Emissions from coal-fired utilities in South Africa and neighbouring countries and potential for reduction

DR LESLEY SLOSS

IEA CLEAN COAL CENTRE

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IEA Clean Coal Centre
Apsley House
Third Floor
176 Upper Richmond Road
London SW15 2SH
United Kingdom

Telephone: +44(0)20 3905 3870

www.iea-coal.org

Preface

This report has been produced by IEA Clean Coal Centre and is based on a survey and analysis of published literature, and on information gathered in discussions with interested organisations and individuals. Their assistance is gratefully acknowledged. It should be understood that the views expressed in this report are our own, and are not necessarily shared by those who supplied the information, nor by our member countries.

IEA Clean Coal Centre is an organisation set up under the auspices of the International Energy Agency (IEA) which was itself founded in 1974 by member countries of the Organisation for Economic Co-operation and Development (OECD). The purpose of the IEA is to explore means by which countries interested in minimising their dependence on imported oil can co-operate. In the field of Research, Development and Demonstration over fifty individual projects have been established in partnership between member countries of the IEA.

IEA Clean Coal Centre began in 1975 and has contracting parties and sponsors from: Australia, Austria, China, the European Commission, Germany, India, Italy, Japan, Poland, Russia, South Africa, Thailand, the UK and the USA. The Service provides information and assessments on all aspects of coal from supply and transport, through markets and end-use technologies, to environmental issues and waste utilisation.

Abstract

This document is one of two papers which will be presented at a one-day workshop in South Africa for open discussion. The Workshop has been sponsored by the US State Department. A full, revised, document will be produced after the event which will include updates and comments from the event.

Acronyms and abbreviations

BAT	best available technique or technology
CEM	continuous emissions monitor
ESP	electrostatic precipitator
FF	fabric filter
FGC	flue gas conditioning
FGD	flue gas desulphurisation
GHG	greenhouse gas
GW	gigawatt
HFT	high frequency transformer
IPP	independent power producer
IRP	Integrated Resources Plan
kWh	kilowatt hour
LNB	low NOx burner
MW	megawatt
SACR	South African Coal Roadmap
SCR	selective catalytic reduction
UCG	underground coal gasification
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency

Contents

List of Figures

List of Tables

1 Introduction

South Africa, like many other emerging economies, is struggling to provide power and electricity for a growing population whilst controlling potentially harmful emissions to the environment. The major challenges for the country include:

- Providing reliable power to a growing population both in South African and surrounding African nations in the South African Power Pool.
- Providing reliable power in an affordable manner.
- Setting and applying emission standards which will reduce harmful environmental effects.
- Installing retro-fit control technologies to older plants with high demand whilst keeping down time as short as possible.
- Fitting control technologies which can achieve the required emissions reductions on high ash coals, which may be more challenging than coals used in developed regions.
- Fitting control technologies which can achieve the required emissions reductions using minimal water, a scarce resource in the region.
- Keeping costs for retrofits and compliance as low as possible so as to keep power affordable in the region.

This document is a draft position paper, based on a literature review, on the challenges faced by the African coal sector with respect to emissions and their potential reduction. This paper is complementary to the separate report by Colin Henderson, which looks more closely at the technologies in place and the potential for upgrading, focusing on systems and control technologies which may be most appropriate for the regional challenges, such as high-ash coals and low water availability. Both these reports will be presented for discussion at the US Department of State/IEA CCC joint workshop to be held in the Kruger Gate Hotel on the 28th February 2017. Feedback from open discussion at the workshop, including representatives from Eskom, DEAT and invited delegates from other nations, will be compiled to update this document into a final report. Tentative suggestions of the most appropriate BAT/BEP options for emissions reduction in Africa will be presented to stimulate discussion. This will include a comparison of legislation and reduction strategies from around the world and a discussion of lessons learned which may help in determining options most appropriate to the unique African situation. The iPOG (an interactive mercury emission calculation tool produced by the Coal Partnership) will be used to demonstrate the various options which may be most appropriate for mercury reduction from the African coal sector and an indication of how successful these options are likely to be at African coal fired utilities.

Funding from the US Department of State for this project work is gratefully acknowledged.

2 Power generation in South Africa

In 1994 only 36% of the country had access to electricity. By 2014, this figure had reached 84%, largely due to low cost electricity from coal. The coal industry employs around 83,000 people in South Africa, whilst the unemployment rate sits at 25% (Fisher, 2015).

South Africa has the challenge of a high capacity demand being placed upon an existing and aging coal fleet. Most of the plants have to run at full or high capacity to provide the energy demand of the country and the expanding African grid. Although two new coal plants are being built, they are currently subject to delays, increasing the pressure further on the existing units and making it difficult for these older units to come offline for repair, maintenance or upgrading and retrofitting. Although there is a concerted move towards renewable energy, these technologies are not yet ready to provide baseload capacity for such a large and growing nation.

The South African Integrated Resources Plan for Electricity (IRP) includes the suggestion that a further 6,250 MW of new coal plants will be required before 2030. Jeffrey and others (2014) believe this figure to be "totally inadequate" if the nation is to continue towards economic and industrial growth. The IRP also includes 9,600 MW of new nuclear capacity but, judging by continuing delays, these may not be online until 2029 at the earliest (Jeffrey and others, 2014). The country could require between 85 and 125 GW of power by 2040 (depending on the amount of renewable energy in the mix), an increase from 42 GW in 2010 (Fisher, 2014).

The Rockefeller foundation committed $10 million of funding to back a $177.5 million wind and solar power programme in Africa whilst announcing plans to cease investment in fossil fuels. The programme includes a scheme to build 1.3 GW of carbon-free generating capacity in Africa by 2018. The fund will finance the Lekela Power Company to invest in wind and solar projects in S Africa, Egypt, Ghana and Senegal. This will play an important part in the move towards realisation of US President Obama's "Power Africa" plan which aimed to add 30 GW of electricity to the continent by 2030. A spokesman for the programme stated that "wind power is about 50% cheaper than new coal capacity in South Africa" (FT, 2016). South Africa also uses a significant amount of coal for coal-to-liquid production, providing around 25% of the country's liquid fuel needs (Fisher, 2014).

