SOUTH AFRICAN COAL ROADMAP

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JULY 2013

PREFACE

The coal industry has been and continues to be the primary source of energy for South Africa. Overcoming the challenges facing our country, including poverty, unemployment and inequality, will require provision of safe and affordable access to energy for all its inhabitants. But despite an abundant endowment of coal in South Africa, its continued use presents many challenges and its future contribution demands careful stewardship.

The need for a Coal Road Map 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 SA Government, due to the impending reorganisation of the DME into two ministries (Energy and Mineral Resources). In March 2010 the Department of Energy formally (re)joined and the initiative was formalised - contributions were requested from participants, enquiries issued for the project management role and a project manager, The Green House, was appointed in June 2010. The Department of Mineral Resources and a wide range of other stakeholders also subsequently provided support. 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 of the current state of the SA coal industry and the key issues facing it – and a description of some future scenarios. This phase was completed in October 2011 and was planned for release on 4th November 2011. Further time for review was requested by various participants and the release was delayed. Nevertheless, early in 2012, after receiving further contributions from participants, it was decided to proceed with Phase II.

Much of the work of Phase II was carried out by a smaller group drawn from the Steering Committee and Board of the initiative, comprising representatives of the Departments of Energy and Mineral Resources, Eskom, Sasol, coal producers and specialists. A scenario analysis approach was pursued and modelled and a Roadmap collaboratively developed. The Roadmap is presented in this document, which should be read in conjunction with the associated Scenarios Report, and the Technical Report that describes the modelling that underpins the scenario development and Roadmap.

The documents were initially distributed in December 2012 for comment to stakeholders who had provided input to the initiative, who had a direct stake in the industry as well as those whose input would contribute to shaping its future. Comments were received, a further audit of the input assumptions was carried out and further edits made in the first half of 2013. This version has been distributed to participants in the SA Coal Roadmap initiative and is also being made more widely available to support industry, policymakers and other stakeholders.

I would like to thank all participants who have contributed to the SA Coal Roadmap process, in kind or through their participation, discussion or other input. The initiative presented a unique opportunity for a very wide range of stakeholders in South Africa's coal industry to collaborate with a single common purpose – the benefit of South Africa and its people.

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South African Coal Roadmap
June 2013

DISCLAIMER

The statements and views of the South African Coal Roadmap are a consensus view of the participants in the development of the roadmap and do not necessarily represent the views of the participating members in their individual capacity. An extensive as reasonably possible range of information was used in compiling the roadmap; all judgments and views expressed in the roadmap are based upon the information available at the time and remain subject to further review. The South African Coal Roadmap does not guarantee the correctness, reliability or completeness of any information, judgments or views included in the roadmap. All forecasts made in this document have been referenced where possible and the use and interpretation of these forecasts and any information, judgments or views contained in the roadmap is entirely the risk of the user. The participants in the compiling of this roadmap will not accept any liability whatsoever in respect of any information contained in the roadmap or any statements, judgments or views expressed as part of the South African Coal Roadmap.

The Coal Roadmap was prepared by The Green House, acting as Technical Project Managers on behalf of the South African Coal Roadmap Steering Committee. The Roadmap and accompanying scenarios and technical reports are based on information, views and data provided to The Green House, supplemented by information obtained from the open literature. The views expressed in this document thus do not reflect those of The Green House.

Enquiries should be directed through the Fossil Fuel Foundation (www.fossilfuel.co.za) or the South African National Energy Development Institute – SANEDI (www.sanedi.org.za).

HIGHLIGHTS OF THE ROADMAP

The South African Coal Roadmap was developed to explore the short, medium and long-term activities and interventions needed to support the coal industry in South Africa to maximise its contribution to South Africa in the face of an uncertain future. The Roadmap was developed through a collaboration of members of the coal value chain in South Africa, including the national Departments of Energy and Mineral Resources.

A scenario-based approach was taken to Roadmap development. Two drivers, the global climate change response and South Africa's mitigation response, were selected from many considered and used to define a set of four distinct future worlds with very different implications for the coal value chain. The future worlds that were explored are:

- **More of the Same**, where limited action is taken on climate change globally and in South Africa;
- **Lags Behind**, where the world moves ahead with greenhouse gas emissions mitigation, but South Africa continues to pursue coal as its primary energy source;
- **At the Forefront**, where South Africa joins the global leaders in emissions mitigation, while much of the remainder of the world takes limited action; and
- **Low Carbon World**, where strong action is taken globally and locally on greenhouse gas emissions mitigation.

Four scenarios, describing a plausible evolution of electricity generation build in the country, technology trajectories and coal-to-liquids (CTL) developments under each of these different futures, were developed. These scenarios were quantitatively modelled and qualitatively assessed to determine the implications of following that trajectory for South Africa. The models and results of the analysis are described in detail in an accompanying Technical Report, while the Scenarios Report provides an overview of the implications of following the four scenarios. The Roadmap distils the actions required for the coal value chain to continue to contribute to a flourishing South Africa.

This Highlights Section aims to provide an overview of the main actions and interventions that make up the Roadmap, beginning with the **overdue actions** that are urgently required to ensure domestic energy supply. This is followed by the **actions required to ensure that exports remain a source of foreign revenue for South Africa.** Further actions are required in the short and medium term in response to **identified signals** that could influence the future of the coal value chain. The signals are described as well as the implications in terms of the alternative paths that might develop as a result. Finally, a set of **ongoing actions** is presented that are required to ensure a sustainable coal value chain in terms of environmental sustainability, skills development and retention, technology development and research and transformation.

BOX 1: IMPLICATIONS OF BEING AT THE FOREFRONT

At the time of writing the Roadmap (May 2013), the future that is evolving is best represented by the scenario ***At the Forefront*** *[1]. South Africa has made ambitious (albeit conditional) pledges towards greenhouse gas emissions mitigation. Other countries are actively working to mitigate emissions, but efforts are uncoordinated, and a global agreement has not yet been reached on the mitigation effort required of individual countries. The IRP 2010 Policy Adjusted electricity generation build plan, which is followed (and extended to 2040) under the* ***At the Forefront*** *scenario, is current government policy. This plan includes diversification of electricity supply to include an ambitious nuclear and renewables build plan. No future CTL plants are on the near horizon in South Africa.*

What does it mean for the country if South Africa is to continue on this trajectory? What needs to be put in place, and what are the implications thereof? The following are some of the considerations identified in the Roadmap.

Coal supply:

- *Whilst modelling and best available data suggest that sufficient coal resources are available to supply all required grades of coal to power stations in the Central Basin until the mid-2020s, there is significant uncertainty associated with the timing, capacity and projected qualities of new mines, as well as the probability of some of these resources going to export. Failure to resolve this will lead to potential coal supply shortfalls and impact electricity supply as early as 2018.*

Therefore in At the Forefront it is assumed that provision is made to supply higher grade coal to the older Central Basin power stations from the Waterberg and thus rail infrastructure is available in the early-2020s to facilitate transport of coal from the Waterberg to the Central Basin to overcome some of the shortfalls in local utility supply - and at the same time to provide access to export markets.

Electricity build plan:

- *Substantial funding is received to support South Africa's renewables and nuclear programme.*
- *The nuclear and renewables programme is implemented on time.*
- *Electricity generation costs by 2035 are approximately 8% higher than if a coal-only electricity build plan had been followed.*

Liquid fuels:

- *Growth in liquid fuels demand is met from imports, a new crude refinery or, at a later stage, a gas-to-liquid (GTL) facility.*

[1] It is recognised that the results of the analysis will need to be updated with the expected release of the Integrated Energy Plan and the review of the Integrated Resource Plan.

Electricity security:

- *South Africa is primarily reliant on local coal, with some electricity imports (hydro and coal). There is also some reliance on processing nuclear fuel overseas, although increased local fuel processing would increase security. Increased global competition for skills and foreign companies to build and service nuclear and renewable plants will contribute to reduced security unless South Africa develops the necessary capacity early.*
- *Continued tight coal supplies could impact energy security, with increasing competition between Eskom and exporters for the remaining Central Basin resources raising the possibility of supply shortfalls.*

Exports:

- *If new utility mine projects are developed for Eskom as modelled in **At the Forefront**, South Africa's coal exports will peak at around 90 Mtpa between 2020 and 2025 and then steadily decline to below current levels by 2030, unless export only mines are proven feasible in the Waterberg, and sufficient rail infrastructure is built to transport this coal to ports.*
- *New ports or upgrades to existing ports will only be required if the Waterberg is successfully exploited for export only mines on a significant scale.*

Competitiveness:

- *South Africa is not projected to gain any global competitiveness benefits from diversification of its energy supply, except in the case of trade with a select few countries that continue to pursue a low carbon trajectory.*

Employment:

- *After an initial increase in employment, there is a loss of jobs in the coal mining sector due to an eventual reduction in coal mining from around 2025. Some jobs are created in renewables but there will still need to be job creation in other parts of the Green Economy to offset this loss.*

Environment:

- *Water demand grows in certain parts of the country, but impacts will be far lower than in a heavily coal reliant future.*
- *Total greenhouse gas emissions from electricity generation will peak and then begin to decline by the mid-2020s. The emissions intensity of electricity supply drops steadily.*
- *South Africa will be vulnerable to the impacts of climate change, as the rest of the world has not decarbonised to the level required to limit the impacts.*

Overdue actions to ensure energy security

To maintain a flourishing South Africa, energy security is a priority. The SACRM process highlighted a number of pressing actions. Under all modelled scenarios, existing coal-fired power stations are required to keep operating. The following actions are overdue and need to be addressed urgently:

Secure contracts for continued coal supply to existing power stations:

- *Agree on an appropriate coal pricing model or price mechanism for new projects to supply Eskom.*
- *Identify the coal resources which should be developed for power station supply in order to expedite these projects, enable the construction of the necessary mines and logistics infrastructure and reduce the growing uncertainly over future energy security.*

Create an environment conducive to mining investment – even if only for new mines that are urgently required to supply the existing power station fleet:

- *Align policy and legislation to streamline processes and provide certainty for establishment of new mines.*
- *Provide clarity on the structure, magnitude and implementation of the carbon tax.*
- *Provide clarity on the likelihood of declaring coal a strategic resource, how this would be implemented and what the implications would be for existing coal mines and new coal investments.*

Resolve the Central Basin coal supply and transport challenges:

- *Accelerate Eskom's current road-to-rail migration programme.*
- *Make a decision on infrastructure planning for sourcing coal from the Waterberg.*

Support government to complete the Integrated Energy Plan (IEP) and update the Integrated Resource Plan (IRP).

Actions required to capitalise on exports

Coal exports provide a substantial source of foreign revenue for South Africa. Indications are that, even in a low carbon world, there will still be a demand for export coal to 2040 and beyond. Actions that are required to ensure that South Africa is able to capitalise on these markets and continue to provide a source of foreign revenue include:

- *Subject to creating a mechanism to align export growth with meeting domestic utility requirements, continue to expedite currently planned upgrades in capacity on the rail line from the Central Basin to Richards Bay Coal Terminal and continue further expansion planning in alignment with demand requirements.*
- *Provide a supportive investment climate to ensure retention of investment capital and its deployment in new coal mines in South Africa.*
- *Ensure that realistic export trajectories are explored prior to developing new port infrastructure at Richards Bay and Matola.*
- *Provide urgent clarity, as part of the IRP update, on the number of new coal fired stations to be constructed.*
- *Explore the economic feasibility of export-only mines in the Waterberg.*

Short term signals

In the short term, **three signals** have been identified that could see a diversion away from the future represented by **At the Forefront** (as described in Box 1). The markers for these signals are already evident, and implications for South Africa and the coal value chain are significant. South Africa cannot "wait and see" to what extent they transpire: urgent action is required to influence as many of these signals as possible:

- **SIGNAL 1**: Confirmation of new base load electricity generation plans under the IRP2010, in particular the status of the first nuclear power station;
- **SIGNAL 2:** Mining investment climate; and
- **SIGNAL 3:** Developments in the global climate change mitigation agenda.

SIGNAL 1: Status of new base-load power under the IRP 2010 TIME FRAME: Present and escalating
It has been suggested that it is already too late to build the first nuclear power stations by 2023, as proposed under IRP 2010, to supply base load growth after Kusile power station is commissioned. It is anticipated that the IRP 2010 Review could provide clarity on the extent to which reduced GDP growth rates and electricity demand impact on this date. The further nuclear build plan specified under IRP 2010 is also considered ambitious in terms of funding and skills requirements. Furthermore, the ambitious renewables build specified under IRP 2010 does not appear to be deliverable in the proposed time frame. Unless the nuclear and renewables builds are moved ahead rapidly, alternative sources of base load electricity will be required. The alternative choices that remain for base load power in the current time frame are gas and coal.
Alternative futures
Stay on lower carbon path and replace first nuclear with gas. Gas base load power can be built relatively quickly, assuming a suitable and affordable source of gas can be found. Replacement of only one nuclear plant with gas reduces overall investment cost by 8% over the 2010-2040 analysis period, so there is a financial motivation for this option. However gas does come with a greenhouse gas emissions penalty over nuclear. Furthermore, heavier reliance on gas reduces energy security, as imported gas comes with infrastructure and supply security concerns (since countries will always prioritise their domestic requirements in times of shortage), as well as reliance on potentially volatile world markets. Domestic shale gas supply is unlikely in the near term.
Look to coal to fill the gap. Coal-fired power stations offer the benefit of having a guaranteed feedstock, and that there is experience with coal-fired power in South Africa. Coal is also somewhat cheaper to build than nuclear - the replacement of only one nuclear plant with coal reduces the overall investment in power station infrastructure by 2% over the 2010-2040 analysis period (this excludes the substantial costs of decommissioning nuclear plants). The greenhouse gas emissions and water consumption penalties are, however, high compared to gas and nuclear. Coal-fired power stations also have the benefits of increased energy security and increased export revenue (assuming coal is sourced from a dual-producing mine).Coal mining will create additional jobs and provide growth opportunities for the industry to a greater degree than that observed in **At the Forefront.**
Do nothing. South Africa will have to turn to stop-gap measures, such as demand-side management, rolling black-outs, the use of generators and the construction of plant that can be built very quickly. Depending on the technologies chosen, this could have negative impacts on both the environment and the economy.

Actions and key policy requirements

- Clarify the level of mitigation effort that will be required of the energy sector, the costs associated with this and how these mitigation efforts will be achieved through carbon pricing.
- Track progress on delivery of the IRP 2010 build programme, including the supporting regulatory environment and infrastructure. This may require the development of and investment in contingency plans such as plant life extension (and associated coal supply requirements) and alternative power station options.
- If coal-fired power stations are to be built to substitute for nuclear, decisions are required soon – lead times for coal although shorter than those for nuclear, are still substantial. A decision to build additional coal-fired power stations may also improve the investment climate for the coal sector if it contributes to greater production of export coal from the Waterberg.
- Streamline the process to accommodate IPPs in the electricity supply mix, both for renewables and non-renewables, and resolve who is responsible for building new base load capacity.

SIGNAL 2: Mining investment climate
TIME FRAME: Present and escalating

Globally-listed mining companies, which currently produce a majority share of South Africa's coal production, have alternatives for investment off a limited capital base. At present, investment in South Africa is being deterred due to the unfavourable policy and legislative environment, and labour risks and better returns in other commodities and geographies. Although some of these investors could be replaced by domestic entities, if the desirability of investing in South African coal mines declines further, this could lead to future reductions in the availability of coal for both local and export markets.

Alternative futures

Global mining companies continue to invest in coal mines in South Africa, with increased local participation and partnerships. This will allow Eskom to meet its supply needs going forward, as well as the continued contribution of exports to foreign revenues. There are a number of knock on effects of the coal mining industry investing in South Africa, not least of which is job creation and retention, and supporting economic growth through security of electricity supply.

Global mining companies seek investments for their capital in other countries and local mining industry does not develop at the required scale. Here coal supply will be significantly constrained, both to Eskom and for export markets. Consequently, electricity supply will be constrained and potentially sub-optimal investments will need to be made in short lead-time generating capacity to avoid the risk of electricity black-outs.

South Africa finds other (possibly more extreme) mechanisms to acquire, fund and develop the coal resources. Eskom demand is met, but at a cost to the national balance sheet and associated indirect costs to the economy.

Actions and key policy requirements

A number of policy actions are required to attract and retain investments. Some of these have been identified previously as "overdue actions". These are repeated here as they are an ongoing requirement for stimulating and retaining mining investment:

- Alignment between government departments on policy and legislation to streamline processes and provide regulatory certainty for establishment of new mines.
- Resolution on government policy affecting coal mining. This includes concluding debates on restricting low-grade exports, allocation of mining rights and future empowerment requirements for Eskom supply, while giving due consideration to wider national socio-economic imperatives around economic growth and transformation, employment and skills development.
- Clarity on the declarations by government of coal as a strategic resource, and what this means for the industry.
- Identify those resources that are critical to Eskom's supply and ensure that they are secured for this purpose.

