from coal for FT is associated with low carbon efficiency; Sasol requires around 120 t H₂ per hour (Mulder, 2009). Recent research into alternative hydrogen sources includes the carbon free production of hydrogen by means “water splitting” (Mulder, 2009).

Sasol partners with tertiary institutions to develop “internal and external talent pools” and this is expressed in part through scholarship programmes for research projects and tuition of undergraduate and postgraduate students (Sasol, 2010c).

### 21.7 Research into climate change mitigation and adaptation

In terms of climate change mitigation, global research and development is focusing on (MIT, 2007):

- Ultra-high efficiency coal combustion plants
- Gasification technologies, including gas treatment
- Long-term carbon dioxide sequestration, including improved methods for CO₂ capture and large scale transport of CO₂, captured and pressurised at point of coal combustion and conversion plants, to injection at storage sites
- Mineral sequestration of CO₂
- Algal CO₂ sequestration
- Syngas technologies, such as improved hydrogen-rich turbine generators and technologies to convert syngas to chemicals and fuels
- Technologies that tolerate variable coal qualities
- Integrated systems with CO₂ capture and storage (CCS)
- Novel concepts such as chemical looping, the transport gasifier, membrane separation of CO₂ and others

A linked research area that requires attention in the coal value chain is climate change adaptation. While climate change mitigation is well understood across the value chain and mitigation strategies are becoming standard practice, adapting to climate change is an area that is poorly understood by the players in the coal value chain. However, increasingly adaptation measures will need to be addressed in order to reduce the impact of the effects of climate change on operations and the communities supported by the coal industry.

### 21.8 Summary of local research activities and capabilities

The table below provides a list of some of the research organisations who have ongoing activities in South Africa, along with their areas of interest.
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<th>Research Focus</th>
<th>Major Focus Area</th>
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<td>Coaltech</td>
<td>Mining Safety</td>
<td>Mining and Extraction</td>
</tr>
<tr>
<td>Coaltech</td>
<td>Mining Safety</td>
<td>Mining and Extraction</td>
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<td></td>
<td>Spontaneous Combustion</td>
<td>Environment</td>
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<td>Coaltech (CSIR)</td>
<td>Electrical Resistance Tomography (ERT)</td>
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<td>Coaltech (UP)</td>
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<tr>
<td>Coaltech (AEL &amp; BME)</td>
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<td>Coaltech (Itasca)</td>
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<tr>
<td>Coaltech (UCT)</td>
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<td>Coaltech (Earth)</td>
<td>Ion-Exchange</td>
<td>Environment</td>
</tr>
<tr>
<td>Coaltech (PU)</td>
<td>Alleviation of compaction</td>
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<tr>
<td>Coaltech (Wits)</td>
<td>Socioeconomic impacts</td>
<td>Socio-economic aspects, training and education</td>
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<td></td>
<td>Mine management</td>
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<tr>
<td>CSIR (Materials Science and Manufacturing)</td>
<td>CCS</td>
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<td></td>
<td>FB</td>
<td>Large Power Generation</td>
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<td></td>
<td>Co-firing</td>
<td>Alternative Energy</td>
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<td></td>
<td>Coal gasification</td>
<td>Large Power Generation</td>
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<td></td>
<td>Beneficiation</td>
<td>Beneficiation and Discards</td>
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<td>GCS</td>
<td>Water Pollution (AMD); Hydrology; Pedology</td>
<td>Environment</td>
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<td>Mintek (Mineralogy and Mineral Processing)</td>
<td>Electron microscope QEMSCAN™; Advanced analysis; Mineralogy; Mineral Processing; X-ray diffraction; MLA; Economics and Market analysis</td>
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<td></td>
<td>CCS</td>
<td>Climate change</td>
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<tr>
<td></td>
<td>Co-firing</td>
<td>Alternative Energy</td>
</tr>
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<td>Rhodes University (Department of Geology)</td>
<td>Petrography; Economic geology; exploration geology</td>
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<td>SANERI South African Centre of Carbon Capture and Storage (SACCCS)</td>
<td>CCS</td>
<td>Climate change</td>
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<tr>
<td>SASOL Research &amp; Development</td>
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<td>UCT/CPUT (ERC)</td>
<td>CCS</td>
<td>Climate change</td>
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<td>University of Cape Town (Minerals2Metals)</td>
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<td>Environment, Beneficiation and Discards</td>
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<td></td>
<td>FBC</td>
<td>Large Power Generation</td>
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<td></td>
<td>Beneficiation: flotation</td>
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<td>University of Johannesburg (Department of Extraction Metallurgy)</td>
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<td>University of Johannesburg (Department of Geology)</td>
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<tr>
<td>University of KZN</td>
<td>Beneficiation: dry fluidised separator</td>
<td>Beneficiation and Discards</td>
</tr>
<tr>
<td>University of Pretoria (Chair of Carbon Materials and Technology)</td>
<td>Beneficiation: graphite</td>
<td>Beneficiation and Discards</td>
</tr>
<tr>
<td>University of the Free State (Institute for Groundwater Studies)</td>
<td>Water pollution (AMD); Water discharge; Geophysics; Modelling; Laboratory</td>
<td>Environment</td>
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<td>Research organisation</td>
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<td>Major Focus Area</td>
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<td>University of the North-West (Mineral Processing/Coal Research)</td>
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<td>Advanced modelling: combustion kinetics</td>
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<td></td>
<td>Advanced modelling: Gasification, CCS</td>
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<td>Beneficiation: thermal drying;</td>
<td>Beneficiation and Discards</td>
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<td></td>
<td>Beneficiation: activated carbon;</td>
<td>Beneficiation and Discards</td>
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<td>X-ray sorting of coal</td>
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<td>Metallurgical coal reduction kinetics</td>
<td>Metallurgical utilisation</td>
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<td></td>
<td>CBM</td>
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<td>LCA</td>
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<td>FB Gasification</td>
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<td></td>
<td>Underground Coal Gasification</td>
<td>Mining and Extraction</td>
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<td>University of the Witwatersrand (Clean Coal Technology)</td>
<td>Optimisation of wet beneficiation processes</td>
<td>Beneficiation and Discards</td>
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<td>Development and application of dry beneficiation processes (fine and sized coal)</td>
<td>Beneficiation and Discards</td>
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<td>Distribution of trace elements in beneficiated products</td>
<td>Beneficiation and Discards</td>
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<td>Advanced prediction of yield from float-sink analyses for optimisation of beneficiation plant</td>
<td>Beneficiation and Discards</td>
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<td>Optimisation of PF combustion</td>
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<td>Optimisation of travelling grate combustion</td>
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<td>Assessment of a CFBC combustion of high ash coals</td>
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<td>Investigation of fine fly ash particulates (PM10s and finer)</td>
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<td>Characterisation of carbon reductants to metallurgical reduction</td>
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<td>Advanced high-tech carbon materials from coal</td>
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<td>Integrated assessment for liability to spontaneous combustion</td>
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<td>IGCC</td>
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<td>Coalbed Methane</td>
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### APPENDIX 1: KEY FACTS AND FIGURES