As mentioned earlier, the South African coal fleet is currently running almost flat out to maintain supply. Although new power is needed to meet growing demand, there are continuing delays with new coal plants and new nuclear capacity may not be on-line until 2029. Eskom has a challenge to maintain output from existing units whilst at the same time is being required to take these very units offline for upgrading and retrofitting (Jeffrey and others, 2014). Fisher (2015) agreed that electricity supply is one of the country's biggest challenges. Rolling blackouts began in November 2014 with load shedding of up to 2000 MW being an imminent risk, although the situation may have calmed since. The grid constraints in the country are held to be at least partly responsible for the slowing in economic development in the country by 10%, around R300 billion (around $25 billion). This issue has led to a reduction in the economic forecast and the downgrading of the country's credit rating, having a negative impact on investment in much needed areas.

Electricity prices (unspecified but presumably wholesale) in South Africa more than trebled from R20c/kWh in 2003 to R70c/kWh in 2014. This is still relatively inexpensive when compared with the predicted electricity provision from Independent Power Producers (IPP) with a forecast average price of R212c/kWh. According to Jeffrey and others (2014) this is because of political decisions made during the 1990s which favoured IPPs over new build by Eskom – but the IPPs did not materialise. The power from the new Medupi plant is expected to cost R1.00/kWh and this may double within the next five years. Most municipalities charge 100% mark-up to cover new plants and new policy measures so that that domestic and business consumers now pay >R140c/kWh.

Jeffrey and others (2014) warned of a "coal cliff" before 2020 due to the shortfall of coal for coal-fired power generation, somewhere between 60-120 Mt/y. Eskom therefore needs 2 billion tonnes, half of its estimated requirements, from new sources over the next 40 years.

Eskom was reported to be facing funding shortfall of around Rand 237 billion (US$16.4 billion) to 2019 (Rowland, 2016).

To be discussed at the workshop:

- *how defined is the expansion of power generation capacity in S Africa? How much growth do we expect in the coal sector compared to other fuels and energy sources?*
- *To what extent do current national policy and economics hinder or help the potential for change?*
- *Biomass cofiring could reduce carbon and other emissions – is this a feasible and sustainable option for South Africa?*

3 The challenge of African coal quality

Coal supplies over 70% of the energy needs in South Africa, 90% of its electricity requirements and >95% of the metallurgical coal (coke) requirements. Jeffreys and others (2014) suggest that, although coal use may decline in the long run, coal use will remain significant in the country over the next three decades and that this is necessary to secure the nation's economy. Coal is South Africa's most profitable resource generating total (domestic and export) sales in excess of $9.3 billion (R100 billion).

South Africa is reported to have coal reserves sufficient to meet both domestic and export demand for over 200 years, with more reserves available from Botswana, Zimbabwe and Mozambique. Despite this, Jeffrey and others (2014) note that the country has no integrated coal policy and a lack of clear strategy for the future.

South African coals are now higher in ash and lower in grade than in the past as the best quality coals have already been mined. Current best quality coals (<15% ash) are either exported or sold at a premium in the domestic market. Coals used within the country are now 20–30% ash with 35–45% ash coals being burned in some of the newer coal-fired plants (Jeffrey and others, 2014).

According to Garnham and Langerman, 2016, five of the Eskom coal plants currently wash coal prior to combustion – Arnot, Duvha, Hendrina, Lethabo and Matimba. All coals must be beneficiated (cleaned) before they can be sold but lower grade coals can be used at some of the specifically designed Eskom plants.

Water scarcity is an issue for coal washing at some sites and so dry coal beneficiation processes are being investigated. Reports on water availability and policies for water use in the coal power sector have been produced by the CCC (Carpenter, 2015, 2016). Waste from beneficiation processes is accumulating at a rate of 60 Mt/y but processes are being studied for potential use of this material, for example in building and road materials.

Coals from South Africa are reported to be low in sulphur, mercury and chlorine. Jeffrey and others (2014) suggest that coal beneficiation to reduce SO_2 could be more effective than FGD installation, although this would depend on the chemical form of the sulphur and mercury in the coal.

To be discussed at the workshop:

- *Is coal cleaning a feasible (taking factors such as cost and residues handling into account) option for reducing emissions?*
- *Can coal cleaning be optimised to enhance plant efficiency and reduce emissions of pollutants other than just sulphur (such as mercury)?*

4 Emissions from coal utilities in South Africa

There is no official emissions inventory for South Africa. In fact, the Government's Department of the Environment and Agriculture states on its website (DEA, 2017): *"There is currently no current comprehensive national emissions inventory for non-greenhouse gas emissions. The absence of such an inventory represents a serious information gap, particularly given the shift from air pollution control focused on large industries to air quality management through the control of a wide range of diverse but significant source types."*

In the absence of any official data, there are a few sources of estimates for major pollutants. As the sole producer of the majority of the country's heat and power, it is unsurprising that Eskom is the largest emitter of particulates, SO_2 and NOx. Particulate emissions (PM_{10}) arise largely from mining activities, biomass burning, industrial and manufacturing and household burning, with less than 10% coming from power generation. For NOx and SO_2, however, power generation is by far the largest source. Power generation was responsible for just under 75% of the country's NOx emissions and just over 75% of the SO_2 emissions in 2012 in the Highveld area. However, Eskom report that the areas of non-compliance for ambient NOx levels in the Highveld region are areas which are not affected by Eskom plants (Patel, 2012).

Back in 2009, Leaner and others estimated mercury emissions in South Africa concluding that coal-fired power plants were by far the greatest source, producing over 30 t/y. The next largest source was the cement sector producing around 4 t/y.