SIGNAL 3: Global climate agreements TIME FRAME: 2015
The world's nations decided in Durban in 2011 that agreement on climate change mitigation targets should be reached by 2015, with implementation by 2020. If the Durban Roadmap achieves its stated aims, South Africa is likely to agree to binding targets for greenhouse gas mitigation, to replace its current pledges, which will suggest that we are moving from **At the Forefront** towards either **Low Carbon World** or **Lags Behind**. South Africa's current pledges were conditional on financial assistance, technology transfer and capacity building and any international agreement (with binding targets) should simultaneously seek to formalise and secure commitments in respect of these conditions.
Alternative futures
Durban Roadmap negotiations are successful, and South Africa agrees to binding targets. This would provide a strong signal of a move towards a diversified electricity generation mix in South Africa. The rate of implementation of nuclear, gas and renewables would have to be accelerated substantially.
Durban Roadmap negotiations fall apart, and South Africa reduces its mitigation ambitions. Without the financial support, technology transfer and capacity building required to support the deployment of lower carbon technologies, South Africa could move back towards coal for baseload power supply and possibly even liquid fuels supply. The implications are that coal supply could then be constrained locally due to increased demand, and infrastructure to support the building of new coal-fired power plants and for coal supply from coalfields outside the Central Basin would need to be accelerated.
Actions and key policy requirements
To ensure robust planning the following is required: • Close monitoring of progress on international negotiations. • Clarity on the level of mitigation effort that will be required of the energy sector, the costs associated with this and how these mitigation efforts will be achieved through carbon pricing.

Medium term signals

In the medium term, **three** further **signals** have been identified that could see a diversion away from the future represented by **At the Forefront** (as described in Box 1), which if they occur would have implications for South Africa and the coal value chain:

- **SIGNAL 4:** Infrastructure to support Waterberg development does not proceed or is delayed;
- **SIGNAL 5:** CCS test injection and associated international developments; and
- **SIGNAL 6:** Development of local liquid fuel supply capacity.

SIGNAL 4: Availability of infrastructure to support Waterberg development TIME FRAME: Present to early 2020s
In addition to rail infrastructure being required from the Central Basin to RBCT, it would seem prudent to increase the capacity of the rail infrastructure between the Waterberg and the Central Basin, both to provide an alternative source of coal to feed some Central Basin power stations that are facing a coal shortfall from the mid-2020s or earlier, and enable Waterberg coal to be transported to RBCT for exports. Whilst modelling suggests that there is no immediate threat to security of supply to Eskom, this assumes that all coal mining investments will be delivered as required and without delays. Given the uncertainties in these assumptions and the fact that over 50% of South Africa's coal resources are in the Waterberg, it is strongly recommended that access to the Waterberg coal fields be enabled without delay. Long lead times are required for rail infrastructure so early planning is required to ensure that this infrastructure is ready. Nevertheless, rail and port infrastructure should not be increased beyond their likely throughputs: the current incremental approach to rail expansions is supported. Water infrastructure is required to supply mines and new power stations, and effective urban infrastructure planning is required to ensure sustainable communities in the region.
Alternative futures
Infrastructure (rail and water) construction and urban planning is done on time and to the appropriate scale. This ensures that those Central Basin power stations that can burn Waterberg coal have an alternative source of coal and sustains increased exports from the Waterberg. Sustainable communities with appropriate services, infrastructure, health care, schools etc. are established in the Waterberg.

Infrastructure planning is delayed and appropriate municipal infrastructure is not developed. Coal supply to the Central Basin power stations is severely constrained and shortfalls arise whenever a new project is delayed or a new mine is optimised for exports. The current projects in the Waterberg are not developed further as the coal cannot be transported to the Central Basin or the ports for export, and the export fraction from any mines supplying new Waterberg power stations similarly cannot be transported to ports and hence markets.

Actions and key policy requirements

- Decisions need to be reached on building of new infrastructure, including scale, funding and pricing models.
- If the rail infrastructure is expanded, mechanisms need to be put in place to ensure that domestic coal supply receives the appropriate priority.
- Co-ordinated municipal planning is required for the Waterberg.

SIGNAL 5: CCS test injection and associated international developments
TIME FRAME: 2017

In a future where South Africa is required to further reduce its greenhouse gas emissions Carbon Capture and Sequestration may be pursued. However, unless viable storage options, a successful test injection and a significant reduction in costs can be demonstrated, this will not be realised. Global funding is likely to be required for CCS to be realised in South Africa.

It is noted that the potential of CCS in mitigating emissions is greater in the CTL industry than coal-fired power generation.

Alternative futures

There is a requirement to pursue CCS in order to further reduce emissions and the above conditions are met: Coal will still be able to play a substantial role in South Africa's energy mix, regardless of whether or not there is pressure from the outside world to reduce emissions.

The above conditions are not met. The impact of this outcome depends on the future that has evolved in response to signals 1 through 4. If South Africa has pursued a coal intensive path and the rest of the world has moved towards a low emission future, South Africa could face international pressures due to the coal intensity of its economy. If, however, the rest of the world has not reached inclusive agreements for greenhouse gas emissions mitigation, there should be no substantial implications for South Africa.

Actions and key policy requirements

If CCS is to be pursued as an option for mitigation of greenhouse gas emissions from the sector, the following is required:

- Establishment of a suitable regulatory framework for CCS.
- Maintenance of support for relevant institutions and study programmes, such as the South African Centre for Carbon Capture and Storage.
- Progress with the program to characterise viable storage options and demonstrate a successful test injection.
- Demonstration of a significant reduction in costs globally.
- Continued engagement with international research and development progress in respect of the capture and transport components of the CCS value chain.
- Securing of global funding.

SIGNAL 6: Development of local liquid fuels supply capacity
TIME FRAME: mid 2020s

The anticipated Integrated Energy Plan will provide direction on meeting liquid fuels demand in South Africa. Together with other drivers, this would influence decisions in respect of any further coal-to-liquids plants. Alternatives considered here include continued and increased imports of refined products, a potential new crude oil refinery at Coega or, further into the future, increased gas-to-liquids capacity.

Note that the CTL decision will be influenced by a number of other factors, including the finalisation of a carbon tax.

Alternative futures

A new crude oil or GTL refinery is built. There is unlikely to be the need for a new coal-to-liquids plant in South Africa and the country would continue to follow the future represented by the At the Forefront scenario in terms of liquid fuel supply.

No new crude oil or GTL refinery is built, liquid fuels supplies become constrained and balance of payments deficit further deteriorates. Either the constraints on greenhouse gas emissions are relaxed, or CCS is proven and delivered economically for CTL plants. CTL may then be pursued as an alternative for liquid fuels supply. This would have implications in terms of coal requirements with a new mine in the Waterberg which in turn requires the necessary infrastructure to be in place to support this development. If CCS is required to be fitted to a new CTL plant, it may prove more beneficial to locate the plant close to the CO_2 storage sites rather than adjacent to the coal mines. This trade-off still needs to be explored.

Actions and key policy requirements

- Plans for proposed refinery to be confirmed.
- Clarity needs to be achieved on the carbon tax.
- Provision needs to be made in any Waterberg infrastructure development for possible future CTL projects.

Ongoing Actions

In addition to the overdue actions and actions and policy requirements in response to signals, a number of ongoing actions are required to improve the sustainability of the South African coal industry.

TABLE 1: ONGOING ACTIONS FOR A SUSTAINABLE INDUSTRY

Requirement for a sustainable industry	Actions
Manage social and environmental impacts and increase efficiency of mining, especially relating to large-scale expansion in the Waterberg, and legacy impacts of mines in the Central Basin	• Co-ordinate timely planning, taking into account whole systems thinking to minimise the impacts of mining and power generation. • Advance cost- and water-efficient mining and beneficiation, including dry beneficiation technologies. • Advance measures to manage and reduce water pollution impacts. • Develop and introduce safer mining techniques. • Ensure cost-effective and environmentally acceptable management of discard and spoils. • Develop techniques for agglomeration/briquetting of coal fines. • Develop know-how in thin seam mining. • Advance mine rehabilitation techniques to preserve biodiversity. • Improve management of coal dust.
Develop skills and support institutions	• Maintain and develop skills to continue to run mines and existing power stations. • Expand the skills base to build and operate new mines and power stations, with specific requirements depending on the technology to be used. • Develop and
Accelerate transformation of the sector	• Explore new business models that involve co-operative partnerships between Eskom or the existing large mining companies and the smaller players. • Explore how Eskom funding or the state mining company together with existing mining industry know-how and resources can provide a platform for start-up of more black owned mines for supply to the utility and export sectors.
Advance coal power station technologies	• Continually assess the applicability in South Africa of high efficiency coal combustion technologies and the deployment of Carbon Capture and Storage. • Explore opportunities for decreasing water demand or increasing water use efficiency.
Plan for closure of mines and power stations in the Central Basin	• Coordinate planning to minimise the impacts of mine and power station closure, through effective environmental planning, development of alternative industries, and re-skilling of individuals.
Update and maintain current National Reserve and Resource data	• The Council for Geoscience completed a much-needed review of South Africa's coal reserves and resources. This Coal Reserves and Resources study should be published as soon as possible to enable and enhance integrated planning by all stakeholders. • The study should be updated every second year and a comprehensive review done every five years.

NOMENCLATURE

CCGT	-	Combined Cycle Gas Turbine
CCS	-	Carbon Capture and Storage / Carbon Capture and Sequestration
COP 17	-	The 17th annual Conference of the Parties who are signatories to the United Nation's Framework Convention on Climate Change, held in Durban, 2011
CRRSA	-	Coal Resources and Reserves Study of South Africa
CSP	-	Concentrated Solar Power
CTL	-	Coal-to-Liquids
CV	-	Calorific Value
DMR	-	Department of Mineral Resources
EIA	-	Environmental Impact Assessment
EMP	-	Environmental Management Plan
ESI	-	Electricity Supply Industry
FBC	-	Fluidised Bed Combustion
FGD	-	Flue Gas Desulphurisation
GHG	-	Greenhouse gas
GTL	-	Gas-to-Liquids
IEP	-	Integrated Energy Plan
IGCC	-	Integrated Gasification Combined Cycle
IPPs	-	Independent Power Producers
IRP	-	Integrated Resource Plan
ISMO	-	Independent System and Market Operator
LNG	-	Liquefied Natural Gas
MCWAP	-	Mokolo and Crocodile Water Augmentation Project
MPRDA	-	Mineral and Petroleum Resources Development Act
NEMA	-	National Environmental Management Act
NOx	-	Nitrogen Oxides
NPC	-	National Planning Commission
NPV	-	Net Present Value
NWA	-	National Water Act
O&M	-	Operation and Maintenance
PF	-	Pulverised fuel
PV	-	Present Value
R&D	-	Research and Development
RBCT	-	Richards Bay Coal Terminal
ROM	-	Run-of-Mine
SACCCS	-	South African Centre for Carbon Capture and Storage
SACRM	-	South African Coal Roadmap
SO	-	Sent out
SOE	-	State Owned Enterprise
SOx	-	Sulphur oxides
US$/tonne	-	US dollar per tonne
WACC	-	Weighted average cost of capital
WUL	-	Water Use License

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INTRODUCTION

Coal plays an important role in the South African economy, and is the primary energy source for electricity generation. It is the feedstock for producing a substantial proportion of the country's liquid fuels, and provides a considerable source of foreign revenue from exports, representing over R 50.5 billion in 2011. It is also responsible for high levels of direct and indirect employment in South Africa. About 78,600 people were employed directly in coal mining alone in 2011.

Given South Africa's abundant coal reserves, including those in the Waterberg basin, and the existing capital invested along the coal value chain, South Africa is likely to continue to include coal as part of its energy mix, where it has the potential for continuing to provide secure and affordable energy supply, extending employment and increasing export revenues. These benefits are particularly relevant in light of South Africa's development priorities of job creation and economic growth.

Nonetheless, the coal value chain faces an uncertain future, which will be determined by a number of inter-related economic, political, social, environmental, financial and technical factors that are explored in this report.

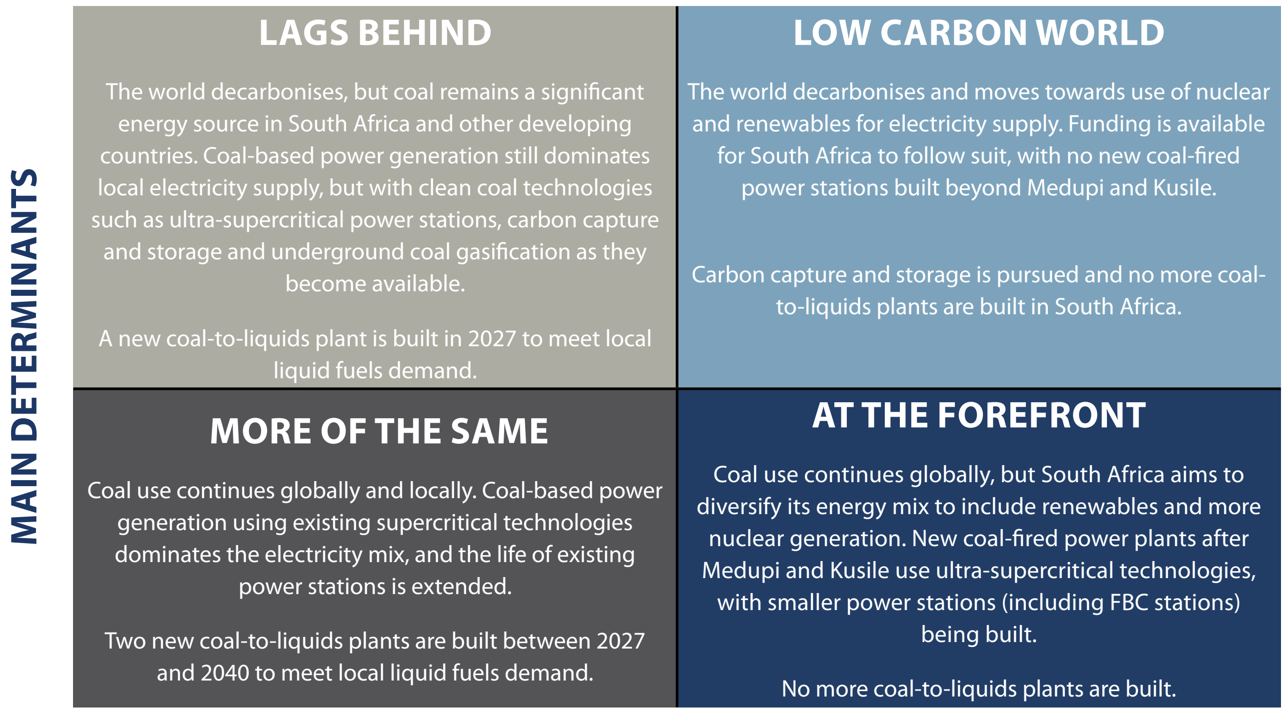
1.1 Charting a future for the industry: the South African Coal Roadmap

The South African Coal Roadmap was developed to explore the short, medium and long-term activities and interventions needed to support the coal industry in South Africa between now and 2040 to maximise its contribution to South Africa in the face of an uncertain future (see Box 2). Development of the Roadmap was undertaken through a collaboration of members of the coal value chain in South Africa, including the national Departments of Energy and Mineral Resources.

A scenario-led approach was taken to Roadmap development. A range of local and global drivers was considered to understand their implications for the evolution of the world in which the coal industry operates. These drivers included the global economy, the South African economy, the global climate change response, South Africa's mitigation response, global coal markets, balancing exports and local demand in South Africa, evolution of local infrastructure and the evolution of technologies including carbon capture and storage. Of these, the global climate change response and South Africa's mitigation response were selected as two drivers that helped to define a set of four distinct future worlds with very different implications for the coal value chain. The future worlds that were explored are:

- **More of the Same,** where limited action is taken on climate change globally and in South Africa;
- **Lags Behind,** where the world moves ahead with greenhouse gas emissions mitigation, but South Africa continues to pursue use of coal as its primary energy source;
- **At the Forefront,** where South Africa joins the global leaders in emissions mitigation, while much of the remainder of the world takes limited action; and
- **Low Carbon World,** where strong action is taken globally and locally on greenhouse gas emissions mitigation.

Four scenarios were then developed, quantitatively modelled and qualitatively assessed to determine the implications of following each trajectory for South Africa.



At the heart of the scenarios is the electricity generation build plan. The generation build plans in the four scenarios were based on different plans developed as part of the IRP2010 planning process, which were extended to 2040. The Roadmap development process was framed by assumptions that:

- There will be no paradigm shifts in the way that the economy and society function. While such shifts could occur, in the absence of knowledge of what these might look like, the Coal Roadmap is developed in the context of the current economic and societal paradigm. Energy demand is thus linked to increased economic and population growth. Energy and electricity demand is assumed to continue to grow to 2040 and beyond.
- Regardless of whether the world continues along a fossil fuel intensive future, or whether it aggressively pursues a low carbon economy, there will continue to be a global demand for coal. This demand will be from existing power stations, and new coal-fired power stations currently under construction, particularly in the Asia-Pacific region, which will still be operating to 2040 and beyond. The assumption of continued global demand for coal is consistent with all projections made by the International Energy Agency, although coal demand will decline post-2020 in a **Low Carbon World**. South Africa's contribution to global seaborne coal trade is relatively small, and hence it is likely that South Africa will continue to be able to export coal.

Once the scenarios had been modelled, the Roadmap was developed by interrogating the scenarios to identify and understand:

- **Actions** that need to be undertaken that are common to all scenarios;
- The implications of following a particular scenario in terms of a number of **objectives**;
- The **signals** that a particular future is evolving; and
- **Activities** that need to be undertaken for the coal value chain to positively contribute to a flourishing South Africa.

The Roadmap is thus not a "conventional" roadmap, providing a single path for the industry to follow to meet an overarching objective. Rather, it aims to support industry, policymakers and other stakeholders in navigating an uncertain future in which there are multiple objectives and trade-offs to explore for the country as a whole to flourish.