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<th>Coal types</th>
<th>Value</th>
<th>Unit</th>
<th>Source</th>
<th>Comment</th>
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</thead>
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<tr>
<td>Potential thermal</td>
<td>t.b.c.</td>
<td>Gt</td>
<td>Based on Bredell, 1987, with assistance from J. Dempers and the CRRSA</td>
<td>As tonnes saleable product</td>
</tr>
<tr>
<td>Potential metallurgical</td>
<td>t.b.c.</td>
<td>Gt</td>
<td>as above</td>
<td>As tonnes saleable product</td>
</tr>
<tr>
<td>Potential anthracite</td>
<td>t.b.c.</td>
<td>Gt</td>
<td>as above</td>
<td>As tonnes saleable product</td>
</tr>
<tr>
<td>Typical sulphur in</td>
<td>&lt;2</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical CV of ROM</td>
<td>16 – 21</td>
<td>MJ/kg</td>
<td>(Eberhard, 2011)</td>
<td></td>
</tr>
<tr>
<td>Typical ash content</td>
<td>20 – 40</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal reserves</td>
<td>8.5</td>
<td>Gt</td>
<td>(Wood Mackenzie, 2010)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td>Metallurgical reserves</td>
<td>0.5</td>
<td>Gt</td>
<td>(Wood Mackenzie, 2010)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td>World ranking</td>
<td>8th</td>
<td></td>
<td>(BP, 2010)</td>
<td>Year: 2009</td>
</tr>
</tbody>
</table>