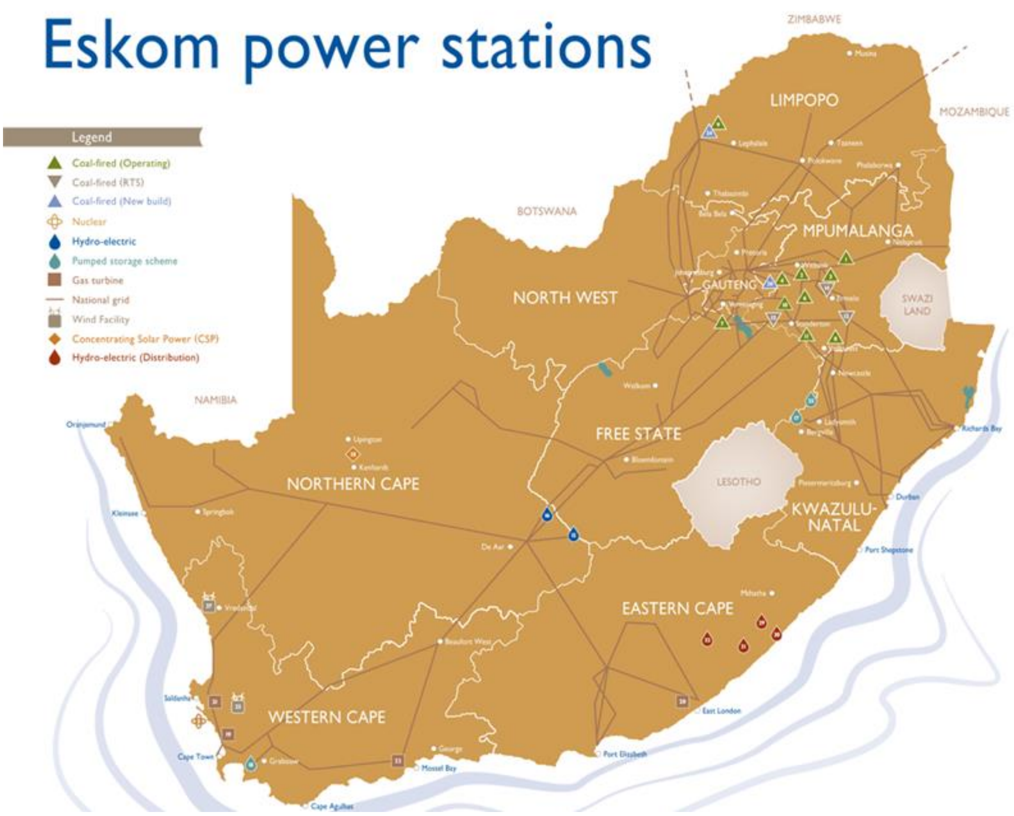

Figure 1 Eskom power stations in South Africa (UNEP, 2014)

It is important to note that the majority of the coal-fired power plants in South Africa are located close together in the Mpumalanga province, as shown by the green triangles in the map in Figure 1.

An article in the Guardian (2014) uses the image in Figure 2 to suggest that pollution from the Duvha Power Station in the background and the coal piles in front are causing local health effects. A spokesman from Eskom suggested: "*It is well established that the brunt of poor air quality in South Africa … are borne by people who burn coal and wood in their homes for cooking and heating. The best way of improving this poor air quality is through the provision of affordable electricity*." Another NGO, Groundwork (citation source TBC), produced a report suggesting that the outdoor air pollution in the Mpumalanga region associated with emissions from the Eskom plant were over three times those associated with burning coal indoors. Clearly there is a significant amount of disagreement on the extent to which power plants and domestic coal use contribute towards local health effects. However, in both situations, a coordinated approach to more efficient production of heat and power from coal and, ultimately, from cleaner alternatives, would be a potential solution.

Figure 2 Locals collecting waste coal from outside the Duhva Power Station for domestic use (Guardian, 2014)

The UNEP Coal Partnership produced a report on mercury emissions from selected Eskom coal-fired power plants (UNEP, 2014). Coals used across the Eskom fleet were sampled along with emissions from two full-scale plants – Duvha and Kendal. The study showed that mercury capture was greater in the plants with fabric filters (FF) than those with electrostatic precipitators (ESP) for particulate control. Mercury concentrations in the South African coals ranged from 120–463 ppb, similar to values cited in published literature. Average mercury emissions from the Duvha plant ranged from 4 μg/m^3 to 40 μg/m^3 but for the Kendal plant the range was much smaller, from 39 μg/m^3 to 49 μg/m^3. The fraction of oxidised mercury ranged from 54–89% at Duvha and 48–70% at Kendal. Since oxidised mercury is far easier to control than elemental mercury, this bodes well for up t0 80%, perhaps more, mercury control through co-benefit effects at plants which will be installing wet FGD systems. Mass balance studies demonstrated that the particulate control systems in units 2 and 3 at Duvha, (fabric filters) were already reducing mercury emissions by over 80% whereas the units fitted with ESP systems only demonstrated around 10-20% inherent mercury reduction. And so, whilst mercury emissions are being reduced by at least 10–20% at plants fitted with ESPs and up to 80% or more at plants fitted with FFs, there is potential for greater cost-effective mercury control through further co-benefit effects (discussed later). Further information on options for mercury control is available in a more detailed report from the CCC (Sloss, 2015)

To be discussed at the workshop:

- *Is there potential for quick and effective pollution control in Mpumalanga through the promotion of cleaner domestic fuel options?*
- *To what extent will the installation of control technologies in the Mpumalanga region be able to reduce ambient concentrations and related health effects?*

5 The existing fleet in South Africa

Eskom is the single, state-owned utility which provides South Africa and neighbouring countries with power. In 2014 there were 13 coal-fired power stations in operation, including three that were recommissioned after being mothballed. The plants run almost continually to produce the power needed. The capacity of the 13 stations totaled 37,745 MW and the total net output was 34,952 MW. These sub-critical plants run at around 34% efficiency. Two new supercritical plants, Medupi and Kusile, have a planned efficiency of 38% at least (Jeffrey and others, 2014). Medupi and Kusile should have been operational by now but, as of 2015, neither plant was expected to be running at full capacity before 2020 (Fisher, 2015). More up to date information on Medupi is provided in the complementary report by Colin Henderson.