BOX 2: PERSPECTIVES ON WHAT CONSTITUTES A FLOURISHING SOUTH AFRICA

The aim of the South African Coal Roadmap was to explore how best the coal value chain can contribute to a flourishing South Africa. The analysis thus explored the implications of the scenarios in terms of the following indicators:

- *Electricity generation infrastructure investment cost;*
- *Electricity generation cost;*
- *Domestic coal price and revenue from local sales;*
- *Export revenue;*
- *Carbon intensity of electricity generation;*
- *Global competitiveness;*
- *Energy security;*
- *Employment and other socio-economic implications;*
- *Water demand and provision;*
- *Transport and water infrastructure requirements;*
- *Greenhouse gas emissions;*
- *Water quality, land transformation and implications for biodiversity;*
- *Solid waste generation;*
- *Implications for coal resources and reserves in South Africa;*
- *Non-greenhouse gas emissions.*

Under no single future or scenario can the performance in all of these indicators be optimised and prioritising certain outcomes necessitates compromises to be made. The principal objective is one of sustainable development: enabling the current generation of South Africans to prosper, without compromising the ability of future generations to do the same. It is recognised that reducing the impact of the energy sector on the environment requires substantial investment, but this will result in lower environmental impacts now and into the future. At the same time, provision of affordable and reliable energy today is critical in meeting our development challenges. The scenarios provide the opportunity to understand the magnitude and direction of these trade-offs.

1.2 Where are we now?

At the time of writing the Roadmap (May 2013), the future that is evolving is best represented by the scenario **At the Forefront**. South Africa has made ambitious (albeit conditional) pledges towards climate change mitigation. Other countries are actively working to mitigate emissions, but efforts are uncoordinated and a global agreement has not yet been reached on the mitigation effort required of individual countries.

The IRP2010 Policy Adjusted electricity generation build plan, which is followed (and extended to 2040) under **At the Forefront**, is current government policy. This plan includes diversification of electricity supply to include an ambitious nuclear and renewables build plan. After building a number of new small Fluidised Bed Combustion (FBC) facilities, the next Pulverised Fuel (PF) coal-fired power station (or stations) to be built, after Medupi and Kusile (both currently under construction), are planned for the late 2020s. No future CTL plants are on the near horizon in South Africa.

The implications of being on At the Forefront are explored in Box 3. However, there are a number of challenges that will need to be overcome if South Africa is to remain on **At the Forefront**, and for the coal industry to continue to play a role in a flourishing South Africa. These are explored in detail in the remainder of this document, and summarised in the highlights section. Key challenges include:

- Appropriate infrastructure planning in the face of uncertainly over future export growth prospects;
- Escalating competition between Eskom and exporters for remaining resources in the Central Basin;
- Cumbersome, ambiguous and time consuming regulatory processes impeding new mine development;
- Uncertainties in government policies creating a unfavourable climate for mining investment;
- Looming coal shortfall for existing power stations with little progress being made in securing coal contracts;
- Increasing cost of mining as resource quality declines and alternative coalfields are developed; and
- Identifying those resources that are critical to Eskom's supply and ensuring that they are secured for this purpose.

BOX 3: IMPLICATIONS OF BEING AT THE FOREFRONT

If South Africa is on this trajectory, the following would be the reality:

Coal supply:

- *Whilst modelling and best available data suggest that sufficient coal resources are available to supply all required grades of coal to power stations in the Central Basin until the mid-2020s, there is significant uncertainty associated with the timing, capacity and projected qualities of new mines, as well as the probability of some of these resources going to export. Failure to resolve this will lead to potential coal supply shortfalls and impact electricity supply as early as 2018.*
- *In **At the Forefront** it is assumed that provision is made to supply higher grade coal to the older Central Basin power stations from the Waterberg and thus rail infrastructure is available in the early-2020s to facilitate transport of coal from the Waterberg to the Central Basin to overcome some of the shortfalls in local utility supply - and at the same time to provide access to export markets.*

Electricity build plan:

- *Substantial funding is received to support South Africa's renewables and nuclear programme.*
- *The nuclear and renewables programme is implemented on time.*
- *Electricity generation costs by 2035 are approximately 8% higher than if a coal-only electricity build plan had been followed.*

Liquid fuels:

- *Growth in liquid fuels demand is met from imports, a new crude refinery or, at a later stage, a gas-to-liquid (GTL) facility.*

Electricity security:

- *South Africa is primarily reliant on local coal, with some electricity imports (hydro and coal). There is also so reliance on processing nuclear fuel overseas, although increased local fuel processing would increase security. Increased global competition for skills and foreign companies to build and service nuclear and renewable plants will contribute to educed security unless South Africa develops the necessary capacity early.*
- *Continued tight coal supplies could impact energy security, with increasing competition between Eskom and exporters for the remaining Central Basin resources raising the possibility of supply shortfalls.*

Exports:

- *If new utility mine projects are developed for Eskom as modelled in **At the Forefront**, South Africa's coal exports will peak at around 90 Mtpa between 2020 and 2025 and then steadily decline to below current levels by 2030, unless export only mines are proven feasible in the Waterberg, and sufficient rail infrastructure is built to transport this coal to ports.*
- *New ports or upgrades to existing ports will only be required if the Waterberg is successfully exploited for export only mines on a significant scale.*

Competitiveness:

- *South Africa is not projected to gain any global competitiveness benefits from diversification of its energy supply, except in the case of trade with a select few countries that continue to pursue a low carbon trajectory.*

Employment:

- *After an initial increase in employment, there is a loss of jobs in the coal mining sector due to an eventual reduction in coal mining from around 2025. Some jobs are created in renewables but there will still need to be job creation in other parts of the Green Economy to offset this loss.*

Environment:

- *Water demand grows in certain parts of the country, but impacts will be far lower than in a heavily coal reliant future.*
- *Total greenhouse gas emissions from electricity generation will peak and then begin to decline by the mid-2020s. The emissions intensity of electricity supply drops steadily.*
- *South Africa will be vulnerable to the impacts of climate change, as the rest of the world has not de-carbonised to the level required to limit the impacts.*

OVERDUE ACTIONS TO ENSURE ONGOING ELECTRICITY SUPPLY

SOUTH AFRICA CANNOT AFFORD EARLY RETIREMENT OF EXISTING POWER STATIONS. IMMEDIATE ACTIONS TO ENSURE ONGOING ELECTRICITY SUPPLY:

- Securing coal supply contracts for existing power stations
- Investment in and development of new mines
- Decisions on water and rail infrastructure for development in the Waterberg
- Agreement on a suitable coal pricing model for new coal supplies
- Resolving Mpumalanga coal transport challenges
- Streamlining policy and legislation processes

Under all modelled scenarios, the early retirement of existing coal-fired power stations (which make up the majority of the current electricity generation infrastructure) is not feasible – regardless of how aggressively South Africa pursues climate change mitigation. This is due to the substantial costs to the economy of replacing electricity supply infrastructure. In fact, this existing coal-fired power station capacity was allowed for in developing government's current stated greenhouse gas emission reduction pledges. Thus, many of the existing coal-fired power stations will need a supply of coal well into the 2030s, with four stations requiring significant volumes of coal beyond 2040.

A number of urgent actions are required to ensure the continued supply of electricity from these power stations.

2.1 Secure new coal supplies for Eskom power stations and ensure investment in new mines for domestic supply

- Existing power stations do not have enough coal contracted to the end of their service lives. In some cases shortfalls will occur as early as 2015
- 4,000 Mt of coal is required before 2050, 2,000 Mt of which is not contracted and 300 to 800 Mt is considered at risk to low-grade exports
- New mines need to be built in either the Central Basin or Waterberg
- Agreement needed on a fair pricing model for coal to ensure investment

When South Africa's coal fired power stations were built, contracts were signed with the mining companies to ensure a guaranteed supply of coal for the envisaged life of each power station (40 years in most cases). However, many power stations are now planned to be operated for significantly longer periods than initially envisaged and for which coal was secured. Moreover, most stations have been run at loads higher than was envisaged when original contracts were concluded and in some cases the coal resources have not been as substantial as initially assumed. Finally, three stations were re-commissioned, but their original coal resources had been reallocated to alternative parties. Eskom's originally contracted coal mines are consequently insufficient for its planned consumption of coal. Over the past five years, Eskom has contracted whatever suitable coal was available and supported the development of numerous new small mines. However, Eskom reports that it still needs to secure, contract and build the mines to provide about 2 billion tonnes of the estimated 4 billion tonnes it requires to supply its current power stations to the end of their planned operating lives. Of this new supply, 300 to 800 Mt is considered at risk to low-grade exports, and the vast majority of the coal resources require extensive further exploration and feasibility studies before formal coal supply contracts can be concluded.

Most of this coal is required before 2040 and shortfalls at some power stations are anticipated as early as 2015. Some of the incremental demand for existing power stations can be met by extending existing mines into adjoining but poorer quality resources, but the majority will need to be met from new mines. Most of the new mines will need to be established in the Central Basin, although there may be some scope to source a part of the requirement from other coal basins such as the Waterberg (Waterberg coal is only suitable to be used in some Mpumalanga Power Stations without major modifications). Furthermore, fulfilling a shortfall of this magnitude can only be achieved by constructing large scale mines utilising the remaining large Central Basin coal resources, most of which are held by the diversified global mining companies. A crucial consideration that impacts coal supply to power stations is thus the tension between lower export grades and higher grade utility supply. This is discussed in detail in Box 8.

Agreement is required on a coal price mechanism to Eskom to speed up commercial negotiations and avoid possible domestic shortfalls. Given competition for a limited capital supply, a favourable return on investment is sought by mining companies to invest in new coal mines (see Box 4). There appears to be disagreement between Eskom and mining companies about what constitutes a "fair" rate of return on investment. This debate is on-going but has become a fundamental issue delaying many of the most urgent new mine developments. An alternative coal price mechanism is explored in Box 5.

Nonetheless, it seems inevitable that the final total cost of coal from new mines will be substantially higher than has been seen historically. This is due to the need for deployment of capital for new mines, coal being sourced from lower quality deposits (which have higher operating costs and will require further processing to meet Eskom's quality specifications), longer transport distances between the mines and the power stations and Eskom's need for more consistent coal qualities.

BOX 4: RAISING CAPITAL FOR ESTABLISHMENT OF NEW MINES

Attracting Investment

Substantial capital investment is required to develop and build any new mine. For a coal mine the investment is typically in the order of R 1,000 to R 1,500 per annual tonne of production capacity installed. A typical new mine supplying a power station with 10 million tonnes of coal per annum would thus require an initial capital investment of the order of R 10 to R 15 billion. Meeting Eskom's projected 60 Mtpa new coal requirement will therefore require investment of between R 60 and R 90 billion for the construction of at least five to ten new mines. This translates into a total capital of between R 60 and R 90 billion, and a further R 20 to R 30 billion to fund potential export expansions as indicated by the Richards Bay coal terminal expansion from the current 70 Mtpa capacity to 91Mtpa.

Enabling this scale of development presents the most significant challenge in meeting Eskom's requirements. Large scale mines can be highly risky investments – a large amount of money must be invested up-front on the assumption that demand and prices will remain robust enough to repay and provide a return on the capital over the life of the project – often in excess of 20 years. Several price mechanisms are conventionally used around the world to reduce this risk, particularly when building mines to supply a single customer, as is the case for domestic power stations. In many cases these mechanisms are some form of a 'cost plus a targeted return' agreement (discussed in Box 5).

At the heart of the deadlock between industry and Eskom over new coal projects is disagreement on the sources of this capital, and the returns that are required to attract the capital.

Competing for funding from the diversified, global mining companies

Mining companies raise capital from a variety of sources, including common equity, preferred equity, straight debt, convertible debt, exchangeable debt, etc. Different sources of finance are expected to generate different returns commensurate with the risk they represent. Each mining company calculates its weighted average cost of capital (WACC) taking into account the relative weights of each component of the overall company capital structure, and this is the minimum return that a company must earn across its asset base to satisfy its providers of capital. This implies that if some assets earn below WACC, others need to earn more than WACC. To reflect the risks inherent in a particular investment decision and minimise the possibility that the new investment will earn below WACC, premiums are usually added to a company's WACC to arrive at an appropriate required return for that project. For example, a technical risk premium may be included to capture the risk inherent in new projects (e.g. execution risk, unfamiliar geology or metallurgy etc.). Similarly, a country risk premium is often added to factor in the risks of doing business in a particular country, such as political instability or legislative uncertainty. Technically, a risk discount should be applied when investing in any project that has a lower risk exposure than that reflected in the WACC; however, this is seldom applied.

Analyst WACCs for valuing large, diversified mining companies are in the range of 6.8% to 9% real. For South African based, predominantly coal, companies this increases to 9.2% to 13.4% real. Assuming that the mining companies carry the technical and operational risk, the inclusion of a technical risk premium (2% - 3%) for greenfield projects raises the return target to between 10% and 17%.

A further factor influencing the investment decisions of most miners is the scarcity of, and competition for, capital. Particularly within the diversified, global mining companies, coal investments compete with other commodities and opportunities in other resource geographies that may offer higher returns without a proportionate increase in risk. Within a portfolio of investment opportunities, the capital allocation is usually based upon the ability of the capital to generate returns for the investor and the intensity of capital required to develop the opportunity. This forms an "attractiveness matrix" for the investor. An international mining commodity attractiveness matrix is shown in the figure below for a diversified mining company. The top left quadrant (high profitability, low capital intensity) is the most attractive.

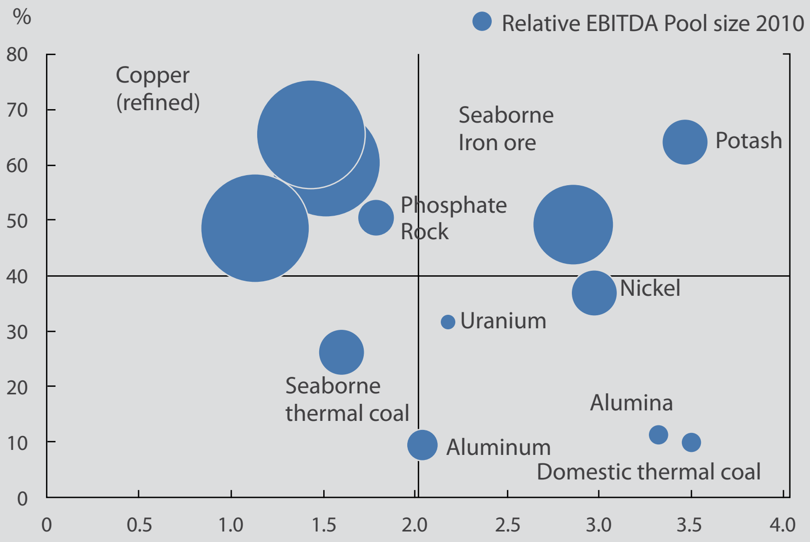


Figure 1: An international mining commodity attractiveness matrix for a diversified mining company

Source: DMR, McKinsey

Figure 1 suggests that globally, investments in thermal coal and particularly domestic thermal coal, provide significantly lower returns and are therefore currently less attractive than investments in base metals, iron ore or metallurgical coal assets. Note that the chart does not provide a complete investment picture, as it does not compare the risk exposure for each commodity, or provide benchmark returns available from non-mining investments or in commodities for supply to domestic industries vital to economic development.

Regardless of the various caveats, the implication of the above discussion is clear – unless South Africa is prepared to pay far higher returns for new coal projects than has been the case in the past, the mining companies, and in particular the diversified global mining companies, cannot logically be expected to supply the capital. Figure 2 demonstrates the sensitivity of coal prices to the return required by the different classes of investors. The graph has been developed using a simple theoretical model assuming a mine requires R 10 billion capital with a relatively low working cost of R 180 per tonne (mining cost excludes beneficiation and logistics costs, but includes capital for maintaining existing production assets and royalties), over a 30 year mine life. This analysis suggests that coal costs from new mining developments requiring beneficiation will be in the range of R 350 to R 420 per tonne. Regardless of the returns paid, these costs are substantially higher than the current average cost of coal to Eskom. Coal supplied to Eskom in the future is also likely to require beneficiation, at additional capital and operating cost to this example.

More importantly, the numbers illustrate the dilemma facing the country in financing the new coal projects. If South Africa wishes to source all the capital for the domestic supply mines from the global diversified mining companies by matching the returns they earn in more attractive commodities, Eskom will pay R 230 per tonne (at zero return), or more, than if the country were to finance the projects itself through the issue of bonds or other low risk, low return instruments. This translates into an additional Eskom coal costs (increased electricity price), however, this also comes at a cost to the national balance sheet and its associated indirect costs to the economy. A trade-off will need to be found between private and public funding of such development.