#### Mining and beneficiation

| Run-of-mine production | 312              | Mt            | (Prevost, 2010)                                                       | Year: 2007                                                              |
| Percent of ROM         | 60               | %             | (Prevost, 2010)                                                       | Year: 2007                                                              |
| World ranking          | 6th              |               | (World Coal Association, 2011a)                                       | Year: 2009                                                              |
| Thermal coal for export| 66               | Mt            | (World Coal Association, 2011a)                                       | Year: 2009                                                              |
| Coking coal import     | 1.2              | Mt            | (IEA, 2011)                                                           | Year: 2008                                                              |
| Coking coal export     | 0.6              | Mt            | (IEA, 2011)                                                           | Year: 2008                                                              |
| Average water use for  | 130              | litres/tonne  | (Pulles et al., 2001)                                                 | including beneficiation, where applicable                               |
| mining                 |                  | mined         |                                                                        |                                                                         |
| Mining and industrial  | 6                | %             | (SSA, 2006)                                                           | Year: 2000                                                              |
| Coal mining contribution to GDP | 1.8 | % | (StatsSA, 2010) | Year: 2009 |
| Coal mining contribution to employment | 70,700 | employees | (Chamber of Mines, 2010) | Year: 2009 |

#### Transport

| RBCT Export            | 71.8             | Mt            | (RBCT, 2010)                                                         | Year: 2010                                                              |
| RBCT nameplate capacity| 91               | Mtpa          | (RBCT, 2010)                                                         | Year: 2011                                                              |
| Richards Bay Dry Bulk  | 0.6              | Mt            | (Wood Mackenzie, 2010)                                               | Year: 2009                                                              |
| Durban Bulk Connections| 1.8              | Mt            | (Reuters, 2009)                                                      | Year: 2009                                                              |
| Matola Coal Terminal  | 1.3              | Mt            | (Wood Mackenzie, 2010)                                               | Year: 2009                                                              |
| Coal transport by road | 50               | Mt            | (Crickmay, 2009)                                                     | Year: 2008                                                              |
| Rail line to RBCT      | 72               | Mtpa          | (Crickmay, 2009)                                                     | Year: 2009                                                              |