Because of the delay in the new plants, many plants within the existing fleet are working beyond their predicted lifetimes and, since coming offline for upgrading and maintenance is often not possible due to demand, breakdowns and enforced outages are increasing 2040 (Fisher, 2015).

It is important to remember that coal-fired plants have a limited designed lifetime. Table 1 shows the expected decommissioning date of the existing Eskom fleet (Patel, 2012). Although some plants are relatively young and will continue operation for several decades, some of the older units (in red) are the oldest in the fleet and will therefore have to consider whether further investments in upgrading and emissions control are justifiable economically.

Table 1 Age of existing Eskom fleet (Patel, 2012)

Station name	Decommissioning date: 50-year life; current plan
Kusile	Not running yet
Medupi	Not running yet
Majuba	2046-2051
Kendal	2048-2053
Matimba	2047-2051
Lethabo	2045-2050
Tutuka	2045-2050
Duvha	2040-2044
Matla	2039-2043
Kriel	2036-2039
Arnot	2031-2039
Hendrina	2030-2036
Grootvlei	2021-2023
Camden	2025-2028
Komati	2024-2028

A separate new Majuba plant has been designed based on underground coal gasification (UCG) technology. This involves gasification of coal underground and then removal of the gas to burn topside in a gas combustion system or for use for chemical production (Couch, 2009). The Majuba plant aimed to use gas from the UCG system to feed into the existing coal-fired plant at the Majuba site. The UCG system is reported to be inherently cleaner than standard coal combustion, since the majority of ash and incombustible material is left underground. However, UCG has yet to be fully commercialized. Although the Majuba UCG plant has the potential for clean combustion of coal gases and reduced emissions of most pollutants, the plant was hindered in the approval process and is currently not operational. A separate company, Africary, is working on potential further UCG projects in South Africa (updates to be presented at the workshop).

To be discussed at the workshop:

- *To what extent is the age of the current fleet hindering investment in upgrades?*
- *Is there an argument for reducing the lifetime of some plants to allow replacement by more efficient or renewable technologies and is this affordable?*
- *Do renewables offer sufficient baseload and grid stability for a growing economy such as South Africa*
- *Although the Majuba UCG plant has effectively been mothballed, further UCG plants are planned by private industry – what potential is there for this to produce cleaner energy from coal in S Africa and neighbouring regions?*

6 Policy and emission limits

South Africa has recently set emission standards for emissions from its coal fleet and has also made a long term plan for energy production in the country.

6.1 Emission limits

Emission limits have been set in the country (Government Gazette, 2010), shown in Table 2, which are less stringent than limits in the EU, USA and China.

Table 2 South African emission limits for coal and biomass units >50 MW (at 10% O_2)

Pollutant	Plant status	Emission limit, mg/m³
Particulate matter	New	50
	Existing	100
SO_2	New	500
	Existing	3500
NOx	New	750
	Existing	1100

A 'new plant standard' applies to all plants applying for authorisation after 1 April 2010, while existing plants had until 1 April 2015 to comply with the 'existing plant standard' and have until 1 April 2020 to meet the new plant standards. Within the standards, existing plants mean any plant or process that has been legally authorised to operate before 1 April 2010, or any plant where an application for authorisation was made before 1 April 2010.

In the past. Eskom emissions of particulates were monitored in real-time with continuous monitoring systems (CEMS) whilst SO_2 and NOx emissions were based on emission factors. The company planned to have CEMs on all stations for SO_2 and NOx by the end of 2014.

Table 3 shows the compliance of the existing fleet with emission standards in 2012 (Patel, 2012; *it is hoped that this information can be updated during the workshop*). For particulate controls, most of the plants are in compliance with a few requiring modification and retrofitting. Since low grade coal is burned at most plants, ESP upgrading is not the best option. Fabric filter retrofits are therefore the most viable option. Eskom has created a rolling plan for retrofitting over the 2013 to 2025 timeline to ensure that the number of units offline for retrofitting has the minimum effect on power output to the grid (Patel, 2012). For SO_2 control, FGD is being installed on some plants but alternative approaches, such as sorbents and the ReACT™ system, are also being considered (Patel, 2012). For NOx reduction, Eskom is focusing on prioritising NOx control at the highest emitting stations first (Tutuka, Majuba, Kriel and Matla) with other plants to follow. The status of pollution control system installation is discussed in Chapter 7.

Table 3 Compliance status of the Eskom fleet with existing and new plant standards (Patel, 2012)

Station type	Station sub-type	Station name	Current compliance with existing plant standards			Current compliance with new plant standards		
			PM	NOx	SO_2	PM	NOx	SO_2
Coal-fired power stations	New build	Kusile	✓	✓	✓	✓	✓	✓
		Medupi	✓	✓	✓	✓	✓	No but will comply 6 years after commissioning
		Majuba	✓	X	✓	✓	X	X
		Kendal	✓	✓	✓	X	✓	X
		Matimba	✓	✓	✓	X	✓	X
		Lethabo	✓	✓	✓	X	X	X
		Tutuka	X	X	✓	X	X	X
		Duvha U1-3	✓	✓	✓	✓	X	X
		Duvha U4-6	✓	✓	✓	X	X	X
		Matla	X	X	✓	X	X	X
		Kriel	X	X	✓	X	X	X
		Arnot	✓	✓	✓	✓	X	X
		Hendrina	✓	✓	✓	✓	X	X
	Return-to-service stations	Grootviel	X	✓	✓	X	X	X
		Camden	✓	✓	✓	X	X	X
		Komati	✓	X	✓	X	X	X

South Africa has recently established requirements for control technologies to reduce acid gas (SO_2 and NOx) emissions from coal-fired power plants. However, due to financial and technical constraints, many of the coal plants are applying for or have already been granted delays and derogations. This also means that, for the moment, the country is achieving minimal co-benefit reduction of trace emissions, such as mercury, which can be reduced significantly in such systems.