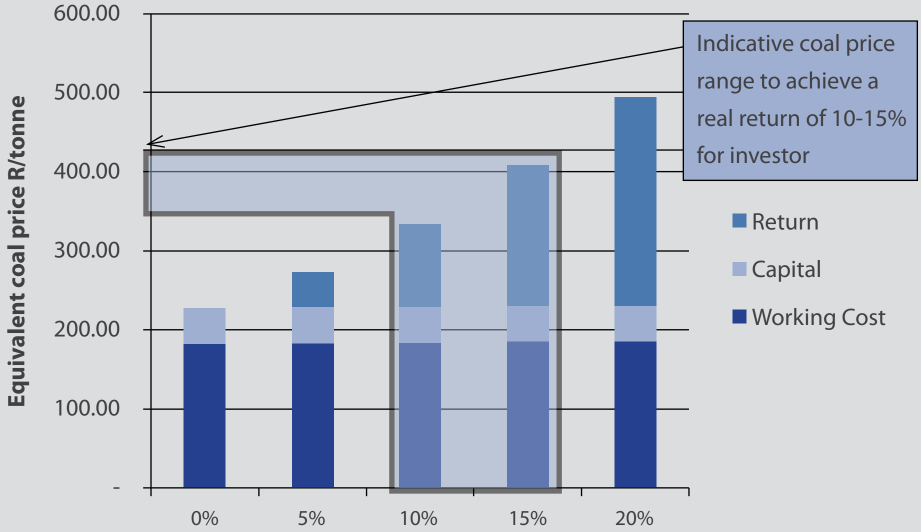


Figure 2: Sensitivity of coal prices to real rate of return

Source: SACRM Expert Group

BOX 5: THE "DEVELOPMENTAL PRICING MODEL"

A model of meeting the returns required by mining companies is premised on at least three additional assumptions that are not necessarily shared by the State:

1. *There are no other sources of funding that may have a risk-reward appetite more suited to domestic coal developments;*
2. *The State should not influence the pricing of resources considered core to the economic health of the country; and*
3. *The State should not intervene with mineral resource rights granted to mining companies.*

In its 2012 document on State Intervention in the Minerals Sector ("SIMS"), the government published its view on the appropriate pricing model for commodities mined for critical domestic industries. In essence this 'Developmental Pricing Model" is an extension of the "cost plus some form of (low) risk-related return" model that has historically been applied to coal supply to Eskom as well as much of the iron ore supplied to the domestic steel making industry. The following points are pertinent regarding this model:

- *The authors explicitly acknowledge the importance of paying sustainable returns that are sufficient to attract the necessary capital - the model is not intended to fix prices below sustainable levels, but rather appears to seek to pay a return that would, in theory, be determined in a competitive market where there are no entry barriers for new players.*
- *The model seeks to account for the risks in an Eskom type coal supply contract, which are typically substantially lower than most export projects:*
  - *Eskom takes the bulk of the legislative, technical, development, operating cost and resource risk in almost all dedicated long term contracts. Miners generally refuse to carry these risks, arguing that they cannot do so for such long contract periods.*
  - *Eskom provides long-term off-take commitments supported by annual 'take or pay' provisions either directly or embedded in the 'cost plus' nature of the contract. This substantially eliminates the risk seen in the export market where demand collapses can reduce annual sales volumes and revenues.*
  - *Eskom provides inflation linked price increases (or enables all costs to simply be passed on to Eskom in the pure 'cost plus' agreements).*
  - *This combination of the above factors effectively means that a miner's targeted return is all but guaranteed, which is typically not the case for export projects.*
- *This implies that a miner's risk exposure on a domestic supply contract is probably lower than that generally reflected in its WACC, and substantively the same as (or lower than) an investment in Eskom, where NERSA ultimately allows Eskom to pass on most of its prudent cost increases to the consumer so as to achieve a targeted return.*
- *The low risk nature of an Eskom or similar domestic supply project allows a greater ratio of debt to equity in the capital structure. As debt is usually cheaper than equity, this should lower the overall cost of capital. This benefit is not reflected in the miners' desired returns, which are usually based on their average company debt: equity ratios.*

- *The country needs long-term price stability and long-term supply security to make the massive investments in power stations and transport infrastructure. It also has to ensure that the country's resources are used to the benefit of all citizens; the Developmental Pricing Model implicitly assumes that this objective is best achieved by securing the lowest sustainable prices for coal and other important commodities.*

Neither the State nor Eskom have publicly stated what they regard as a desired and 'fair' rate of return. However, it can probably be assumed to be in the region of 8% to 10% real, which is slightly above the return range that Treasury seeks from its investments in SOE's.

The litmus test of the "Developmental Pricing Model" is whether the required funding can be raised at a substantial enough discount to the miners' targeted returns to justify the additional effort and risk involved in raising such large amounts of capital, and whether the incumbent miners and/or emerging new miners will be prepared to operate the mines without having a significant equity upside. Should the model fail this test, much of the burden of financing, developing and operating the new mines will fall on the State. Given the obvious complications of the State 'owning and operating' the coal resources and the many other pressing priorities for State funding and attention, the net benefits of a pure 'go it alone' outcome on the long term health of the overall economy have to be questioned.

Other pricing models for domestic coal have been proposed. These include explicitly linking domestic coal prices to the export coal price (either at parity or at some discount), or establishing a 'domestic market coal price'. Many of these models suffer from fundamental flaws and none offer the supply security and price stability required to enable the massive investments that must be made in efficient electricity generation, coal supply and coal transportation infrastructure. They are therefore not discussed further.

2.2 Align policy and licensing procedures

Alignment and certainty of regulatory and permitting procedures for new mines

Lack of security of tenure on prospecting rights introduces uncertainty, while also enabling 'hoarding' of prospecting rights

An update to the IRP and finalisation of the IEP is required to assist in planning

In addition to South Africa offering a favourable investment environment for coal mining, the regulatory environment needs to be supportive of investment. At present, mining companies face a number of challenges, including failures in adherence to mandatory approval processes, discretionary decision making and lack of certainty, when attempting to obtain the necessary approvals for establishment of new mines (see Box 6). A good example of the current ambiguity is the fact that 19 of the 46 mines supplying Eskom were not in possession of water use licenses in the first quarter of 2013. These challenges affect the timely delivery of mining investments in mines in South Africa, and need to be urgently addressed.

The current security of tenure provisions on prospecting rights also contribute to an environment that is not conducive to investment in new mines. With approximately three years left to convert many prospecting rights to mining rights, there is considerable uncertainty as to what will happen when existing prospecting rights expire from 2015. This uncertainty is particularly significant in view of the need for substantial investment in new mines by 2015 (see Box 4). There is the concern that this will exacerbate the pressures on the development time lines for new mines to supply Eskom, with the likelihood of prospecting rights falling to smaller players, with limited capacity to fund and develop mines. This may signal a need for new business models that involve co-operative partnerships between either Eskom or the existing large mining companies and the smaller players.

Acceleration of transformation in the mining industry is also an imperative, which may be achieved by establishing such co-operative transactions. With potential Eskom funding and existing mining know-how, new mines required for supply to the utility sector may provide a platform for start-up of more black owned mines. The state mining company may also play a role in such development.

Additional policy considerations that affect mining investment include:

- Resolving uncertainty in statements regarding coal as a strategic resource and clarifying the policy implications thereof, including the consequences if the classification of coal as a strategic resource calls for limiting coal exports, which, in turn, may have a negative impact on coal mining investment. Here due consideration needs to be given to wider national socio-economic imperatives around economic growth, employment and skills development;
- Achieving certainty on the application of a carbon tax;

- Meeting Broad-Based Black Economic Empowerment (BB-BEE) requirements and accelerating junior miner development; and
- Implementing interventions to prevent hoarding/ speculating in mining tenure, including creating a mechanism to resolve situations where a coal resource needs to be urgently developed for domestic utility supply, but is not one of the miner's investment priorities.

In terms of the electricity sector and the energy sector more broadly, the key urgent policy requirements are updating of the Integrated Resource Plan (IRP) and finalisation of the Integrated Energy Plan (IEP), to assist in long-term planning.

BOX 6: AN ENABLING LEGISLATIVE/ POLICY FRAMEWORK FOR MINING IN SOUTH AFRICA

Numerous licenses and permits are required under South African law prior to opening a mine. Although the Acts and respective Regulations under which applications are made follow international best practice, the legislative framework within which they exist lacks integration and alignment. Figure 3 below illustrates the critical licensing requirements for establishment of a new mine.

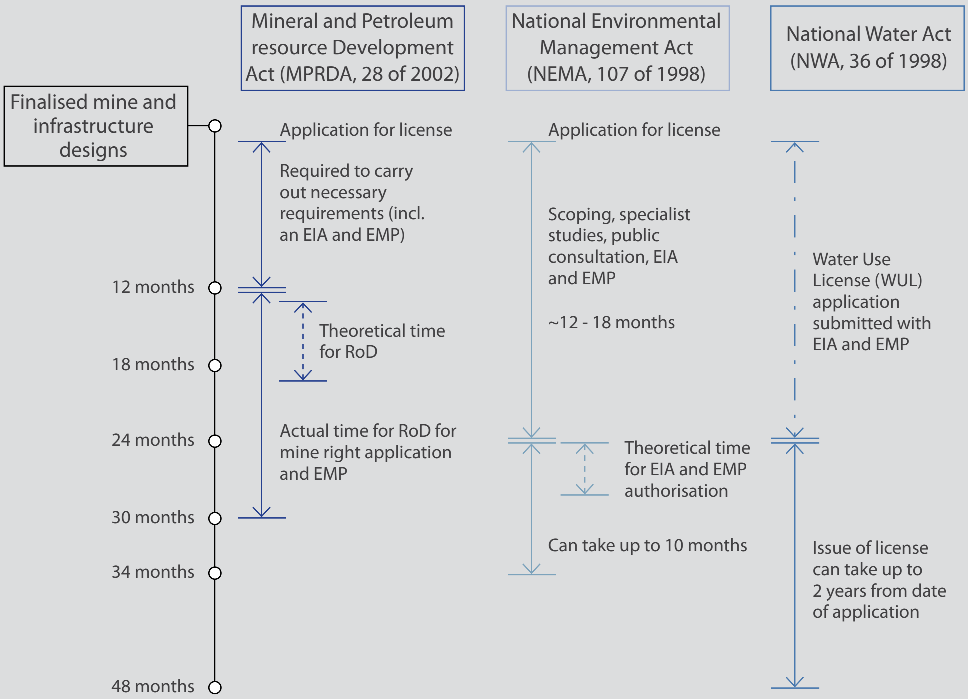


Figure 3: Schematic of licensing requirements for new mines

Environmental Impact Assessments (EIAs) are required by both the Mineral and Petroleum Resources Development Act (MPRDA, 28 of 2002) and the National Environmental Management Act (NEMA, 107 of 1998). The requirements in respect of these Acts, although similar in principle, differ significantly with respect to time frames for submissions by the developer to the approval authorities. The MPRDA process is designed to take approximately 12 months whereas the NEMA process can take anything from 18 to 24 months - or longer. In both cases, these processes should only commence once the mine and infrastructure designs have been finalised, and both require scoping, specialist studies, public consultation, impact assessment and the development of mitigation measures to manage the impacts of mining. It would be preferable to carry out one EIA and environmental management plan (EMP) process acceptable to both departments. However, since tenure periods of prospecting rights are limited and due to the discrepancy in time frames and requirements, the EIA process is often required to commence prior to finalisation of designs. This results in additional cost as public consultation, impact assessment and management planning have to be repeated when mine designs are finalised.

Strict adherence to time lines specified by the MPRDA is required of the developer. However, both the departments of Mineral Resources and Environment as well as provincial competent authorities do not always adhere to stipulated time frames for review and approval. This results in delays to approval that affects the commencement of mining projects. An authorisation under NEMA for the EIA and EMP is required to be issued within 120 days, but can take up to 10 months; under the MPRDA, the Act allows for 6 months *for the Record of Decision (RoD) in respect of the mining right application and EMP, however this usually takes 12 to 18 months. These time frames do not include appeals processes, which also differ between Acts.*

A Water Use License (WUL) is also required under the National Water Act (NWA, 36 of 1998) prior to using water for mining. The WUL application is usually submitted at the same time as the EIA and EMP and can take up to two years to be issued. In the Central Basin, coal mines are frequently located in areas where pans and wetlands are present. The Department of Water Affairs has indicated that the NWA does not allow them to authorise mining through these areas. No alternatives have been offered. This presents a critical hurdle to project development, as the amount of mineable coal cannot be defined, nor can the mine plan and design be completed to comply with other processes. Finally, this uncertainty also impacts on the economic viability of projects and consequently the pivotal question of whether sufficient coal remains in the Central Basin to meet domestic requirements and expand exports. A clear methodology for evaluating the trade-offs between environmental and economic factors and clarity on who makes the ultimate decision is required to provide certainty for future mine development and to minimise risks from appeals. A further opportunity could be to identify areas where mineral deposits and environmental features coincide to determine how many of the reserves are ultimately mineable.

The MPRDA, NEMA and NWA all require public consultation. The disparities between processes can result in stakeholder fatigue and lack of participation. This compromises the process which can then be appealed.

Obtaining multiple permits from several government departments thus poses a significant risk to mining projects. It is critical that relevant legislation in South Africa be urgently aligned to create an enabling environment for investment.

2.3 Decide on opening alternative coalfields

Additional coal could be required from the Waterberg for existing power stations

Rail and water infrastructure need to be suitably sized and appropriately funded

Effective planning is required for sustainable communities

Modelling and best available data suggest that sufficient coal resources exist in the ground in the Central Basin to supply existing power stations and Kusile over their expected service lives if South Africa remains on **At the Forefront**. Crucially, however, the availability of the coal in the ground does not guarantee its delivery to the power stations, which depends on a number of factors, including the ability to open new mines and associated transport infrastructure on time and the degree to which Eskom has access to this coal. Under all scenarios, the supply of high-grade utility coal from the Central Basin is very constrained from the mid-2020s, and just one mine switching to low-grade exports rather than supplying Eskom creates an immediate domestic coal shortfall. Likewise, even small delays in constructing new mines will cause shortfalls in both domestic utility and export coal supply. To reduce these supply risks, provision for alternative sources of high-grade supply from the early 2020's would seem prudent. The Waterberg, as the largest coal resource in the country, is the most likely source of such coal and it is strongly recommended that access to the Waterberg coal fields be enabled without delay. Long lead times are required for rail infrastructure so early planning is required to ensure that this infrastructure is ready. Eskom is already in an advanced stage of securing coal from two potential new mines in the Waterberg.

Where the decommissioning of power stations is pushed out further from current plans, there is likely to be a shortfall of high-grade utility coal from the mid 2030s. This will place South Africa in difficult position as the stations currently scheduled for decommissioning in the early 2030's cannot burn coal from the Waterberg coalfield and redirecting exports to these stations may become the only means of securing the required coal. Only four of Eskom's Central Basin power stations (Majuba, Tutuka, Kusile and Kendal) can burn Waterberg coal without major plant modifications. Of the four, two (Kusile and Kendal) utilise relatively low grade coal of which no shortfall is forecast in the Central Basin, and while Majuba and do have large shortfalls, significant uncertainty remains over how the high volatile Waterberg coal will perform in the boilers. The remaining stations are the older ones and, given forecast tight generation capacity balance, it is highly unlikely that Eskom will be able to take them off-line for the long periods required to conduct the modifications (which amount to replacing the entire mill section with a different technology). It is also improbable that such a scale of modification will be economic, given the limited remaining operating lives of the stations.

In both **At the Forefront** and **Low Carbon World** the construction of coal-fired power stations after Kusile is limited. The current industry view is that, without new power stations in the Waterberg to procure the lower grade coal, exports from the Waterberg will not be economically viable at forecast global coal prices. Therefore, unless South Africa commits to build several new coal-fired stations in the Waterberg, or industry is able to make 'stand-alone' exports from the Waterberg economically viable, the theoretical case for significantly increasing the capacity of the large scale heavy haul railway line would be questionable. Thus, without enabling exports from the Waterberg, a lower-coal future (as modelled in under **At the Forefront** and **Low Carbon World**) will result in a stagnant South African coal industry that may decline from the mid 2020s.

The SACRM scenarios suggest that the medium- and long-term growth of the South African coal industry is ultimately dependent on the opening of the Waterberg coal basin. The timing, scale and nature of this depends on in turn on South Africa's realistic future generation mix, how the remaining Central Basin coal resources will be allocated between domestic and export markets, and who will bear the potential risk associated with being the 'first mover'. However, with Eskom potentially needing to rail coal from the Waterberg as early as 2020, and the limited alternative options for export growth, the decision cannot be delayed.

2.3.1 Infrastructure requirements for opening of new coalfields

The enabler to opening of new coalfields, including the Waterberg, is the development of infrastructure, including water pipelines, rail lines, transmission grid and urban development.

The Waterberg coalfield in particular is water scarce, and water needs to be brought in from the Crocodile River system to support its development. The Crocodile River system is ultimately fed by return flows from the Vaal system. The decision surrounding establishment of **water pipelines** to provide this supply is arguably the most urgent to be made, given the long lead times associated with approvals and land acquisition. One of the critical challenges relates to who pays for the pipeline, since accessing water pipeline infrastructure funding from the national fiscus requires purchasers for the water to be identified in advance, which is in turn related to the certainty of future coal and electricity demand. At this stage there is no clear long-term plan of how many power stations could be built in the Waterberg and by whom. There is a concern that any pipeline that is built will only provide sufficient water for existing or secured users, providing little room for expansion.

However, a trade-off exists, with tariffs decreasing with increasing pipeline capacity. If a coal-intensive future evolves, and new coal-fired power stations end up being built in the Waterberg, water demand will grow substantially. If a low carbon trajectory is pursued, no significant additional water is required beyond that needed for Medupi. Underinvestment in water supply infrastructure could thus result in bottlenecks developing in the future, whilst overinvestment could result in unutilised capacity. Given the smaller incremental capital for a larger pipeline, it is thus recommended that sufficient water supply infrastructure be put in place to support the possible large-scale development of the Waterberg.

Rail infrastructure is required to transport export coal from newly developed coalfields to ports. There is also the likely requirement that coal will need to be transported from newly developed coalfields back to the Central Basin to make up for potential shortfalls in existing power station supply for the reasons described above.

The scale and timing of establishing a heavy haul line depends on the future that evolves. Assuming the decision is taken to build a heavy haul line from the Waterberg, sizing this line appropriately is important given the relative costs of incremental capacity increases. Currently announced plans by Transnet Freight Rail (TFR) indicate that an incremental upgrade of the line is being pursued which appears to be the lowest risk option. Currently planned upgrades on this line are likely to be sufficient, unless a heavy coal future is pursued and/or export only mines are opened in this coalfield.