#### Electricity

<p>| Eskom coal consumption | 122.7            | Mt            | (Eskom, 2010a)                                                       | Year: 2009                                                              |
| Eskom coal burnt average CV | 19.22 | MJ/kg | (Eskom, 2010a) | Year: 2009 |
| Eskom coal burnt average ash content | 29.56 | % | (Eskom, 2010a) | Year: 2009 |
| Coal share of electricity generated | 93 | % | (Eskom, 2010a) | Year: 2009 |
| Total installed capacity | 44,170           | MW            | (SAPP, 2009)                                                        | Year: 2009                                                              |
| Eskom net maximum capacity | 40,870          | MW            | (Eskom, 2010a)                                                    | Year: 2009                                                              |</p>
<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
<th>Unit</th>
<th>Source</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation</strong></td>
<td>232,812</td>
<td>GWh</td>
<td>(Eskom, 2010a)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Eskom GHG emissions</strong></td>
<td>225.5</td>
<td>Mt CO₂e</td>
<td>(Eskom, 2010a)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Eskom emission intensity</strong></td>
<td>1.03</td>
<td>kg CO₂/kWh</td>
<td>(Eskom, 2010a)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Eskom water use</strong></td>
<td>316</td>
<td>Mm³/year</td>
<td>(Eskom, 2010a)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Power generation share of national water use</strong></td>
<td>2</td>
<td>%</td>
<td>(SSA, 2006)</td>
<td>Year: 2000</td>
</tr>
<tr>
<td><strong>Electricity and gas sector contributor to GDP</strong></td>
<td>2.10%</td>
<td></td>
<td>(StatsSA, 2010)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Eskom employment</strong></td>
<td>36,547</td>
<td>employees</td>
<td>(Eskom, 2010a)</td>
<td>Year: 2009/10</td>
</tr>
<tr>
<td><strong>South African power exports</strong></td>
<td>14,645</td>
<td>GWh</td>
<td>(based on StatsSA, 2010)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td><strong>South African power imports</strong></td>
<td>12,193</td>
<td>GWh</td>
<td>(based on StatsSA, 2010)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td><strong>Installed wind power</strong></td>
<td>21.8</td>
<td>MW</td>
<td>(WWEA, 2010)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Installed hydro power</strong></td>
<td>668</td>
<td>MW</td>
<td>(Merven et al., 2010)</td>
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<tr>
<td><strong>Eskom ash generation</strong></td>
<td>36.01</td>
<td>Mt</td>
<td>(Eskom, 2010a)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td><strong>Eskom ash reused</strong></td>
<td>1.2</td>
<td>Mt</td>
<td>(Eskom, 2010d)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td><strong>Sasol mining production</strong></td>
<td>39</td>
<td>Mt</td>
<td>(Sasol, 2010b)</td>
<td>2009</td>
</tr>
<tr>
<td><strong>Sasol CTL share of SA liquid fuels</strong></td>
<td>27%</td>
<td></td>
<td>(Kopler, 2009)</td>
<td></td>
</tr>
<tr>
<td><strong>GHG emissions (South Africa)</strong></td>
<td>60</td>
<td>Mt CO₂e</td>
<td>(Sasol, 2010a)</td>
<td>Year: 2010</td>
</tr>
<tr>
<td><strong>Sasol water consumption (Global)</strong></td>
<td>151</td>
<td>Mm³/year</td>
<td>(DWA, 2009)</td>
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</tr>
<tr>
<td><strong>Sasol contribution to SA GDP</strong></td>
<td>4</td>
<td>%</td>
<td>(Sasol 2005)</td>
<td>Year: 2004/5</td>
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<tr>
<td><strong>Employment (South Africa)</strong></td>
<td>28,978</td>
<td>employees</td>
<td>(Sasol. 2010b)</td>
<td>2010</td>
</tr>
<tr>
<td><strong>National yield</strong></td>
<td>13,227</td>
<td>Mm³/year</td>
<td>(DWAF, 2004a)</td>
<td>Year: 2000</td>
</tr>
<tr>
<td><strong>National demand</strong></td>
<td>12,871</td>
<td>Mm³/year</td>
<td>(DWAF, 2004a)</td>
<td>Year: 2000</td>
</tr>
<tr>
<td><strong>Inter-basin transfers</strong></td>
<td>3,000</td>
<td>Mm³/year</td>
<td>(own calculations from DWAF, 2004a)</td>
<td>Year: 2000</td>
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<tr>
<td><strong>Coal consumption</strong></td>
<td>5.33</td>
<td>Mt</td>
<td>(DMR, 2010)</td>
<td>Year: 2009</td>
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<tr>
<td><strong>GHG process emissions of iron and steel production</strong></td>
<td>18</td>
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<td>(DEAT, 2009)</td>
<td>Year: 1994</td>
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<tr>
<td><strong>Iron and steel industry GDP contribution</strong></td>
<td>1.4</td>
<td>%</td>
<td>(Dieterich, 2007)</td>
<td>Year: 2006</td>
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<tr>
<td><strong>Basic iron and steel manufacture employment</strong></td>
<td>52,000</td>
<td>employees</td>
<td>(StatsSA, 2010)</td>
<td>Year: 2009</td>
</tr>
<tr>
<td><strong>Blast furnace</strong></td>
<td>55</td>
<td>%</td>
<td>(SAISI, 2010)</td>
<td>Year: 2009</td>
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<tr>
<td><strong>Direct reduced</strong></td>
<td>23</td>
<td>%</td>
<td>(SAISI, 2010)</td>
<td>Year: 2009</td>
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<tr>
<td><strong>EAF</strong></td>
<td>14</td>
<td>%</td>
<td>(SAISI, 2010)</td>
<td>Year: 2009</td>
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<tr>
<td><strong>Other</strong></td>
<td>8</td>
<td>%</td>
<td>(SAISI, 2010)</td>
<td>Year: 2009</td>
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<tr>
<td><strong>Cement</strong></td>
<td>1.75 – 2</td>
<td>Mt</td>
<td>own calculation</td>
<td>Year: 2010</td>
</tr>
<tr>
<td><strong>Paper and pulp</strong></td>
<td>1.75</td>
<td>Mt</td>
<td>own calculation</td>
<td>Year: 2010</td>
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<tr>
<td><strong>Sugar mills</strong></td>
<td>0.25</td>
<td>Mt</td>
<td>own calculation</td>
<td>Year: 2010</td>
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<tr>
<td><strong>Residential use</strong></td>
<td>1</td>
<td>Mt</td>
<td>(Strydom and Surridge, 2009)</td>
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<tr>
<td></td>
<td>Value</td>
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<tr>
<td><strong>Climate change</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>National GHG emissions</td>
<td>434.5</td>
<td>Mt CO₂/ year</td>
<td>(DEAT, 2009)</td>
<td>Year: 2000</td>
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<tr>
<td>Estimated potential CCS storage capacity</td>
<td>150,000</td>
<td>Mt CO₂</td>
<td>(Council for Geoscience, 2010b)</td>
<td></td>
</tr>
<tr>
<td>Estimated potential CCS storage capacity on land</td>
<td>3,000</td>
<td>Mt CO₂</td>
<td>(Council for Geoscience, 2010b)</td>
<td></td>
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<tr>
<td><strong>Other fuels in South Africa</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>SA oil reserves</td>
<td>15</td>
<td>million bbl</td>
<td>(WEC, 2010)</td>
<td></td>
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<tr>
<td>Crude oil refinery capacity</td>
<td>497,000</td>
<td>bbl/ day</td>
<td>(Sapia, 2009; EIA, 2010)</td>
<td></td>
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<tr>
<td>Synfuel production capacity</td>
<td>195,000</td>
<td>bbl/ day</td>
<td>(Sapia, 2009)</td>
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<tr>
<td>Total liquid fuel consumption</td>
<td>24,900</td>
<td>Ml</td>
<td>(Sapia, 2009)</td>
<td>Year:2008</td>
</tr>
<tr>
<td>Net liquid fuel import</td>
<td>2,100</td>
<td>Ml</td>
<td>(Sapia, 2009)</td>
<td>Year:2008</td>
</tr>
<tr>
<td>Natural gas proved reserves</td>
<td>28</td>
<td>billion m³</td>
<td>(CIA, 2011)</td>
<td></td>
</tr>
<tr>
<td>Natural gas production</td>
<td>3.2</td>
<td>million m³</td>
<td>(EIA, 2010)</td>
<td>Year:2008</td>
</tr>
<tr>
<td>Natural gas consumption</td>
<td>6.5</td>
<td>million m³</td>
<td>(EIA, 2010)</td>
<td>Year:2008</td>
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</tr>
<tr>
<td>Codes of Good Practice for the South African Minerals Industry, 2009</td>
<td>Coal Supply</td>
</tr>
<tr>
<td>Housing and Living Conditions Standard for the Minerals Industry, 2009</td>
<td>Coal Supply</td>
</tr>
<tr>
<td>Stakeholders’ Declaration on Strategy for the sustainable growth and meaningful transformation of South Africa’s Mining Industry 30 June 2010</td>
<td>Coal Supply</td>
</tr>
<tr>
<td>Amendment to Minerals Charter, 2010</td>
<td>Coal Supply</td>
</tr>
<tr>
<td>National Industrial Policy Framework, 2007</td>
<td>Coal Use</td>
</tr>
<tr>
<td>Industrial Policy Action Plan, 2007</td>
<td>Coal Use</td>
</tr>
<tr>
<td>DPE Strategic Plan, 2010</td>
<td>Transport</td>
</tr>
<tr>
<td>White Paper on National Transport Policy, 1996</td>
<td>Transport</td>
</tr>
<tr>
<td>National Freight Logistics Strategy, 2005</td>
<td>Transport</td>
</tr>
<tr>
<td>National Commercial Ports Policy White Paper, 2002</td>
<td>Transport</td>
</tr>
<tr>
<td>White Paper on National Environmental Management, 1997</td>
<td>Environment</td>
</tr>
<tr>
<td>White paper on a National Water Policy for South Africa, 1997</td>
<td>Environment</td>
</tr>
<tr>
<td>Draft White Paper on Water Services, 2002</td>
<td>Environment</td>
</tr>
<tr>
<td>National Climate Change Response Green Paper, 2011</td>
<td>Environment</td>
</tr>
<tr>
<td>Discussion Paper for public comment: reducing greenhouse gas emissions, the carbon tax option, 2010</td>
<td>Environment</td>
</tr>
<tr>
<td>Draft National Waste Management Strategy, 2010</td>
<td>Environment</td>
</tr>
<tr>
<td>National Water Conservation and Water Demand Management Strategy, 2004</td>
<td>Environment</td>
</tr>
<tr>
<td>Integrated Resource Plan for Electricity 2010-2030</td>
<td>Electricity</td>
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<tr>
<td>Medium Term Risk Mitigation Project accompanying IRP2010</td>
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### Legislation related to the coal value chain