Many plants have had to derogate to 2020. These derogations are due to a number of factors including challenging coals, water availability, cost, time for retrofitting and so on. However, in December 2013, Eskom applied to the DEA (Department of the Environment and Agriculture) for rolling postponements to comply with the minimum standards*. The utility argued, among other things, that the benefits of compliance did not justify the R200bn ($18.6bn) cost of retrofitting its plants with the necessary filters and technologies and the need for plant downtime while they were installed (Guardian, 2014).*

South Africa signed the UN Minamata Convention on Mercury in 2013 and it is expected that the convention will be ratified within the next year. The current proposed draft of the BAT (best available technology) for mercury control at stationary sources is not prescriptive and therefore the country will be required to propose a national plan, including an indication for potential control options for coal-fired utilities, to be considered. The mercury issue is discussed in more detail in Chapter 8.

With regard to greenhouse gas (GHG) emissions and climate change, South Africa has almost exclusively dealt with the issue through policies, strategies and regulations rather than legislation. The focus has been in developing market-based mitigation mechanisms and promoting renewable energy and energy efficiency. The only legislation on this issue was a carbon tax introduced in 2012, with expected implementation in 2016. South Africa has pledged to reduce its GHG emissions by 34% by 2020 and by 42% by 2025 compared to a business as usual scenario (Nalbandian-Sugden, 2016).

6.2 Long term energy policy

The South African government has been working towards a long term plan for energy production in the country. The South African Coal Roadmap (SACR) was developed in 2013, based around 4 scenarios, as shown in Figure 3.

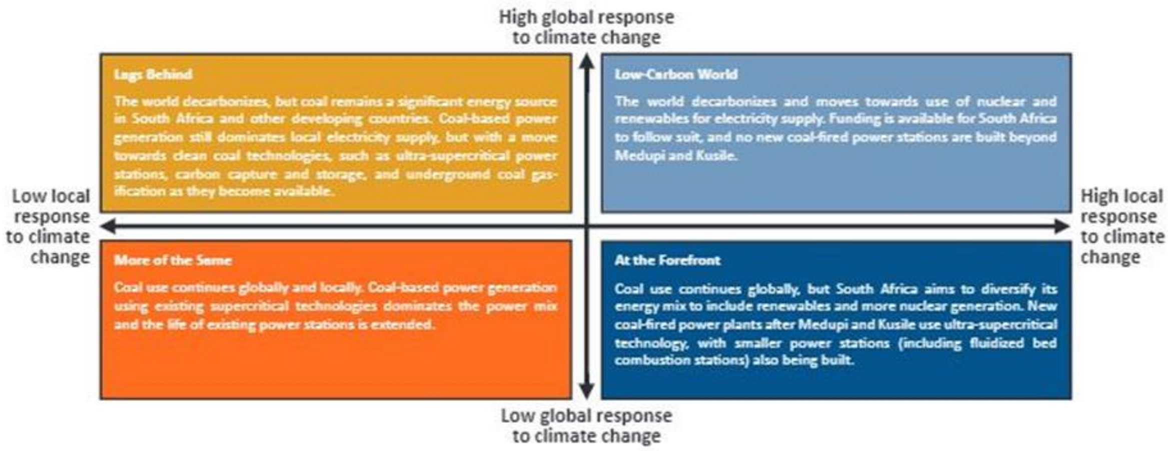

Figure 3 The four scenarios used as a framework for the SACR (Fisher, 2014)

The figure shows the different ways the South African coal sector will change depending on the local and global responses to climate change. In the low response scenarios, the country will continue with little or no change. If the country does choose to lead with climate change issues, it will do so by moving away from coal towards nuclear and renewables. The most positive approach, where the global and local political wills both work towards a low carbon economy, the country is likely to rely heavily on funding to make the changes required. The SACR diagram implies that South Africa could move away from coal but in order to do so would require an increased move towards renewables and nuclear and that any significant change will require international funding and support.

The SACR lists several recommendations to ensure security of supply, delivery and pricing for coal in the country in the future. The Integrated Resource Plan for Electricity 2010-2030 (IRP) includes 9 GW of nuclear by 2023. However, this is unlikely (Fisher, 2015). 1700 MW of renewable energy is now on the grid. Investment is required to achieve more – infrastructure simply to maintain the “more of the same” scenario in Figure 3 is almost R930 billion and the bill would increase to R2060 billion for the “low-carbon world” (Fisher, 2015).

There are no suitable basins for underground storage of CO_2 in South Africa and so any carbon capture would have to consider either local use (limited or non-existent) or long-range transport (Jeffrey and others, 2014).

Topics to be discussed at the workshop:

- In light of the financial, technical and logistical challenges being faced, what are the most appropriate ways South Africa could move forward with emissions control?
- Are there any short term fixes which could ease some of the pressures of compliance?
- What priority should be given to meeting international concerns regarding climate change?

7 Current status of emissions control

As mentioned in the previous chapters, new legislation means that control technologies are required on many of the Eskom plants in order to reduce emissions. Current control technologies on the existing Eskom fleet are summarised in Table 4 (Garnham and Langerman, 2016).