Additional **transmission infrastructure**, with servitudes, is required in order to transmit the power to other demand centres. Finally, development of new coalfields requires the development and implementation of programmes to support the evolution of **sustainable communities**. Other community services also require planning and support, including education, health and safety, housing and transport planning. Furthermore, there needs to be a focus on localised job creation and skills development, and a focus on transforming temporary construction jobs into permanent jobs. Planning for industrial developments should therefore be co-ordinated with municipalities to ensure consistent spatial development planning and support for development of bulk infrastructure to ensure continued effective supply of utility services.

2.4 Resolve coal transport challenges to Central Basin power stations

Eskom's road-to-rail migration needs to be accelerated

Manage implications associated with a large reduction in coal truck capacity requirements

In 2010, approximately 22% of the coal supplied to Eskom was delivered via road. Road transport of coal brings with it a number of negative externalities including damage to road surfaces, high risk of accidents and fatalities, and human health impacts due to air pollution. To address this issue, Eskom is currently undertaking a road-to-rail migration in conjunction with Transnet Freight Rail to ultimately allow for delivery of up to 32 Mt per year of coal to Camden, Tutuka, Majuba, Grootvlei, Kendal and Hendrina power stations. In 2011/12, 8.5 Mt were transported to Majuba and Camden power stations, this increased to 10.1Mt in 2012/13, with a plan to increase this to 11.5 Mt in 2013/14. The roll out thus needs to be urgently accelerated to achieve the desired volumes, through construction of the necessary branch lines to power stations from main lines, construction of rail receiving infrastructure at power stations and procurement of the necessary rolling stock for coal transport. At the same time, consideration should be given on how to deal with the projected sharp decline in coal truck capacity requirements and associated loss of jobs and small to medium businesses that developed around this specific sector of the transport industry.

More importantly, however, the future transportation requirements within the Central Basin will depend on which coal resources are developed to supply Eskom and which are developed for export (or in the case of multi-product mines, the relative proportions of each product). The different transport options (road, rail and conveyor) have different economics and each is more suited to different supply configurations. Many of the transport infrastructure developments also have lead times as long as, or longer than, mine development lead times. However, in many cases Eskom (or Transnet in the case of rail) cannot commit the funds to develop the transport infrastructure unless it has first secured the coal resource, without potentially creating extensive duplication and possible 'white elephants'. Likewise, Eskom and/or Transnet cannot design and right size the infrastructure until they have clarity on how much coal will be supplied from each mine and the approximate duration of the eventual coal contract. Consequently, creating an efficient and affordable coal transport infrastructure in the Central Basin will be impossible until the remaining coal resource have been designated for either Eskom, exports or other domestic customers.

WHERE TO NOW? PLANNING FOR NEW POWER STATIONS

NEW POWER STATIONS ARE REQUIRED TO MEET GROWING ELECTRICITY DEMAND. CLARITY IS REQUIRED ON:

- Delivery of nuclear and renewables build, and what the alternatives would be
- Location of any new coal-fired power stations
- Streamlining of procurement from IPPs
- The carbon tax

With growing demand for electricity, as well as the retirement of some of Eskom's older power stations in the medium term, significant new power generation capacity needs to be added to the South African grid over the next 30 years. Power stations require lengthy planning periods – a nuclear power station requires a lead time of over ten years and a coal fired power station eight years. However, various renewable technologies can be built in under five years, with establishment of wind farms being possible in as little as two years.

Table 2 below illustrates the build plan for new power stations as provided by the IRP 2010 Policy Adjusted scenario to 2030, extrapolated to 2040. For comparison, if only large coal-fired power stations are built instead of nuclear and renewables as is seen under **More of the Same** and **Lags Behind**, then just over eight new large scale coal-fired power stations of 4,500 MW each could be required by 2040, and if no new coal-fired power stations are built as under **Low Carbon World**, the number of nuclear stations grows to 18 by 2040, with an extensive renewables build also being required. The requirement for new power station build is thus substantial, regardless of the future that evolves.

TABLE 2: BUILD PLAN FOR POWER STATIONS UNDER THE IRP 2010 POLICY ADJUSTED SCENARIO TO 2030 AND EXTRAPOLATED TO 2040 IN THE SACRM

Technology	Coal Fired Power Stations	Nuclear	Renewables and gas
IRP 2010 Policy Adjusted	Six small fluidised bed combustion (FBC) units. Medupi, Kusile and one further PF coal-fired power station online from 2027.	Six new nuclear power stations about the size of Koeberg (1.6 GW) between 2023 and 2029.	42 wind farms of 200 MW each, 12 concentrated solar power (CSP) of 100 MW each and 8,400 MW of solar (PV), totalling 18,000 MW.
Extrapolation 2030 - 2040	Three large-scale PF stations of 4,500 MW each (or a number of smaller FBC stations)	Four nuclear plants	23 wind farms of 200 MW each, 5 base load CCGT power stations of 711 MW each, 4,070 MW of solar PV. Also requires lesser amounts of co-generation, CSP, import power from hydro and coal and OCGT for peaking. The total build of renewables and gas is 20,060 MW.

Given the lead times on new power station infrastructure; the fact that South Africa has limited experience in the large-scale roll out of renewables; and funding requirements to meet the cost of new infrastructure, urgent decisions need to be made about how the power station build plans are to be achieved. In the near future, the following actions are important:

- Clarify delivery of the nuclear and renewables programmes or alternatives for the next base load power station;
- Decide on where to locate new coal-fired power stations;
- Facilitate procurement of electricity from Independent Power Producers (IPPs); and
- Achieve certainty on the carbon tax.

3.1 Clarify delivery of the nuclear and renewables programmes or alternatives for the next base load power station

Nuclear and renewables build is ambitious; nuclear could be delayed

Decision is required on next base load power stations: NPC suggests gas as "plan b"

New grid infrastructure will be required, depending on the grid mix

The ambitious nuclear build under the IRP 2010 requires urgent resolution of issues of costs, financing and procurement mechanisms, through to localisation of manufacture and possible uranium mining and enrichment, to managing safety, environmental and public acceptability concerns. It has been suggested that the first nuclear power stations could already be running late relative to the plan.

The renewables programme proposed under the IRP is also very ambitious. Whilst not requiring the same lead times as nuclear or coal-fired power, achieving the IRP renewables build plan would require rapid scale-up of local manufacturing and installation capacity if the localisation benefits expected from this programme are to be realised. Much of the substantial upfront capital requirement will also need to be sourced.

If building of the first nuclear power stations as required by IRP 2010 is unachievable, the National Planning Commission (NPC) has suggested the use of gas as a so-called "plan b", with potential sources of gas including off-shore natural gas, shale gas from the Karoo and liquefied natural gas (LNG) imports (See Box 7). Gas also represents a transitional alternative to renewables.

The benefits of gas as "plan b" over coal are the potentially shorter lead times required for building gas fired power stations (three years for gas as opposed to eight years for coal, assuming gas supply infrastructure is in place); avoidance of many of the localised environmental impacts associated with coal combustion and to a lesser extent coal mining (as this will likely continue to provide exports); lower greenhouse gas emissions per unit of power produced; and suitability of locating gas power plants at the coast where imported gas could be readily delivered and cooling water is available.

Gas-fired power stations are also much cheaper to build than coal or nuclear, with the replacement of only one nuclear plant by gas reducing overall investment cost by 8% over the 2010-2040 analysis period, and the differential could be even greater when taking into account the decommissioning costs of nuclear. It is noted that the lead time for exploiting local shale gas is likely to be longer than for natural gas or LNG, and on a par with nuclear. Shale gas is thus not considered a feasible option for the next base load power station.

There could, however, be benefits in pursuing coal as "plan b" over gas for the next base load power station. These include:

- Greater energy security in using local coal resources as compared to imports of LNG or offshore natural gas,
- National economic benefit through investment in mines and the earning of export revenues from multi-product coal mines supporting coal-fired generation capacity.

Coal is somewhat cheaper than nuclear – the replacement of only one nuclear plant with a coal plant to give the same electricity output reduces overall investment cost by about 2% over the 2010-2040 analysis period. As with gas, the differential could be greater when taking into account the decommissioning costs of nuclear.

The decisions taken as to which suite of technologies is used for the next base load power stations will start to point towards the longer term future for the coal value chain and its role in the South African economy. If nuclear stations fail to be built and coal is pursued as "plan b", South Africa may be moving away from the **At the Forefront** scenario towards **Lags Behind** or **More of the Same**, depending on developments in the rest of the world. In this case further activities as detailed below need to be undertaken to maximise coal's benefit to South Africa. If, however, gas is opted for as "plan b", this may point to a smaller role for coal moving into the future and the signalling of a future more representative of the scenario evaluated under **Low Carbon World**. These are important considerations for the larger incumbent mining companies as they consider whether to make the major investments in the South African coal sector that are required to meet the domestic supply shortfall.

BOX 7: THE POTENTIAL ROLE OF GAS IN SOUTH AFRICA'S ENERGY MIX

South Africa's National Planning Commission in its August 2012 National Development Plan recommended that gas should be explored in South Africa as an alternative to coal for energy production. It suggested that a greater share of gas should be incorporated in the energy mix, both through importing LNG and, if reserves prove commercial, using shale gas. Infrastructure should be developed for importing LNG, mainly for power production, over the short to medium term. Using gas as a substitute for coal could help cut South Africa's carbon intensity and greenhouse gas emissions. Gas has also been suggested to be a good complement for wind and solar-powered plants.

The degree to which gas will make inroads into the Southern African energy mix will depend on three factors:

- *The availability of gas from various potential regional sources;*
- *The relative cost of electricity generation electricity – capital, fuel and operating (which will take into account the higher combustion efficiencies of gas compared to coal), and the cost of production of liquid fuels from gas versus coal; and*
- *The impact on South Africa's greenhouse gas emissions, and the extent to which the South African government will require reductions from the energy sector in the future.*

Three key potential sources of gas exist for South Africa, each with its own set of challenges.

- *Local shale gas resources have been indicated. The exploitation of shale gas is controversial due to the potential environmental impacts of its extraction.*
- *Natural gas resources in Mozambique, East Africa or South Africa's limited gas reserves (off the West Coast would require pipeline infrastructure.*
- *While significant quantities of LNG are now available on the world market as a direct result of the success of shale gas exploitation in the USA, dependence on imports would decrease local energy security and potentially create price volatility.*

3.1.1 Requirements for new transmission grid infrastructure

If new power stations are built in the Central Basin, then grid infrastructure is largely in place, although the transfer capacity is constrained and would require expansion. However, if power stations are to be built elsewhere, expansion of the existing grid in that region will be required, depending on the scale of power station build. In the recent past, many delays have been experienced in obtaining the necessary transmission servitudes, which can become a limiting factor in making electricity available on the national grid.

Nuclear and gas power stations will likely be located at the coast due to the availability of cooling water as well as gas supply flexibility. Extensive grid expansion will be required to transmit electricity from the coast to the inland demand centres, although this will be balanced to some degree by saving on current losses associated with transmission from inland centres to the coast. If the substantial renewables roll-out is realised, further grid infrastructure challenges will present themselves. Renewable resources are dispersed across the country, with solar resources being greatest in the Northern Cape, and wind being spread across the country, but mostly at the coast and on the escarpment. Extensive grid infrastructure would thus be required to be built in places where limited infrastructure exists. There are also challenges with controlling grid stability when renewable technologies generate an intermittent supply into the grid, if the percentage of the intermittent supply in the total mix is high.

3.1.2 Employment and skills considerations

Regardless of how the future evolves, except for **Low Carbon World**, there is a substantial build of PF and FBC coal-fired power stations. Cost-effective implementation of these technologies will require development of local manufacturing capabilities (steelwork, boiler pipes etc.), and substantial growth in the technical skills base – including certified welders and artisans, power station operators, project managers and engineers. The number of skilled individuals required is anticipated to grow dramatically moving into the 2020s and 2030s. The industry needs to retain existing skills and assist in expanding the skills base through on-going engagement with tertiary education institutions.

Skills are also clearly required for the building of nuclear and renewable power stations. The coal industry should engage with the remainder of the energy sector to determine how its extensive knowledge base could be transferred to large-scale roll out of these technologies, and to support nuclear fuel supply if uranium is to be enriched locally.

Coal mining employment remains substantial in the near term, regardless of how the future evolves. However, mining employment is likely to decline in the Central Basin as coal resources are depleted and mines start to close, with growth in mining jobs only occurring in the Waterberg post-2023 under a future where a number of new power stations are opened in the Waterberg, such as in **More of the Same** and **Lags Behind** and **At the Forefront** to a lesser extent. The industry needs to plan for recruitment and training, and possibly relocation or reskilling of personnel to meet changing demands.

3.2 Decide where to locate new coal-fired power stations

Location of next coal fired power stations needs to be agreed

This impacts rail and water infrastructure decisions

Under the IRP 2010, the location of new power stations is not specified. If this plan is to be followed, the new smaller FBC power stations identified could be built either in the Central Basin or in coalfields such as the Waterberg. There are also options as to where the next new PF coal-fired power station or stations can be built. For example, indications are that a sufficiently large deposit still remains in the Central Basin able to support a new PF coal-fired power station over its lifetime, so the decision to locate the next power station in an alternative coalfield is not automatic. However, water and air quality considerations, as well as competition with exports for remaining Central Basin resources, means that this is less likely, and the next power station will more than likely be sited in the Waterberg.

Siting coal-fired power stations in the Waterberg will increase water demand in this water-scarce area substantially, requiring new water supply infrastructure. As mentioned previously, the grid capacity will also need to be expanded as new power stations are built outside of Mpumalanga, to allow for power to be transmitted to demand centres. Finally, road infrastructure may need to be built ahead of construction of new mines and power stations for transport of materials, equipment and personnel where such infrastructure does not already exist.

New coal-fired power stations in the Waterberg also have implications for rail infrastructure requirements. Furthermore, if new power stations are built in the Waterberg the mines supplying those power stations will very likely be dual producing, so will produce export coal that will need to be transported to ports. This implies an additional rail transport from that coalfield over that which would otherwise be required.

3.3 Facilitate procurement of electricity from Independent Power Producers (IPPs)

Review of the IRP 2010 and assignment of responsibility to fill the gap

Implementation of ISMO needs to be expedited

Favourable market conditions need to be created for IPPs

South Africa has identified a role for IPPs in generating electricity for feed into the grid. The presence of IPPs will impact the dynamics of coal demand and supply. For IPPs, whether renewable, fossil or other, to play a more active role in the electricity supply industry (ESI), the following are required:

- Review of the IRP 2010 and allocation of responsibility to fill the gap in electricity supply capacity resulting from Renewable and Nuclear seemingly behind the curve as required by IRP 2010;
- Expediting implementation of the Independent System and Market Operator (ISMO) which would help to facilitate competitive generation and ease of access to the grid;
- Creation of market conditions that provide longer term investment security conducive to private investment in generation and associated infrastructure, including provision of off-take agreements to IPPs.

3.4 Achieve certainty on the carbon tax

Clarity on design and magnitude of carbon tax is required to support investment

Any new investments in fossil fuel based generation infrastructure need to account for the tax on greenhouse gas emissions in their financial analysis. In the March 2012 budget review, a structure and magnitude of the tax was proposed, with suggestions that it could be introduced in the 2013/14 budgetary year, although this was already delayed at the time of writing. The proposal included a base tax of R 120/t CO_2e, a tax-free threshold of 60%, and various further adjustments for the carbon efficiency of a company relative to a peer benchmark, up to 10% tax-free for companies that will find it difficult to reduce their process emissions in the short term, up to 10% for companies that are trade-exposed, and up to 10% allowance for carbon offsets.

It is highlighted that a tax at this level is lower than that explored in development of the IRP 2010 build plans, which started at R 165/MWh (of coal-fired generation) in 2010 Rands, escalating to R 332/MWh in 2020 until the end of the period (2030) before escalating again to R 995/MWh in 2040. A lower carbon tax used in modelling could result in less renewables and more coal-fired power stations being economically feasible.

The structure of the tax was yet to be finalised at the time of writing this Roadmap. In the interim, various investment decisions cannot be supported until certainty about the specifics of the tax (including its quantum) are known. This issue needs to be resolved.

CAPITALISING ON COAL EXPORTS

COAL EXPORTS CAN CONTINUE TO PROVIDE A SIGNIFICANT SOURCE OF FOREIGN REVENUE FOR SOUTH AFRICA

There will continue to be a global demand for coal regardless of the future

Growth in exports needs rail infrastructure expansion

The Central Basin can support some growth in exports, provided Eskom supply is prioritised

A supportive investment climate is required

The possibility of export only mines in the Waterberg needs to be explored

Under current pricing arrangements, multi-product mines offer the most value to Eskom and exporters, but can reduce the quantity of coal available for Eskom

South Africa is a relatively small player in the global coal trade and exports only around a quarter of its production; however, coal exports provide an important source of foreign revenue for the country. The demand for South African coal exports will likely remain strong to 2040 and beyond. Even under a **Low Carbon World**, where global demand for coal may flatten or even decline, continued demand from India and Asia for coal for power stations currently under construction means this export demand should remain strong. Much of this demand is forecast to be for lower grades of coal than have historically been exported.

Coal exports in 2012 totalled 75 Mt, 67.7 Mt of which was exported through the Richards Bay Coal Terminal. Maintaining and growing exports above these levels is predicated on new mines being opened and rail capacity being expanded. Looking at projects and resource estimates, there is some potential for growing exports from the Central Basin and at least some of the coal will come from new mines that supply both Eskom and export markets (see Box 8). However, indications are that the higher-grade resources in the Central Basin coalfields - those with a run-of-mine calorific value in excess of 22 MJ/kg - will be essentially depleted by 2040 (for the export volumes and domestic demand assumed under all of the SACRM scenarios), while substantial volumes of lower grade resources will still be available after 2040 to meet the demands of Eskom's stations that are required to operate after that date.