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<tr>
<td>Minerals and Petroleum Resources Development Act (MYPDA), 2002</td>
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<tr>
<td>Electric Regulation Act, 2006</td>
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<tr>
<td>National Energy Regulator Act, 2004</td>
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<tr>
<td>National Energy Act, 2008</td>
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<tr>
<td>Minerals and Energy Laws Amendment Act, 2005</td>
</tr>
<tr>
<td>Income Tax Act, 1962</td>
</tr>
<tr>
<td>Transport Laws Repeal Act, 2010</td>
</tr>
<tr>
<td>National Land Transport Act of 2009</td>
</tr>
<tr>
<td>Transport Agencies General Laws Amendment Act, 2007</td>
</tr>
<tr>
<td>National Ports Act, 2004</td>
</tr>
<tr>
<td>International Trade Administration Act, 2002</td>
</tr>
<tr>
<td>National Ambient Air Quality Standards, 2009</td>
</tr>
<tr>
<td>Water Services Act, 1997 and Amendment Act, 2004</td>
</tr>
<tr>
<td>National Environment Management: Air Quality Act, 2004</td>
</tr>
<tr>
<td>National Water Act, 1998</td>
</tr>
<tr>
<td>Broad Based Black Economic Empowerment Act, 2003</td>
</tr>
<tr>
<td>Occupational Health and Safety Act, 1993</td>
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<thead>
<tr>
<th>Area of Value Chain</th>
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<tbody>
<tr>
<td>Coal Supply</td>
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<td>Socio-economic</td>
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<td>Socio-economic</td>
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</tbody>
</table>
Institutions