Table 4 Current control technologies on the existing Eskom fleet (Garnham and Langerman, 2016)

Power station	Particulate control		SO_2 control	
	Existing	Planned	Existing	Planned
Arnot	FF	No change	None	None
Camden	FF	No change	None	None
Duvha	FF, ESP and FGC	HFT on ESPs	None	None
Grootvlei	FF, ESP and FGC	All units to FF	None	None
Hendrina	FF	None	None	None
Kendal	ESP and FGC	HFT on ESPs	None	None
Komati	ESP and FGC	None	None	None
Kriel	ESP and FGC	FF retrofit	None	None
Kusile	FF	None	Wet FGD	None
Lethabo	ESP and FGC	HFT upgrade	None	None
Majuba	FF	None	None	None
Matimba	ESP and FGC	HFT upgrade	None	None
Matla	ESP and FGC	HFT upgrade	None	None
Medupi	FF	None	None	Wet FGD
Tutuka	ESP	FF retrofit	None	None

FF fabric filter/baghouse FGC flue gas conditioning (to enhance ESP performance)
ESP electrostatic precipitator HFT high frequency transformer
LNB low-NOx burner

At the moment, the majority of plants are fitted with ESP and many also have flue gas conditioning for high ash coals to enhance particulate capture. Some plants are being retrofitted to add FF or up upgrade the high frequency transformers which control the ESPs. The new six-unit supercritical Kusile station will have FGD installed from the start. The first of the 800 MW units are expected to come on line this year (2017).

FGD systems will also now be added at Medupi (shown in Figure 4) – another new six x 800 MW supercritical plant that is gradually commissioning and expected to be fully on-line by 2022. The 4790 MW plant will be the biggest dry-cooled power station in the world, demonstrating a state-of-the art water recycling system, of significant importance in water-restricted regions (Robb, 2017).

Figure 4 Medupi -Eskom's Supercritical, dry-cooled plant (Robb, 2017)

As mentioned in the complementary report by Colin Henderson, South African coals have mid-range sulphur contents which can be controlled by standard sulphur control systems including wet FGD and other systems – the challenge is not so much the coal as the water availability and cost. Dry FGD systems may be more appropriate for the South African situation but these require more expensive sorbents and create new waste disposal costs. More advanced dry sorbent and regenerable systems may be ideal for South African plants but would need to be proven at demonstration stage to be able to cope with South African coals (high ash) and would be significantly more expensive than standard sulphur-control systems, although they would provide simultaneous multi-pollutant control (including fine particulates and mercury). For NOx control, low NOx burners should prove adequate at most South African plants. This would, however, remove any co-benefit mercury control that could have been achieved through the installation of SCR systems for NOx control.

Garnham and Langerman (2016) have estimated mercury emissions from the Eskom coal fleet based on recorded volumes of coal burned at each plant and annual contents of mercury measured in these coals. Mercury contents ranged from 0.17 (at the Arnot plant) to 0.38 ppm (at the Matimba plant), although it was recognized that these values could vary at each plant. Emission reduction factors were also used to take into account mercury capture in existing control systems. Emission reduction factors produced by the US EPA in 2013 differ somewhat from those used by UNEP in their 2015 emission estimation toolkit and so both factors were used and the results compared.

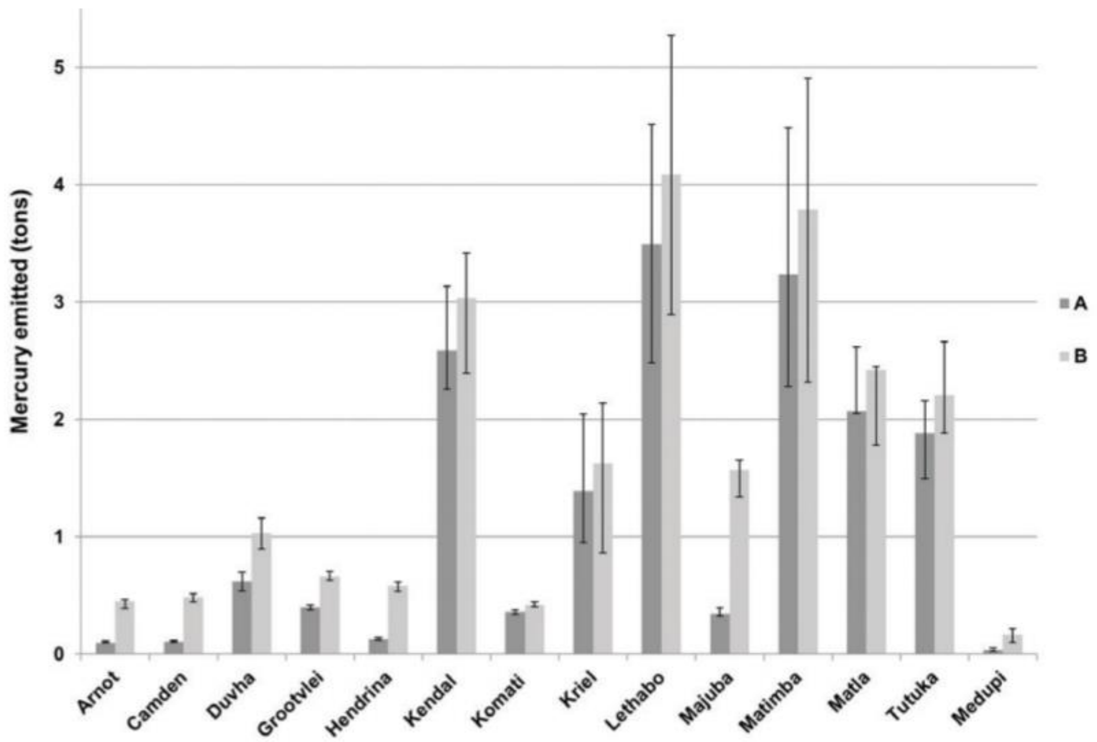

Figure 5 **The mercury emitted per power station in 2015 estimated using both the US EPA and UNEP calculation methods (Garnham and Langerman, 2016)**

From the graph in Figure 5 it is clear that the US EPA and UNEP calculations give similar results in terms of which power plants are responsible for the greatest emissions. Currently Kendal, Lethabo and Matimba emit the greatest quantities of mercury to air and would therefore be most appropriate for the consideration of reduction activities. Matimba and Lethabo together contribute 38% of the total mercury emissions from the Eskom fleet in 2015. As Garnham and Langerman stress in their paper, further emission monitoring at these plants would help to determine the most accurate, plant specific emission factors.