The SACRM analysis suggests sufficient coal reserves and resource remain in the Central Basin to grow total exports to a peak of approximately 90 Mtpa in 2023, after which exports will decline steadily, unless South Africa follows a more coal intensive path, or export-only mines in the Waterberg prove economically viable. Exports from the Central Basin are forecast to peak at around 80 Mtpa, also in 2023. Importantly, this growth in exports assumes that Eskom's requirements are prioritised and the majority of new mines are optimised to maximise supply to Eskom rather than being optimised around exports. If this assumption is relaxed, exports could grow to higher levels, but there will be insufficient higher-grade resources in the Central Basin to meet Eskom's requirements.

At present, exports of coal are primarily constrained by the ability to transport coal to Richards Bay Coal Terminal (RBCT), rather than the port capacity. Growth in exports can only be achieved if the carrying capacity of this export rail infrastructure is increased to a consistent and predicable level. The SACRM analysis suggests that an expansion of rail capacity to around 85 Mtpa total exports and 75 Mtpa of Central Basin exports is sustainable, assuming a 20-year amortisation of capital. As in the case of utility supply, the supply situation will be extremely tight at these levels and any delay in building new mines, or mines producing lower volumes than expected, will likely result in exports being lower than this transport capacity. This could in turn place pressure on domestic utility supply.

Given the distribution of South Africa's remaining resources, any growth in exports above these levels will require mines to be developed in other coalfields, notably in the Waterberg. This resource is sufficient to both unlock supply for the domestic market and for the country to continue to export coal. However, the Waterberg coalfield has not yet been extensively explored, and early indications are that the nature of the resource is such that a coal supply agreement with a power producer that requires a low-grade utility coal product is in most cases a pre-requisite to profitably opening new export mines. This suggests a possible win-win situation for exports and local supply, provided that South Africa builds new power stations suited to burning such coal. However, even in the futures represented under **More of the Same** and **Lags Behind**, where such new power stations are built, this results in the country's total exports only being maintained at the forecast peak of approximately 90 Mtpa (although it should be noted that relatively conservative export yields are assumed under both these scenarios). Nonetheless, it is evident that to sustainably grow South Africa's exports much beyond the SACRM estimate of 85 Mtpa requires the potential for export-only mines in the Waterberg to be urgently realised.

Sufficient and well-timed development of the Waterberg could ease some of the tensions currently felt between exports and domestic security (see Box 8). In particular, there is potential for the Waterberg to augment supply of higher-grade utility coal required in the Central Basin for two older power stations (whilst recognising that it will almost certainly be uneconomical to modify most of Eskom's Central Basin power stations to use Waterberg coal due to inter alia the coal's high volatile matter), and in so doing, free up additional Central Basin coal for export.

BOX 8: TENSIONS BETWEEN EXPORTS AND DOMESTIC COAL SUPPLY SECURITY

Background

Many power stations in the Central Basin have historically been supplied with coal via long-term contracts from dedicated resource blocks, but these mines are nearing the end of their lives, and Eskom will be required to source new supplies to continue to operate these power stations. Certain of these plants burn coal of qualities in the range 22 to 24 MJ/kg, which compete directly with the new RB3 export grade (typically 23.5 MJ/kg, although there are reports of even lower grades being exported), for which producers can command higher prices than sales to Eskom. Supplies to some stations requiring coal at slightly lower qualities are also at risk, given that this coal can usually be washed up more profitably to supply the export market. As things currently stand, Eskom has made very limited progress in securing the coal it requires to keeps its power stations supplied for their planned (extended) operating lives. The possibility exists that unless the price Eskom is prepared to pay approaches a similar level to what the mines obtain from exporting this coal, or unless new players enter the industry with alternative funding or lower return expectations, producers could export a portion of the coal which is required for local use. Eskom estimates that up to 800 Mt of coal required by its Central Basin stations will compete directly with exports.

Eskom projects that new supplies of around 60 Mtpa will be needed by 2020 to provide sufficient coal for their power stations. This is to replace coal from declining mines, to extend the lives of certain power plants and for new committed builds – in other words; this requirement exists regardless of the future that evolves.

The Council for Geoscience's Coal Resources and Reserves Study of South Africa (CRRSA) reportedly indicates that while higher grade coal resources and reserves are on the decline in the Central Basin coalfields, South Africa has abundant lower grade coal resources and reserves but whose qualities are well below Eskom's requirements for the older power stations that urgently need new coal mines to be developed. The SACRM analysis of coal resources indicates that, in theory at least, sufficient coal remains in the Central Basin to meet Eskom's requirements and permit some growth in coal exports. However, this conclusion is premised on the assumption that the majority of new mines in the Central Basin are optimised around Eskom's rather than export requirements. However, there are very extensive resources in the Waterberg coalfield, which is estimated to account for up to two thirds of South Africa's resources. This suggests that there are sufficient resources to support both export and domestic markets, while recognising that the different types of coal are not completely interchangeable.

Attracting investment

Meeting the projected demand of 60 Mtpa from new mines will require investment of between R 60 and R 90 billion for the construction of a nominal five to ten new mines, based on the mine costs identified in Box 4. Enabling this scale of development presents the most significant challenge in meeting Eskom's requirements. Various options for investment can be explored, including co-funding of mines or increased participation by the state mining company, but a significant portion will require investment by the private sector. An attractive investment climate and fair returns are required in order to enable this investment. The relatively high returns expected from export sales provide incentives to establish new mines as well as lower required returns on domestic sales (see Table 3 below). Potential restrictions on exports and other uncertainties limit this incentive and may discourage investment at the scale required. Given the long lead times required for the development of mines, these challenges need to be resolved soon, and the capital investment must be committed before 2015.

An illustrative example is shown in Table 3, which shows the returns on a hypothetical mine in the central coalfields producing different product suites, expressed as Net Present Value (NPV) at a discount rate of 12.5%. This discount rate is in the range that many investors would require in order to justify investment in such a project, given that access to capital is limited and that options exist to invest in other commodities or jurisdictions. The three options illustrated are:

1) *a multi-product mine (supply to Eskom and high-quality export);*
2) *supply only to Eskom; and*
3) *supply only for export (a lower quality blend). All three options are based on 7.8 Mtpa ROM production and assume a relatively high-quality resource.*

TABLE 3: ILLUSTRATIVE NPV OF INVESTMENT IN A MINE IN THE CENTRAL BASIN REGION

	Saleable Tonnage (Mtpa)	Coal Quality - CV (MJ/kg)	Yield	Assumed Eskom Price (R/tonne)	Assumed Export Price (US$/tonne FOB RBCT)	NPV @12.5% (Million R)
OPTION 1: Supply to export and Eskom				200	95	1,050
Export	3.8	27	49%			
Supplied to Eskom	2.1	22	27%			
OPTION 2: ROM coal supply to Eskom				310*		0
Supplied to Eskom	7.8	22	100%			
OPTION 3: Lower quality export blend (no supply to Eskom)					80	1,200
Export	5.9	23-25	76%			

**This is a calculated price that would achieve a hurdle rate of 12.5% (for illustrative purposes)*

The table clearly highlights the tensions between exports and domestic supply security:

- *The investor receives the highest value from either a multi-product or export only mine - the lowest NPV is in Option 2 – supply to Eskom only. Eskom's cost of coal is also higher in option 2, suggesting that the "multi-product" operating model is a preferred option for both Eskom and the investor returns achieved on export coal support a lower price to Eskom for domestic use, while at the same time guaranteed domestic markets offsets the risks for exporters.*

This analysis is resource and assumption specific, and more typical of the higher quality deposits of the Central Basin, of which relatively few remain unexploited. For lower quality resources, the secondary product is no longer of sufficient quality to be used by Eskom's older power stations. For example, with a lower-grade resource, washing to produce a medium or lower-quality quality export product results in middlings with a CV well below 20 MJ/kg, which is unsuitable for most of Eskom's current fleet. The above example further illustrates that part of Eskom's higher calorific value requirements (20 – 24 MJ/kg) are threatened by being sold as exports at higher prices, unless some form of market regulation is introduced – however this could, in turn, impact miners' decisions to invest in such mines.

Nevertheless, there are still several projects in the Central Basin where optimising the mine to produce an Eskom and an export product does enable an increase in the total quantity of coal that can be sold and/or reduces costs for both parties whilst still producing acceptable qualities. In these instances, the optimisation either increases the ROM production, or there is more coal in the resource than Eskom requires. In these instances multi-product mining is the clear first choice option.

The multi-product approach remains an option in other coal basins, such as the Waterberg. As discussed previously, this resource's characteristics are such that a mine would be unable to economically produce export coal alone, therefore a domestic supply agreement as well as an exportable product is currently required to enable mine development and to maximise value.

It is clear that there is, and will likely continue to be, tension between coal exports and domestic supply security. Trade-offs need to be made on a resource-by-resource basis - a single optimisation model would not be appropriate. Clearly therefore, ongoing co-operation is required between Eskom and industry to maintain domestic supply, enable sustainable export growth and maximise value to the country.

THE FUTURE OF COAL TO LIQUIDS

BUILDING OF FURTHER COAL-TO-LIQUID PLANTS IN SOUTH AFRICA DEPENDS ON:

Decisions to build liquid fuels supply facilities in SA rather than importing fuel

Whether future liquid fuels should come from crude oil, gas or coal

The techno-economic feasibility of CCS in mitigating emissions

The scale and design of a carbon tax

Coal-to-liquids currently plays an important role in the provision of liquid fuels and chemical products in South Africa. While there may be some improvements in the efficiency of stationary and mobile liquid fuels combustion technologies, and some advancement in alternative mobility options (including a shift away from private vehicles and increased use of public transport and electric/hybrid vehicles), there is likely to be continued liquid fuel demand in South Africa in the medium and long term, regardless of the future world that evolves.

South Africa has a number of decisions to make regarding liquid fuels supply, which will in turn determine the role for CTL (or alternatively gas-to-liquids or GTL) in the country. The future of the CTL industry as the second largest coal consumer after electricity generation in South Africa will consequently impact the future direction of the coal value chain. Use of coal in other applications is considered in Box 9.

5.1 Developing new local capacity for production of liquid fuels, and determining the preferred feedstock

SA may continue to import refined fuels until output of a new facility can be absorbed

Options for liquid fuels supply are imported crude, gas or coal

The National Development Plan released by the National Planning Commission suggests that it may make sense to continue to import refined liquid fuels until such time as demand can absorb the output of either a new CTL, GTL or crude oil refinery facility, or a major upgrade of an existing liquid fuels producing facility.

If ultimately a decision is made that further local liquid fuels production capacity is required, three feedstock options exist, namely crude oil, gas (shale gas and/or imported natural gas), and coal. Each of the feed stocks has its advantages and disadvantages. GTL and CTL may prove to offer advantages in terms of local energy security in a world where oil prices rise and there is instability in oil producing regions. Conversely, imported crude and gas have the disadvantage of lower energy security as compared to local feed stocks, recognising that local shale gas could take ten or more years to deliver. The primary disadvantages of using coal as feedstock are the capital requirement and greenhouse gas intensity of the CTL process, with the latter potentially disadvantaging the export of South African products in a Low Carbon future.

5.2 The role of Carbon Capture and Storage in mitigating emissions from coal-to-liquids

CCS has to overcome challenges before it can mitigate CTL's emissions

If CTL (or GTL) continues to be considered an option for meeting liquid fuels demand in South Africa, Carbon Capture and Storage (CCS) may be required to play a role in mitigating emissions, depending on the future world that evolves and South Africa's mitigation action and introduction of a carbon tax. The implementation of geological CCS is largely dependent on finding suitable geology for long-term storage of CO_2 and on international funding and technology advances; it is thus linked to global action on climate change. However, a number of regulatory, cost and implementation challenges are associated with CCS, as discussed in more detail later in this document.

5.3 Achieve clarity on the scale and design of the carbon tax

A carbon tax could impact heavily on competitiveness of CTL

Following on from the above two points, and given the greenhouse gas intensity of coal-to-liquids processes, the scale and design of a carbon tax will impact heavily on the competitiveness of coal-to-liquids against other liquid fuel options.

BOX 9: USE OF COAL IN OTHER APPLICATIONS

Coal is used in South Africa in thermal applications such as industrial boilers and households, by the cement industry, and in metallurgical applications. Based on past trends, it is unlikely that thermal coal use in these markets will change significantly – while demand for energy in such applications may grow, this is likely largely to be met by other energy carriers such as gas. Furthermore, the carbon tax will make it more cost effective for industries to source alternative fuels, and a slow decline in coal use in industrial boilers is possible. This application does, however, represent a relatively small component of the overall demand for coal in South Africa. Local non-Eskom use of thermal coal is currently about one quarter the size of thermal exports (20 Mtpa), so a decline in local thermal use could be appreciable in terms of increasing exports.

Coal in metallurgical applications is dominated by iron and steel and ferro-alloy production. Here the coal is less easily substituted than in thermal uses as it is part of the refining process, acting as a reductant. The potential future of coal in these industries is thus closely linked with commodity growth trajectories.

CONTRIBUTING TO A FLOURISHING SOUTH AFRICA

TRANSITION TO A LOWER CARBON ELECTRICITY GENERATION MIX HAS POSITIVE AND NEGATIVE IMPLICATIONS, INCLUDING THOSE RELATED TO:

- Economic implications: capital investment, electricity price, export revenue
- Employment
- Greenhouse gas emissions
- Other environmental impacts

At present fossil fuels, and particularly coal, dominate South Africa's primary energy supply. Through the IRP 2010 and the National Climate Change Response White Paper, the Government has provided a strong signal of its intention to reduce the greenhouse gas intensity of the energy supply mix, and move towards a more diversified electricity supply grid. Such a transition will have both positive and negative implications for South Africa. Consideration is now given to what these implications may be under different scenarios (a full exploration of the scenarios can be found in the accompanying Scenarios Report). Understanding these implications provides an opportunity to assess the trade-offs, understand the timing over which different impacts may be experienced, and help guide what may need to be put into place to ensure the maximum possible benefit for South Africa.

6.1 The economy

- The cost of building nuclear and renewables infrastructure is substantially higher than coal
- The differential in generation cost is less pronounced than upfront investment
- A scenario with a diversified electricity mix will produce lower export coal revenues

6.1.1 Electricity generation infrastructure investment cost

The different electricity build plans explored as part of the Roadmap development process each represent different levels of ambition in terms of diversification of electricity supply and transition to lower greenhouse gas intensity technologies. The cost of meeting the new infrastructure requirements is significant under any scenario, and the contribution of coal in the mix has implications for mining investment and exports as discussed above. Implications for the rest of the economy include those related to procuring capital to meet the build plans, electricity generation cost (which in turn determines electricity price and affordability), investment in mining, and export coal revenues.

Investment is substantial regardless of the scenario that evolves: a total of around R 0.93 trillion is required between 2010 and 2040 in **More of the Same** and around R 2.06 trillion in **Low Carbon World**. The timing of investment is also important: **Low Carbon World** requires around three times the investment of **More of the Same** between 2010 and 2030. No new coal-fired capacity is built under **Low Carbon World** so this high investment is required for renewables and nuclear build, whereas in **More of the Same** demand is met by coal-fired build. In a low carbon world foreign capital is likely to be made available to support transition to alternative energy sources, which may offset some of the implications of the high investment costs in **Low Carbon World**. On the other hand, building additional coal-fired power stations under **Lags Behind** is likely to be difficult to fund using global investments as the world decarbonises. Under **More of the Same** and **At the Forefront**, global investors will be less likely to base investment priorities on the carbon intensity of generation infrastructure.

In all scenarios, reducing demand for electricity could significantly reduce investment requirements as explored in Box 10.

BOX 10: USING ENERGY MORE SMARTLY

Building new power stations, regardless of what technology trajectories are pursued, has massive economic implications for South Africa, with the total investment required between 2010 and 2040 being in the order of R 1 trillion in the case of a ***More of the Same****, and more than double that in* ***Low Carbon World****. New power station infrastructure also requires a huge base of skilled personnel to achieve the build required, regardless of the technologies employed.*

Smarter use of energy, which includes both overall energy efficiency and peak load shifting, has a strong role to play in reducing investment requirement, overcoming an expected skills shortage, and in reducing greenhouse gas emissions associated with provision of energy services. If annual demand for electricity can be reduced by 10% between 2030 and 2040 against the demand projections used in this study, this could save, for example, capital investment of some R190 billion over the 10 year period under ***At the Forefront.*** *This is due to fewer power stations being required: 6,000 MW less capacity in coal-fired power stations, one less nuclear power station and a lower requirement for renewables. This has direct consequences for the amount of coal required over the same time frame.*

The country thus needs to implement incentives, funding, communication strategies, policy and training, tariff structures and other mechanisms to support:

- *Incentivising energy efficiency across all sectors of the economy, while recognising that implementation of energy efficiency opportunities is already being driven by rising energy prices;*
- *Managing peak demand for electricity (for example through increased utilisation of 'time of use tariffs' (including in the residential sector) and further roll out of existing programmes such as geyser controls;*
- *Establishing of smart grids, to improve the efficiency of production and distribution of electricity;*
- *Increasing the roll-out of solar water heaters to reduce demand for electricity primarily in the residential sector; and*
- *Reducing liquid fuels demand in the country, including through modal shifts in transport.*

Ongoing education programmes for all energy users are required to focus on reducing both peak and overall demand for electricity.