Note that there is no forum for the full coal industry. The various parts of the coal value chain are represented below, this list does not attempt to be fully comprehensive, but rather to give an outline of the range of institutions within each area of the value chain.

South African institutions

General
- Fossil Fuel Foundation
- National Economic Labour and Development Council (NEDLAC)
- Treasury
- National Planning Commission

Mining
- South African Chamber of Mines (SACOM)
- Southern African Institute of Mining and Metallurgy (SAIMM)
- South African Minerals Association
- Mining Industry Growth, Development and Employment Task Team (MIDGETT)
- National Union of Mineworkers; Allied Unions of SA; Cosatu; Solidarity; United
- NPC (new policy unit in the DMR)
- Department of Mineral Resources (DMR)
- South African Mining Association (SAMDA).
- Regional branches of the DMR
- Regional Mining Development and Environmental Committee
- Local government (interaction around social issues)
- Minerals and Mining Development Board
- Regional mining development and Environmental Committee
- South African Minerals Development Association
- Council for Geoscience
- Minerals Bureau
- South African Small Scale Mining Chamber
- The Council for Mineral Technology (Mintek)
- Coaltech Research Association
- South African Colliery Managers Association
- South African Colliery Engineers Association

Transport and logistics
- Department of Transport
- Transnet
- Department of Public Enterprises
- Inter-departmental Task Team on Logistics
- National Ports Authority
- Chartered Institute of Logistics and Transport
- South African Road Federation

Coal use
- Department of Public Enterprises
- Department of Energy
- Department of Trade and Industry
- Sasol
- Eskom
- National Energy Efficiency Agency (NEEA)
- South African Energy Research Institute (SANERI)
- South African Energy Development Institute (SANEDI)
- South African Renewables Initiative (SARI)
- National Energy Regulator of South Africa (NERSA)
- DOE's Renewable Energy Subsidy Office (REFSO)
Environment
- Department of Environmental Affairs (DEA)
- South African Centre for Carbon Capture and Storage
- South African Carbon Dioxide Storage Atlas
- Rehabilitation Oversight Committee of the DMR
- Inter-Ministerial Committee on Climate Change
- National Environmental Advisory Forum (NEAF)
- Committee for Environmental Co-ordination
- Intergovernmental Committee on Climate Change
- National Committee on Climate Change
- Catchment Management Agencies
- Water User Associations
- Advisory Committees under the Water Act of 1998
- Water Tribunal
- Water Service Institutions
- Water Board
- Water Services Provider
- Environmental Management Inspectorate
- South African Bureau of Standards (SABS)
- South African Coal Environmental Professionals Association

Socio-economic
- Department of Labour
- National Union of Mineworkers; Allied Unions of SA; Cosatu; Solidarity; United

Jointly owned service entities:
- The Collieries Training College
- Environmental Control Services
- The Rescue Drilling Unit

International institutions
- International Energy Agency (IEA)
- Coal Industry Advisory Board
- Global Mining Initiative
- Mining and Energy Research Network
- World Mine Ministries Forum
- Global Mining Campaign
- International Council on Mining and Metals (ICMM)
- World Bank
- International Finance Corporation (IFC)
- IEA Global Carbon Capture and Storage Institute
- IEA Working Party on Fossil Fuels
- IEA Greenhouse Gas R&D Programme
- Global Carbon Capture and Storage Institute
- Carbon Sequestration Leadership Forum
- World Trade Organisation
- Euromines
- Minerals Council of Australia
- Camara Minera de Mexico
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