Garnham and Langerman also considered the mercury emissions per energy unit of the plants studied. The results from this analysis emphasise that on an energy basis, Kendal is actually not as polluting as Figure 5 suggests. Instead, Lethabo and Matimba are producing more mercury on a per-energy-output basis. Again, this suggests that mercury control strategies at these plants could provide the most economic and effective means of emissions reduction.

Garnham and Langerman then went on to project potential annual emissions of mercury from the total Eskom fleet between 2016/17 and 2025/26, using both the US EPA and UNEP calculations, as shown in Figure 6.

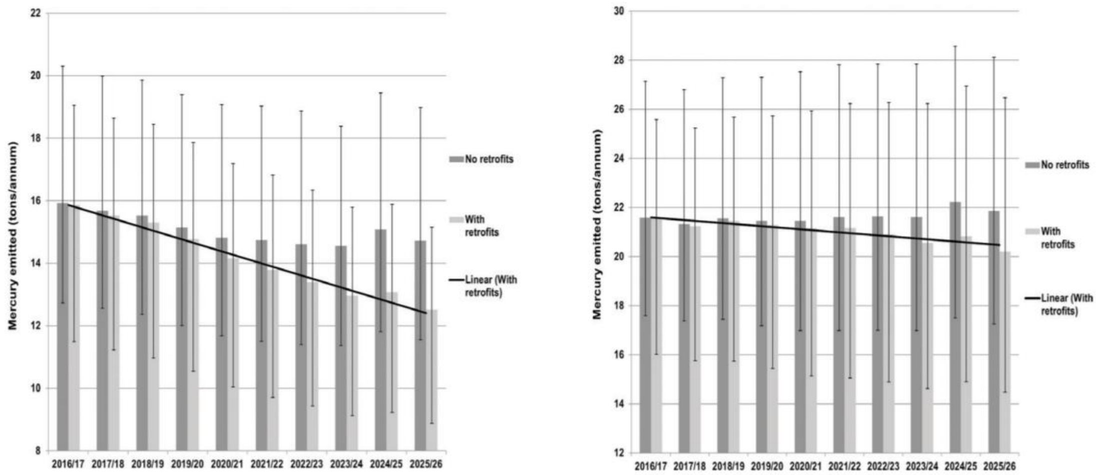

Figure 6 Projected annual mercury emissions from 2016/17 to 2025/26 assuming no retrofits and the implementation of Eskom's emission reduction plan, based on US EPA (left) and UNEP (right) calculations (Garnham and Langerman, 2016)

Mercury emissions are expected to decline from the Eskom fleet over the next decade, based on the current activities Eskom has underway. These include the upgrading of particulate control systems at several plants and installation of FGD systems on the currently commissioning Medupi, as shown in Table X. However, the estimate based on the US EPA calculations (Figure 1) shows a more pronounced reduction in emissions than that based on the UNEP factors (Figure 2). This is because the reduction factors provided by the US EPA show much greater mercury reduction in pollution control systems than those provided by UNEP, especially for FF (89% vs 50% respectively) and ESPs (36% vs 25% respectively). For the moment, without a mass balance across these plants, it is not possible to determine whether the US EPA or UNEP values are most suitable for Eskom plants. Production of plant specific emission and reduction factors for S African coals and plants would go a long way to determining expected reductions in emissions and could even highlight the most effective routes to enhance these reductions.

In their conclusions, Garnham and Langerman (2016) raise three important issues:

- The need for emission reduction, focusing on priority pollutants and maximising co-benefit mercury reduction and
- The cost of control technologies and the resulting impact on the national economy whilst ensuring electricity demands are met; and
- The age/life-expectancy of the plants, which ties in with cost and economic feasibility. "Implementing costly technology on an old power station is not necessarily sustainable".

Garnham and Langerman (2016) propose a cap on mercury emissions from the Eskom coal fleet rather than a specific limit for individual plants, arguing that this would allow for economic feasibility and flexibility to ensure that the maximum amount of reduction is achieved in a sensible and economic manner.

Topics for discussion at the workshop:

- *With water in limited supply and power in high demand, how can the country build emissions reduction into an already challenging energy situation?*
- *Are there any emerging multi-pollutant systems which may become available that would be suitable for demonstration in South Africa?*
- *Considering issues with high ash, low water availability, aging plants, high capacity demand and so on, can South Africa build mercury control into existing activities in a cost effective manner?*

8 Other African countries

Currently coal production in South Africa accounts for 94.6% of coal production in Africa (Rowland, 2016). The South African coal sector growth is expected to be limited due to high production and logistics costs. However, neighbouring countries have an untapped export potential. For example, in **Mozambique**, if the expected investment is carried out, coal production capacity is forecast to increase from 10 Mt/y, at present, to more than 50 Mt/y by the early part of the next decade (Nalbandian-Sugden, 2016). India is reportedly investing in development of Mozambique's metallurgical coal. Mozambique produces hydro-electric power and, having no fossil fuel plants of its own, obtains much of its power from the South African Power Pool and therefore is currently facing period of insufficient power. Chinese investors, Shanghai Electric Power, signed a joint development agreement with Ncondezi Energy to build a 300 MW coal-fired plant in the Tete Province providing US$25.5 million for a 60% stake in the project. The project, which includes a coal mine development in the same location, intends to develop the power plant in 30O MW phases until it reaches 1800 MW (Rowland, 2016).