6.1.2 Electricity generation cost

The implications for the cost of generating electricity of the different futures are less pronounced than the upfront capital costs. This is because even through renewables and nuclear build have higher upfront costs, they have lower fuel and O&M input costs. In the 2031 to 2040 period, the cost of generation is 9% higher in **At the Forefront** and 36% higher in **Low Carbon World** when compared to **More of the Same**. The cost of clean coal technologies, especially CCS, is found to be appreciable, with **Lags Behind**, which employs ultra-supercritical power stations in all new build and CCS on new build after 2034, coming out with a generation cost essentially the same as that of **At the Forefront**.

Note that electricity generation cost excludes the cost of transmission and distribution, as well as the cost of carbon transport and storage, and the environmental levy on electricity generated from non-renewable resources.

6.1.3 Coal export revenue

The final economic indicator used to compare scenarios is the revenue generated from coal export sales. Under **More of the Same** and **Lags Behind**, a greater local demand will lead to greater investment in mines, and hence greater production of exports, especially where the demand for utility coal leads to substantial development in the Waterberg. If **Low Carbon World**, and to a lesser extent **At the Forefront**, are the futures that are evolving provision will need to be made for developing alternative sectors of the economy to make up for lower export revenues from coal exports. Alternatively, production of export coal from the Waterberg needs to be decoupled from production of utility coal, as indications are that there will still be demand for low-grade exports in a low carbon future. The constraint is thus more around sufficient exploration being undertaken in the Waterberg to show this decoupling is feasible, and around having sufficient infrastructure to transport the coal to market, rather than there being no market for export coal in these scenarios.

Although the direct economic performance of the coal-intensive scenarios appears to be better than that for those scenarios with a diversified energy mix, it is recognised that the stated costs do not account for other impacts or "externalities", including the impacts of the coal sector on the environment, nor the effect of carbon taxes or environmental levies. The environmental impacts are explored in the sections that follow.

6.2 Employment

Employment in the coal mining sector is high, particularly in a coal-intensive scenario

Job creation across the economy is critical regardless of the future

The coal value chain provides high levels of employment, both directly in its operations and indirectly associated with suppliers of goods and services. Almost 80% of the direct employment associated with the coal value chain (78,600 people in 2011) is in coal mining itself. Employment will drop off in the Central Basin in the 2020s and 2030s as mines and power stations close, with similar job losses being seen under all scenarios – to the order of 20,000 to 30,000 jobs lost in the Central Basin between 2010 and 2040 in coal mining alone. These job losses are compensated for by employment gains in the Waterberg under **More of the Same** and **Lags Behind**, as new power stations and mines are opened – between 49,000 and 53,000 jobs are created in coal mining alone in the Waterberg under these scenarios. **At the Forefront** only has limited job creation in the sector in the Waterberg, as few new mines and power stations are opened. In **Low Carbon World**, there is almost no new direct employment creation in the sector. Furthermore, should restrictions on exports become government policy, it is possible that employment will decline where the restrictions result in a curtailment in new mining development, and the employment gains under **More of the Same** and **Lags Behind** might not be achieved.

Contributing to prosperity for South Africa under all scenarios will require development of alternative sectors of the economy. It is recognised that some of the differential in employment between a coal intensive and a low carbon future would be taken up in the development of the alternative Green Economy that includes building of nuclear and renewables, but the impact on employment of using less coal is considerable.

6.3 Water

Under all scenarios, water demand decreases substantially

Water demand is substantially higher in a coal intensive future

Indirect water impacts of a coal intensive future should not be ignored

Additional water supply is required in arid areas under a low carbon future

Under all scenarios, water demand decreases substantially, both in absolute terms and in the intensity of water consumption for electricity supply. This is largely due to the migration from wet-cooled coal-fired power stations to dry-cooled stations, as the older stations in the Central Basin (supplied by the Vaal River water supply System) are closed and are replaced by new power stations in the Waterberg.

The coal intensive scenarios, **More of the Same** and **Lags Behind**, are clearly more water intensive than **At the Forefront** and **Low Carbon World**. Whilst the water consumption of solar electricity technologies in particular is very small compared to coal-fired generation technologies, much of this would occur in arid regions where additional water infrastructure is likely to be required even to supply these relatively small volumes. Additional water supply infrastructure will thus be required regardless of the future that evolves, although the volumes required and location of demand differs between scenarios.

Securing a stable and cost-effective water supply to the Waterberg is crucial to long-term energy security under **At the Forefront**, and even more so under **More of the Same** and **Lags Behind**. Only under **Low Carbon World** is this not an issue.

In addition to direct water demand for power stations and mines, three further considerations related to water need to be taken into account, particularly for the Waterberg. Firstly, the reinforcing effect of the energy-water nexus in a high coal future such as in **More of the Same** and **Lags Behind** should not be underestimated (see Box 11), even though this knock-on effect on water resource availability has not been quantified explicitly in this study. Secondly, water demand to support additional industry and population growth in the Waterberg area is considerable. Finally, the impacts that will occur as a result of climate change, which include higher temperatures and higher variability in rainfall, both which impact negatively on water availability, need to be kept in mind.

Innovative solutions to water supply to the Waterberg are being explored (see Box 12), with the most urgent considerations being decisions around the construction of pipelines (the size and number), and how to finance these. The current plan for future water supply to the Waterberg is to transfer water from the Crocodile River (West). These transfers are suggested to be potentially beneficial to the Crocodile River system, which is principally fed by treated effluent from Gauteng. Transferring the water for industrial use to the Lephalale area potentially offers the efficient use of this lower-quality water. There will also be increasing opportunities for reuse of water in the Lephalale area, where increasingly large return flows will follow from growing communities and industry.

BOX 11: THE ENERGY-WATER NEXUS

Coal mines and coal-fired power stations require water to operate. At the same time coal mines and coal combustion decrease water availability through their impacts on water catchments and water quality. These feedback loops between water and energy provision in our carbon-based economy have been termed the "energy-water nexus", with arguments that carbon-based energy has a much higher water impact than what is accounted for directly. Furthermore, climate change compounds the issue through a variety of feedback mechanisms between the global carbon and water cycles. For example, higher temperatures increase evaporation rates, which in turn cause changes in precipitation, which impact on stream flow and runoff rates. In general, climate predictions are that dry areas are likely to become dryer still. Compounding this further is that mitigation measures, such as carbon capture and storage (CCS), increase the water requirements of the power station. Decisions around energy security thus have strong implications for water security, and consequently for food security.

BOX 12: WATER SUPPLY OPTIONS FOR THE WATERBERG

Phase 1 of the Mokolo and Crocodile Water Augmentation Project (MCWAP) is currently under construction, and on completion in 2014 will supply 30.5 Mm^3/a. MCWAP makes provision for 3 further phases: Upon completion of Phase 2 (2018) there would be a total supply of approximately 130 Mm^3/a, Phase 3 is planned to make up any river conveyance and other losses (e.g. illegal irrigation losses), whilst Phase 4 could supply an additional 200 Mm^3/a in return flows from sewage outfall works situated on the Klip River to the Crocodile River (West). The phases after the first phase of MCWAP are based on transferring water from the Crocodile River (West) to the Lephalale area. The water transferred is envisaged to be primarily return flows from the Gauteng Region. The timing and volumes of the further phases of MCWAP (particularly 3 and 4) will depend on growth in water demand in Lephalale and in Gauteng. A further consideration is that the decommissioning of power stations in the Vaal River System frees up over 200 Mm^3/a of water by 2040. This water could potentially augment the return flows to the Waterberg, although its availability will depend on competing water demand by industries, communities and agriculture in other catchment areas.

It is generally assumed that, since the Waterberg is water stressed, any new power stations in this area will be dry rather than wet cooled (as is the case with Matimba and Medupi). There is an order of magnitude difference in the water requirements of a dry versus wet cooled plant, with the former (without FGD and CCS). However, the water savings of dry cooling comes with a drop in net thermal efficiency compared to wet cooling of a few percentage points. Factoring in the cost of this drop in net thermal efficiency could point to desalination becoming a cost effective solution, where the energy costs of pumping and desalinating either sea water or effluent water are compensated by savings in thermal efficiency (i.e. on a R/MWh basis, a wet-cooled plant using desalinated water can be cost and carbon equivalent to a dry-cooled plant).

6.4 Greenhouse gas emissions

Greenhouse gas emissions associated with coal combustion are a major concern

Transition to a diversified grid will help to mitigate emissions

Coal power stations with higher efficiency will reduce emissions per unit power

The application of CCS is subject to overcoming a number of challenges

Coal-fired power generation and Coal-to-Liquids are associated with high emissions of greenhouse gases, which is the principal driver behind the move to a lower carbon economy and an electricity mix that includes more renewables and nuclear. At the Forefront and Low Carbon World thus have substantial benefits over Lags Behind and More of the Same, both in terms of annual greenhouse gas emissions from electricity supply and the emissions intensity of electricity.

Two key opportunities exist for reducing the greenhouse gas intensity associated with coal usage, being increasing the efficiency of power stations and Carbon Capture and Storage (CCS). The latter is, however dependent on overcoming a number of challenges as discussed in the next section.

6.5 Other environmental considerations

Mining creates land disturbance, damage to pans and wetlands and pollution of water

Discards, fines and power station ash require large land areas for disposal

High level nuclear waste requires long-term management

Renewables require large tracts of land

Other air pollutants can be partially managed through technology

Both renewable and non-renewable technologies give rise to environmental impacts in addition to the water use and carbon emissions considered above. Solid waste, local air pollutants as well as land transformation and biodiversity impacts are also of concern.

More of the Same and **Lags Behind** have the highest solid waste impacts, associated with discards, fines and power station ash, due to the continued reliance on coal. The volume of discards generated in the Waterberg are much higher on a per tonne coal product basis than in the Central Basin, given the lower yields. Land use planning to make allowance for the safe disposal of this large volume of material in such a way that it does not affect other land users, air quality, or biodiversity in the area is challenging. Land transformation is even more of an issue when combined with the fact that mining in the Waterberg will be predominantly in extensive opencast pits. **More of the Same** builds 6 new large-scale power stations in the Waterberg, a sobering fact, considering that the footprint of the mine supplying the two current Waterberg power stations is over 20 km^2. However, whilst a certain extent of surface disruption is unavoidable for a certain length of time, if planned and managed properly, mining pits will be backfilled as mining progresses, and should be closed and rehabilitated by the end of the mine's life. Very careful planning is required if rehabilitation is to be achieved with minimal possible loss of biodiversity.

Under **At the Forefront** and **Low Carbon Economy**, provision will have to be made for the long-term management of high-level nuclear wastes, which are of concern not for their volumes as much as for their hazard and their cost of disposal. Whilst the actual built land footprint of nuclear power stations is relatively small, they tend to have large "exclusion zones" surrounding them, which, depending on their location, could lead to competition for land resources. However, they conversely have positive biodiversity impacts, given these land areas typically become natural reserves. Similarly, renewable technologies require large tracts of land for their establishment, with nearly 1,500 km^2 required for the wind power built under **At the Forefront**, and just under 500 km^2 required for the solar power build. However, a relatively small portion of this is actually built over so water and biodiversity impacts will depend strongly on the way in which the land is developed. Much of South Africa's solar resource is located in the Northern Cape where land competition may be less of an issue. Wind farms are often co-located on agricultural land, where their visual and noise impact are of concern. Land use planning will need to take these factors into account.

Air pollution impacts associated with coal mining and coal combustion include particulates (dust and fly ash), oxides of nitrogen (NO_x) and oxides of sulphur (SO_x). These emissions lead to the numerous atmospheric impacts commonly associated with coal combustion. All future coal-fired power stations, including those currently under construction, are anticipated to have flue gas desulphurisation (FGD). This will mitigate these emissions to a considerable extent, although it should be recognised that emissions control technologies have an efficiency penalty, come at a cost of additional water requirements at the power station, require large volumes of limestone and/or dolomite (with associated mining and transport), and generate considerable volumes of gypsum product (which is saleable if of sufficient quality and markets can be found) or gypsum waste (calcium sulphate slurry with entrained fly ash).

PLANNING FOR THE LONG-TERM FUTURE OF COAL

INDICATIONS ARE THAT COAL WILL CONTINUE TO PLAY A ROLE IN SA'S ELECTRICITY MIX, IN THE SHORT TO MEDIUM TERM. IN THE LONGER TERM, ITS ROLE WILL DEPEND ON THE ABILITY TO MITIGATE NEGATIVE IMPACTS AND THE FUTURE THAT EVOLVES

Advancements in coal-fired power are critical

The application of CCS is subject to overcoming a number of challenges

Planning is needed for closure of mines and power stations in Mpumalanga

In the medium term, coal-fired power will continue to have a core role to play in South Africa's energy mix, even if the mix is diversified to include more nuclear and renewables. In the longer term, the role of coal in a low carbon future is likely to be largely dependent on the successful implementation of greenhouse gas mitigation measures, particularly increased combustion efficiency and the implementation of Carbon Capture and Storage (CCS), as well as measures to mitigate the other negative environmental impacts associated with coal-fired power discussed previously. Even if the world and South Africa do not transition to a low carbon future, there are local environmental and energy benefits to improving the efficiency of coal utilisation. To ensure that value from coal is delivered in such a way as to maximise benefit while minimising impact on the environment, various longer-term options need to be explored.

7.1 Technology development requirements for coal mining and processing

A number of technology development requirements have been identified in coal mining and beneficiation to help increase efficiency and minimise impacts on the environment for new and existing mines. These include:

- Cost- and water-efficient mining and beneficiation, particularly for multi-grade seams, including further R&D on dry beneficiation technologies;
- Development and introduction of safer mining techniques;
- Cost-effective and environmentally acceptable management of the considerable volumes of discard and spoils;
- Development of techniques for agglomeration/ briquetting for fines;
- Development of know-how in thin seam mining; and
- Advancements in mine rehabilitation.

7.2 Advancement of coal-based power generation

Explore application of ultra-supercritical IGCC and oxy-fuel in SA

Advance R&D in flue gas desulphurisation

Demonstrate application of Underground Coal Gasification

Develop other opportunities for GHG mitigation and advanced water treatment

The efficiency of coal-based electricity is continually being advanced, with **ultra-supercritical pulverised coal** combustion technologies offering improvements in thermal efficiency of 5% or more over supercritical PF, the technology employed at Medupi and Kusile. Current ultra-supercritical plants have a net efficiency of around 43% (LHV).

Integrated Gasification Combined Cycle (IGCC) is another coal technology offering efficiencies comparable to ultra-supercritical PF combustion, and providing higher efficiencies when combined with CCS. However factors such as the ability to burn lower quality coals, the ability to cycle the power plant more readily in response to grid conditions, better operational availability and lower capital cost would seem to favour pulverized coal combustion over IGCC, although it is recognised that improvements in IGCC are a possibility.

Oxy-fuel combustion, which is competitive with IGCC when used in combination with CCS, burns coal in oxygen rather than air. Oxy-fuel combustion has the additional benefit of producing a relatively pure stream of CO_2, making capture for CCS easier. However, oxy-fuel combustion plants currently only exist at demonstration scale.

It is likely that regardless of the decision taken on base load power, the use of **fluidised bed combustion** (FBC) will grow in South Africa. FBC is suited to smaller modular applications, and thus has good potential for being taken up by Independent Power Producers (IPPs). Future advances, such as advanced supercritical FBC, will likely make this a very competitive technology, with high thermal efficiencies possible with very low quality coals (although utilising lower quality coals inevitably involves a trade-off with higher CO_2 emissions). A further benefit of FBC is that it enables capture of sulphur dioxide in-situ, and avoids the additional water needed for post-combustion flue gas desulphurisation (FGD). Furthermore, FBC's ability to burn low-grade coal means that beneficiation can be avoided, resulting in further water savings at the mine. FBC thus looks to have particularly good potential in the Waterberg.

R&D in the medium term should focus on determining the applicability of these technologies to South African coals, with a view towards employing them for any new coal-fired power stations which may be built in the 2020s and 2030s.

Additional research in the medium-term is required on **flue gas desulphurisation** (FGD), as indications are this will be required on all power stations going forward. In particular, R&D is required on:

- Reducing water consumption of FGD;
- Finding suitable deposits of limestone sorbent (in terms of reactivity and proximity of deposit to power stations), including exploring trade-offs in the volumes required with different sorbents, transport distances required and the type of wastes/products that result; and
- Understanding the quantities and qualities of gypsum product that will result from the large-scale deployment of FGD with South African coals, which in turn requires:
- Finding potential markets for gypsum from power stations, particularly since different grades of gypsum will results from different technologies (e.g. wet or dry FGD). A notable difference is with in-situ capture of SO_2, such as with FBC, where the gypsum and fly ash are mixed.
- Finding potential uses for gypsum from power stations where the quality is found not to be suitable for conventional building applications, e.g. a neutralising agent for backfill of opencast mines.

As a further coal-based technology, **Underground Coal Gasification** (UCG) offers the potential to exploit coal seams that are not accessible with conventional mining. There are a number of key research needs relating to UCG. In the medium term these include demonstrating the economic and technical feasibility of UCG and managing its environmental impacts, including removing toxics from the syngas product, and avoiding water contamination. In the longer term, progress on implementing this technology involves identifying coal seams for UCG and exploring the possibility of combining CCS with UCG to determine whether this is a better option than with convention coal combustion. A suitable policy regime to support UCG will also need to be established.

Finally, other research opportunities related to coal fired power include those relating to GHG mitigation, such as biomass co-firing (while recognising the environmental and social impacts of such options and providing for the substantial amount of biomass required) and advanced water treatment. The latter includes exploring water treatment plants and options for consequent brine disposal, and longer-term research into "zero-water" power stations, for example through flue gas condensation. Future power stations with CCS offer the possibility of zero water use, where flue gases will need to be cooled before capture of CO_2.

7.3 Understanding the role for Carbon Capture and Storage in mitigating greenhouse gas emissions

CCS could allow coal to continue to contribute to meeting South Africa's energy needs with reduced CO_2 intensity. Although technically viable, there are a number of challenges:

- Identifying and proving integrity and injectivity of storage sites in SA
- High capital cost implications of sequestration of CO_2 from coal combustion
- High energy penalty associated with sequestration from coal combustion
- High infrastructure requirements

Developments in clean coal technologies, including ultra-supercritical PF and IGCC, will never be sufficiently low carbon in themselves to have a future in a carbon constrained future such as in **Low Carbon World**, without the addition of CCS. CCS is anticipated to reduce CO_2 emissions from power stations by as much as 90%. However, the development of clean coal technologies that work well with CCS are an important enabling factor for CCS. Government and industry are working to promote CCS and ensure the necessary skills for the implementation of CCS through the establishment and work programme of the South African Centre for Carbon Capture and Storage (SACCCS).

Current information indicates that the costs and energy penalties associated with CCS are appreciable, yet the technology is continuing to be pursued, for two main reasons. Firstly, even with such significant price increases compared with the price of traditional coal-fired electricity infrastructure, it may still be cost-competitive with nuclear and renewable options. Secondly, international studies show that a global energy mix without CCS will not be able to achieve stabilisation of greenhouse gas emission levels at 450 ppm.

CCS has an effect on both the thermal efficiency and the auxiliary power requirements of a coal-fired power station - together this results in a drop in net plant efficiency (see Figure 4 below). This means that more coal is required to produce the same power output of a similar plant without CCS (to overcome the efficiency penalty), whilst additional (or larger) units are required to generate the power needed to run the carbon capture equipment.

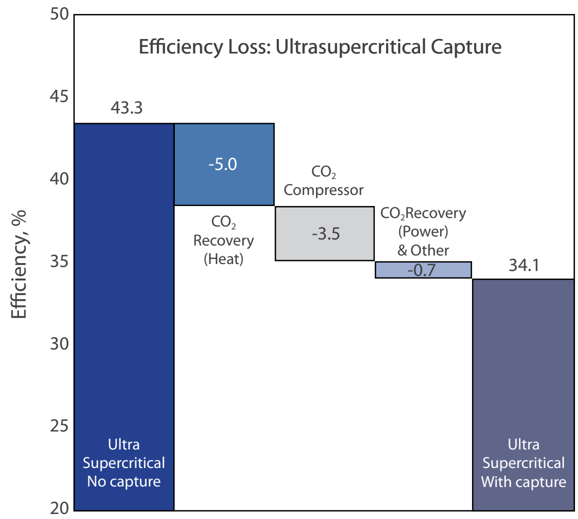


Figure 4: Parasitic energy requirements for an ultra-supercritical PF power station with post combustion CO_2 capture

Source: MIT study: The Future of Coal (2007)

CCS has been demonstrated on a relatively small scale globally. According to the Global Status of CCS: 2012 report, 8 large-scale CCS projects around the world are storing around 23 Mt CO_2 each year. Two of the further eight plants currently under construction will be the first industrial scale projects in the electricity generation sector. These global volumes are small when considering that a single 3,600 MW power station emits over 20 Mt CO_2 per year. Thus, the priority objective with respect to coal is the successful global large-scale demonstration of the technical, economic, and environmental performance of the technologies that make up the major components of a large-scale integrated CCS system - **capture, transportation and storage**. Securing funding for such demonstration plants is a strong focus of global CCS efforts, and it is crucial that these global efforts get underway if these technologies are to advance. It is equally important that local efforts get underway and that the CCS test injection project planned by the SACCCS is realised, Projected dates for the commercial availability of the CCS technology internationally vary between 2025 and 2035. Considering that electricity generation project development lead times can easily extend beyond 10 years, the urgency of this research should not be underestimated.

7.3.1 Carbon capture

Carbon capture and compression account for approximately 80% of the costs of CCS (in plants where the storage site is reasonably close by). R&D into CO_2 capture for coal combustion and conversion systems is thus critical in making CCS economically feasible. Most of this R&D will occur overseas, but it is important that South Africa be aware of adaptations required for local coals and conditions.

The fact that the high cost of CCS capture systems is largely around concentrating the CO_2 stream points to CCS being better suited to CTL and GTL plants than power stations, since around 50% of CO_2 emissions are already in a concentrated stream.

7.3.2 Transportation and storage

The Atlas on Geological Storage of Carbon Dioxide in South Africa suggests that 150,000 Mt of CO_2 can potentially be stored offshore in saline geological formations. On-shore storage potential was found to be very limited. The current reality is thus that storage sites are far removed from the main CO_2 sources in South Africa. Feasibility studies are required on the infrastructure requirements (pipelines) and the costs of long-distance transport of CO_2 to demonstrate the technical and economic viability of CCS in South Africa. The feasibility of alternatives to the long-distance transport of CO_2 also needs to be explored, such as locating power stations at the coast (see Box 13).

Given the high cost and technical complexity of off-shore storage, R&D into alternatives to geological sequestration should also be explored, e.g. mineral sequestration, in which the CO_2 is reacted above ground with magnesium and calcium containing minerals, and algal sequestration, in which the CO_2 is pumped into a pond and is used to grow algae subsequently recovered for their energy value.

7.3.3 A suitable regulatory/legislative framework for CCS

A clear and rigorous regulatory process that has public and political support is a prerequisite for implementation of carbon sequestration on an industrial scale. Such a regulatory process will need to resolve issues associated with the definition of property rights, liability, site licensing and monitoring, ownership, compensation arrangements and other institutional and legal considerations. Regulatory protocols will need to be defined for sequestration projects, including site selection, injection operation, surveillance, and eventual transfer of custody to public authorities after a period of successful operation. Thus it is imperative that the planned demonstration of sequestration by the SACCCS includes a properly instrumented storage site, and that a suitable regulatory framework is developed in tandem.

BOX 13: LOCATING CTL PLANTS AND POWER STATIONS WITH CCS AT THE COAST

Coal-fired electricity generation in South Africa has traditionally comprised a mine-mouth model in order to reduce transport costs. In countries that import their coal, the coal-fired power stations are often situated on the coast, which has additional advantages for the efficiency of the power station as well as access to seawater for cooling. With much of the storage potential for CO_2 *being located off the South African coast, the question needs to be asked whether it would be preferable to locate coal-fired power stations with CCS at the coast near to storage sites for* CO_2 *and an abundant source of water, while railing the coal from the Waterberg where the bulk of the country's remaining resource is located. This would require understanding the trade-off of the cost of transporting coal and sorbent to the coast and any implications for both rail and transmission infrastructure, against the costs of transporting water to the power stations and* CO_2 *to the coast. A preliminary investigation by Eskom indicated that the cost of electricity from a coal-fired power station would almost double with the inclusion of CCS – and yet this is still cost-competitive with some other forms of low carbon electricity generation. This investigation also indicated that a coal-fired power station without CCS would have a lower lifetime cost if built at mine-mouth, while an identical power station that does include CCS would have a lower lifetime cost if placed at the coast.*

7.4 Planning for mine and power station closure in Mpumalanga

At least 6 power stations and many mines will close in Mpumalanga before 2040

Resulting job losses could ultimately lead to the decline of existing urban centres

Diversification in skills and industrial activity will help mitigate the impacts of this

Regardless of the future for coal that evolves, at least six power stations and a number of mines in Mpumalanga will be decommissioned during the 2020s and 2030s. Furthermore, coal resources in the Central Basin will eventually be depleted. This will result in gradual loss of employment opportunities in the region, with supporting industries declining in tandem with mine and power station closure, and could ultimately lead to the slow decline of urban centres. Early and integrated planning is required to mitigate these social impacts. In a high coal future, where significant expansion of the Waterberg has taken place, it might be possible to alleviate some of these social impacts by encouraging and facilitating relocation of small industries and individuals to the new centres of coal industry. In tandem with this, early action on skills training and community development will be required to foster the development of alternative economic activities in the region.

7.5 Building resilience to climate change

The extent of the impacts of climate change will depend on the future world that evolves

Implications for the coal value chain relate to extreme weather events, water availability and communities

Impacts are highly localised and individual players need to identify actions and build resilience

It is now widely accepted that the world is going to experience the impacts of climate change due to increased levels of greenhouse gas emissions in the atmosphere from human activities. Such impacts include those associated with extreme weather events (floods, droughts and heat waves), as well as changes in the long-term average climate. The knock-on effects of climate change will further impact on the availability of water resources, agriculture (and hence food security), forestry and human health.

There are significant costs associated with adapting to climate change impacts. Examples include costs of new infrastructure, changing agricultural practices, protecting biodiversity, protecting coastlines and improving resilience of rural and urban communities. Addressing food security issues, particularly in the poorer, least developed areas, represents a considerable challenge for the country, and may require substantial levels of government support.

The extent of climate change and consequent impacts and the associated costs, including those for the coal value chain, depend largely on global efforts on mitigation of greenhouse gas emissions, and less so on the greenhouse gas emissions trajectory followed by South Africa. This is due to South Africa being a relatively small emitter as compared to the world's major emitters. On this basis, impacts and the consequent adaptation costs are expected to be lower in **Low Carbon World** and **Lags Behind**, where global action is taken on climate mitigation, than they are in **More of the Same** and **At the Forefront**, where greenhouse gas emissions continue relatively unabated. The timing of action is critical to determining the scale of impacts and adaptation costs: early action may imply a greater upfront cost, but will reduce adaptation requirements down the line. Delayed action will in turn result in a need for greater investment in adaptation and in dealing with the costs of impacts.

Examples of impacts that may be experienced by the coal value chain include those associated with extreme weather events (such as floods, heat waves, severe storms and snow) that could disrupt production and transport of coal, electricity and liquid fuels, long-term changes in water availability (with increases in some areas and decreases in other areas) and the impacts on communities which in turn affects energy consumption patterns. Estimating the actual costs of impacts and adaptation requirements is challenging, with requirements and costs being highly localised. As such players in the coal value chain need to actively engage in assessing the potential impacts for their operations, and development of interventions to improve resilience to climate change.

CHARTING THE UNCERTAIN FUTURE

The future that is likely to evolve and the path that may be followed by South Africa depends on a myriad of external factors, and the response to these factors in South Africa will be based on local priorities. Charting a future for the coal industry under this uncertainty is challenging, and so responses need to be robust. A summary is presented here of events that will provide a signal of the direction both the world and the local context in which the coal industry operates is taking, and some of the industry and policy related activities that are important given our current understanding of the world. At the same time, these activities will constantly need to be adjusted as the world in which the coal industry is placed continues to evolve.

8.1 Key events that signal the future direction for the coal industry

A number of critical factors have been identified that will signal a change in the future for the coal industry in South Africa as represented by the **At the Forefront** scenario. There are a number of actions and policy requirements to ensure that the coal industry continues to provide a positive contribution to a flourishing South Africa. These are summarised in the table below.

TABLE 4: SIGNALS, IMPLICATIONS AND RESPONSES

Time frame	Signal	Actions and policy requirements
Present and escalating	**Status of new nuclear under the IRP 2010:** It has been suggested that it is already too late to build the first nuclear power stations by 2023, as proposed under IRP 2010, to supply base load growth after Kusile power station is commissioned. It is anticipated that the IRP 2010 Review could provide clarity on the extent to which reduced GDP growth rates and electricity demand impact on this date. The further nuclear build plan specified under IRP 2010 is also considered ambitious in terms of funding and skills requirements. Furthermore, the ambitious renewables build specified under IRP 2010 does not appear to be deliverable in the proposed time frame. Unless the nuclear and renewables builds are moved ahead rapidly, alternative sources of base load electricity will be required.	Clarify the level of mitigation effort that will be required of the energy sector, the costs associated with this and how these mitigation efforts will be achieved through carbon pricing. Track progress on delivery of the IRP 2010 build programme, including the supporting regulatory environment and infrastructure. This may require the development of and investment in contingency plans such as plant life extension (and associated coal supply requirements) and alternative power station options. If coal-fired power stations are to be built to substitute for nuclear, decisions are required soon – lead times for coal although shorter than those for nuclear, are still substantial. A decision to build additional coal-fired power stations may also improve the investment climate for the coal sector if it contributes to greater production of export coal from the Waterberg. Streamline the process to accommodate IPPs in the electricity supply mix, both for renewables and non-renewables, and resolve who is responsible for building new base load capacity.
Present and escalating	**Mining investment climate:** Globally-listed mining companies, which currently produce a majority share of South Africa's coal production, have alternatives for investment off a limited capital base. At present, investment in South Africa is being deterred due to the unfavourable policy and legislative environment, and labour risks and better returns in other commodities and geographies. Although some of these investors could be replaced by domestic entities, if the desirability of investing in South African coal mines declines further, this could lead to future reductions in the availability of coal for both local and export markets.	Alignment between government departments on policy and legislation to streamline processes and provide regulatory certainty for establishment of new mines. Resolution on government policy affecting coal mining. This includes concluding debates on restricting low-grade exports, allocation of mining rights and future empowerment requirements for Eskom supply, while giving due consideration to wider national socio-economic imperatives around economic growth and transformation, employment and skills development. Clarity on the declarations by government of coal as a strategic resource, and what this means for the industry. Identify those resources that are critical to Eskom's supply and ensure that they are secured for this purpose.

Time frame	Signal	Actions and policy requirements
2015	**Global climate agreements:** The world's nations decided in Durban in 2011 that agreement on climate change mitigation targets should be reached by 2015, with implementation by 2020. If the Durban Roadmap achieves its stated aims, South Africa is likely to agree to binding targets for greenhouse gas mitigation, to replace its current pledges, which will suggest that we are moving from **At the Forefront** towards either **Low Carbon World** or **Lags Behind.** South Africa's pledge was made conditional on financial assistance, technology transfer and capacity building and any international agreement (with binding targets) should simultaneously seek to formalise and secure commitments in respect of these conditions.	Close monitoring of progress on international negotiations. Clarity on the level of mitigation effort that will be required of the energy sector, the costs associated with this and how these mitigation efforts will be achieved through carbon pricing.
Early 2020s	**Availability of infrastructure to support Waterberg development:** In addition to rail infrastructure being required from the Central Basin to RBCT, it would seem prudent to increase the capacity of the rail infrastructure between the Waterberg and the Central Basin, both to provide an alternative source of coal to feed some Central Basin power stations that are facing a coal shortfall from the mid-2020s or earlier, and enable Waterberg coal to be transported to RBCT for exports. Whilst modelling suggests that there is no immediate threat to security of supply to Eskom, this assumes that all coal mining investments will be delivered as required and without delays. Given the uncertainties in these assumptions and the fact that over 50% of South Africa's coal resources are in the Waterberg, it is strongly recommended that access to the Waterberg coal fields be enabled without delay. Long lead times are required for rail infrastructure so early planning is required to ensure that this infrastructure is ready. Nevertheless, rail and port infrastructure should not be increased beyond their likely throughputs: the current incremental approach to rail expansions is supported. Water infrastructure is required to supply mines and new power stations, and effective urban infrastructure planning is required to ensure sustainable communities in the region.	Decisions need to be reached on building of new infrastructure, including scale, funding and pricing models. If the rail infrastructure is expanded, mechanisms need to be put in place to ensure that domestic coal supply receives the appropriate priority. Co-ordinated municipal planning for the Waterberg.

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2017	**CCS test injection:** In a future where South Africa is required to further reduce its greenhouse gas emissions Carbon Capture and Sequestration may be pursued. However, unless viable storage options, a successful test injection and a significant reduction in costs can be demonstrated, this will not be realised. Global funding is likely to be required for CCS to be realised in South Africa. It is noted that the potential of CCS in mitigating emissions is greater in the CTL industry than coal-fired power generation.	Establishment of a suitable regulatory framework for CCS is a challenge that needs to be overcome if CCS is to be pursued. Maintain support for relevant institutions and study programmes, such as the South African Centre for Carbon Capture and Storage. Proceed with the program to characterise viable storage options and demonstrate a successful test injection. A significant reduction in costs needs to be demonstrated internationally. Continue with international research and development engagements in respect of the capture and transport components of the CCS value chain. Global funding needs to be secured.

Time frame	Signal	Actions and policy requirements
Mid 2020s	**Development of local liquid fuels supply capacity:** Direction taken on meeting liquid fuels demand in South Africa, together with other drivers, could influence decisions in respect of any further coal-to-liquids plants. Alternatives here include continued and increased imports of refined products, a potential new crude oil refinery at Coega or, further into the future, increased gas-to-liquids capacity. Note that the CTL decision will be influenced by a number of other factors, including the finalisation of a carbon tax.	Plans for proposed refinery to be confirmed. Clarity needs to be achieved on the carbon tax. Provision needs to be made in any Waterberg infrastructure development for possible future CTL projects.

8.2 Concluding remarks

The South African Coal Roadmap presents an overview of the complex and uncertain world that the coal industry faces moving into the future, and the local and global drivers that will determine the direction in which the world is moving. While long-term planning under such uncertainty is challenging, the Roadmap identifies a number of short and medium term actions that need to be taken, decisions that need to be made and issues that need to be resolved, regardless of the future that evolves. Industry and the government need to urgently address these considerations to ensure a secure supply of energy for the country, and continued contribution to export revenues and employment.

At the same time, the industry needs to take cognisance of events which signal its long-term role in the country, and respond in such a way as to maximise its contribution to a flourishing South Africa.

Participants in the Roadmap process, including industry and government, would value the opportunity for engagement to resolve the challenges facing the coal industry moving into the future. Enquiries should be directed through the Fossil Fuel Foundation (www.fossilfuel.co.za) or the South African National Energy Development Institute – SANEDI (www.sanedi.org.za).