Edenville Energy is advancing plans for the Rukwa coal-to-power project in southeast **Tanzania** which will include a coal washing plant. The project is a phased scale up of the feasibility study created for the proposed Lahmeyer 300 MW plant in 2014 (Edenville, 2017). Kibo Mining is also completing a feasibility study of a 250–300 MW Mbeya coal-to-power project., previously also called the Rukwa Project. This interest in coal-to-power projects in Tanzania is a result of the call from the Tanzanian government for new sources of power to support the country's rapid growth. At the moment, the development work appears to be concentrating on the evaluation of the coal reserves in the area (Kino, 2017). No information could be found on the type of combustion systems (subcritical or supercritical) being proposed for these projects. However, since Tanzania currently has no emission limits for coal-fired plants it is possible that subcritical plants with limited flue gas control could be approved.

Coal-fired power capacity in **Botswana** currently sits at around 130 MW across four small units. The Government of Botswana announced in December 2015 that is was seeking independent power producers to develop with fifth and sixth units of the Morupole Power Plant, a local of 300 MW of new capacity. Shumba Energy, an independent power producer is already developing two coal-fired plants in the country – the 600 MW Mabesekwa Export Independent Power Plant and the 300 MW Sechaba Coal Independent Power Plant. Funding for these new plants is still being sought. Once completed, the plants will feed power into both the Botswana national grid and the South African grid (Rowland, 2016).

Zambia has a 300 MW mine mouth coal plants and **Namibia** has 4x30 MW coal-fired units with a 2 x 150 MW circulating fluidised bed plant planned.

Botswana and Zambia are accession signatories of the Minamata Convention. Further information on the prospects for coal production in Botswana, Mozambique, Zambia, Zimbabwe and Namibia can be found in a previous report from the CCC (Baruya and Kessels, 2013).

Topics for discussion at the workshop:

- Is there any form of cooperation between African nations to ensure a coordinated approach towards energy production and emissions control?

9 Conclusion

The conclusion of this report will be produced following the Kruger workshop once comments, suggestions and corrections have been collated.

10 References

Baruya P, Kessels J (2013) *Coal prospects in Botswana, Mozambique, Zambia, Zimbabwe and Namibia.* CCC/228. London, UK, IEA Clean Coal Centre, 80 pp (Dec 2013)

Carpenter A M (2015) *Water availability and policies for the coal power sector.* CCC/256. London, UK, IEA Clean Coal Centre, 102 pp (Aug 2015)

Carpenter A M (2016) *Potential water sources for coal-fired power plants.* CCCC/266. London, UK, IEA Clean Coal Centre, 97 pp (Jun 2016)

Couch G (2009) *Underground coal gasification.* CCC/151. London, UK, IEA Clean Coal Centre, 129 pp (Jul 2009)

DEA, Department of the Environment and Agriculture, South African Government (2017)

http://soer.deat.gov.za/258.html (Feb 2017)

Edenville Energy (2017) http://www.edenville-energy.com/ (2017)

Fisher N (2015) South Africa's road to growth is paved with coal. *Cornerstone;* 3 (2); 12-16 (2015)

FT, Financial Times (2016) Rockefeller fund backs renewables. *Financial Times,* (Jul 28th, 2016)

Garnham B L, Langerman K E (2016) Mercury emissions from South Africa's coal-fired power stations. *Clean Air Journal:* **26 (2);** 14-20 (2016) http://www.cleanairjournal.org.za/download/caj_vol26_no2_2016_p14.pdf

Government Gazette (2010) Republic of South Africa, Government Gazette No. 3306431, March 2010, Pretoria, Vol. 537. *Available from:* https://www.environment.co.za/documents/legislation/SA-national-list-activities-associated-emmissions-environmental-south-africa.pdf

Guardian (2014) South Africa's coal-fired power stations carry heavy health costs. *The Guardian,* 1 pp (Sep 9 2014)

Jeffrey R, Falcon R, Kinghorn A (2014) The benefits and challenges associated with coal in South Africa. *Cornerstone;* 2 (3); 66-70 (2014)

Kibo (2017) http://kibomining.com/ (2017) A perspective on South African coal fired power station emissions. *Journal of Energy, South Africa;* 26 (3) 11pp (Aug 2015)

Leaner J J, Dabrowski JM, Mason RP, Resane T, Richardson M, Ginster M, Gericke G, Peterson CR, Masekoameng E, AshtonP J, Murray K (2009) *Mercury Emissions from Point Sources in South Africa*. In: Spinger Science Business Media, LLC (2009)

Mills S (2010) *Coal use in the new economies of China, India and South Africa.* CCC/161. London, UK, IEA Clean Coal Centre, 45 pp (Jan 2010)

Nalbandian-Sugden (2016) *New regulatory trends: effects on coal-fired power plants and coal demand.* CCC/262. London, UK, IEA Clean Coal Centre, 116 pp (Dec 2015)

Patel E M (2012) Practical considerations in the implementations of emissions reduction solutions at Eskom's coal fired power plant. http://www.energy.gov.za/files/4thEUSouthAfricaCleanCoalWorkingGroup/Practical%20Considerations%20in%20the%20Implementation%20of%20Emissions%20Reduction%20Solutions%20in%20SA%20Coal%20Fired%20Power%20Plant%20Final.pdf 33 pp (Nov 2012)

Pretorius I, Piketh S, Burger R, Neomagus (2015) http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-447X2015000300004

Robb D (2017) Conserving water at the world's largest air-cooled coal plant. Power Engineering Mag, 2 pp http://www.powerengineeringint.com/articles/print/volume-24/issue-3/features/conserving-water-at-the-world-s-largest-air-cooled-coal-plant.html?cmpid=enl_PEI_PEIDigest_2016-12-29 (Jan 2017)

Rowland J (2016) The good, the bad and the ugly. *World Coal;* 25 (2); 11-14 (Feb 2016)

Sloss L L (2015) *The emerging market for mercury control.* CCC/245. London, UK, IEA Clean Coal Centre, 75 pp (Feb 2015)

UNEP (2014) *Collaborative studies for mercury characterisation in coal and coal combustion products, Republic of South Africa.* Geneva, Switzerland, United Nations Environment Programme, Coal Partnership. 47 pp (Jan 2014)