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Eskom Presentation to the Portfolio Committee on Mineral Resources and Energy

Clean Coal Technologies

Date: 09 March 2021

Context

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Key elements

Plant

- Eskom's generation mix consists of 87 % coal-fired power stations with a nominal capacity of approximately 39 gigawatt with over 90 % of Eskom's electricity being generated from fossil fuels;
- The generation of electricity utilizing fossil fuels has an adverse effect on local levels of pollutants and contributes to increasing the levels of greenhouse gases in the atmosphere;
- Primary energy costs contribute approximately 60 % of Eskom's operating expenses which is predominantly related to coal costs. Any improvement in plant efficiency would reduce coal utilized and therefore have a positive financial benefit.

Legislation

- National environmental requirements such as the National Environmental Managements Air Quality Act are requiring fossil-fired power plans to meet increasingly more stringent emissions requirements;
- International environmental requirements such as the Paris Agreement on climate change requires to reduce Greenhouse Gas (GHG) emissions up to 42 % by 2025;
- The Carbon Tax Bill states that any entity that conducts an activity which results in GHG emissions above the allowed threshold will have to pay a carbon tax;
- Water management strategies are formalised in the Environmental Management Policy (more specifically its Water Management Policy).

Impact

- Installation of additional abatement technologies have an impact on power station output as well as requires additional capital, operating and maintenance costs
- Non-compliance with required legislation would result in reduced output at power stations or complete shutdown of units
- Full compliance to the Minimum Emissions Standard (MES) would cost Eskom more than 300 billion Rand
- Primary energy costs escalating at rate far in excess of inflation

Clean Coal Technologies Research Portfolio

Mandate

To research and/or develop technology options that assist Eskom to implement solutions that have a positive environmental impact and/or improved cost efficiencies.

Control of Oxides of Sulphur and Nitrogen (SOx and NOx), Mercury (Hg) and Particulates

- Continuous Assessment of Developments in Emission Control Technologies
- Techno-Economic Evaluation of the Production of Sulphuric Acid utilising Multi-pollutant Emission Control Technologies
- Circulating Fluidised Bed Flue Gas Desulphurisation (CFB FGD) Demonstration Plant at Kendal Power Station
- Dual Flue Gas Conditioning Demonstration
- Source Testing Association Membership

Carbon Abatement

- Carbon Capture, Transportation, Utilisation and Storage:
  - South African Centre for Carbon Capture and Storage (SACCCS)
  - National Carbon Capture Pilot Plant (CCPP) at Kusile Power Station
  - Pilot Carbon Dioxide Storage Project (PCSP)
  - South African Bureau of Standards Technical Committee (SABS TC) 265 participant: Carbon Capture, Storage and Transportation
- Fuel Substitution
  - Torrefied Biomass Co-firing at Arnot Power Station
  - Biomass Action Plan for Electricity Generation in South Africa (BAPEPSA)
  - International Energy Agency's (IEA) Bioenergy task 32: Biomass Combustion and Co-firing Membership

Plant Performance Optimisation

- Low Fuel Ignitors: Plasma and Mini Oil Gun Technologies
- Materials &Technologies for Performance Improvement of Cooling Systems (MATChING)
- Capture of Evaporated Water with Novel Membranes (CapWa-Pro)
- Planning Committee of The 7th Conference on Industrial Fluidization, South Africa
- IEA Clean Coal Centre (CCC) Membership

Control of SOx, NOx, Mercury and Particulates

Developments in Emission Control Technologies for Power Sector and Industrial Processes

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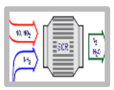
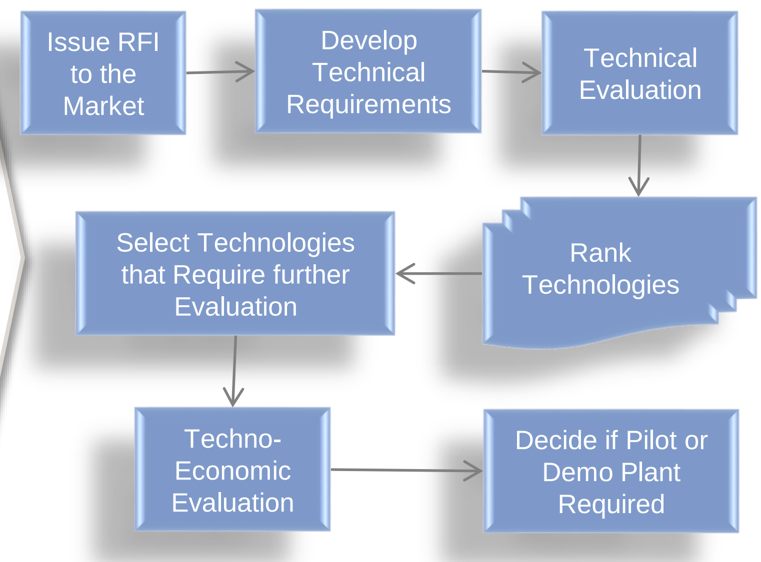
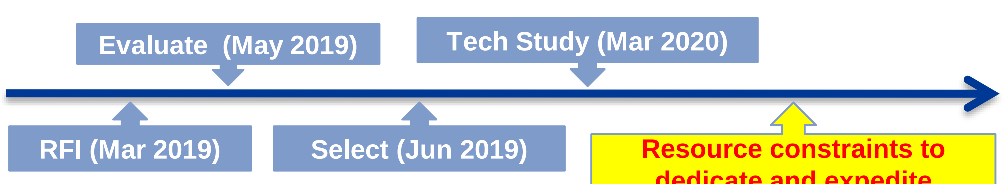
Technology Description

#	Technologies		Details
1		SOx	• Wet, semi-dry and dry FGD technologies, dry sorbent injection • Waste and by-product stabilization
2		NOx	• Low NOx burners, selective/non-selective catalytic reduction (SCR, SNCR)
3		Mercury	• Quantification of source emissions • Activated carbon • Pre-combustion additives
4		Particulates	• Fabric filter plant (FFP), electrostatic participators (ESP), High Frequency Transformers, Dual Conditioning
5		Multi-pollutant	• Techno-economic evaluation of the production of sulphuric acid utilising multi-pollutant emission control technologies

Technology Evaluation



Technology Timeline

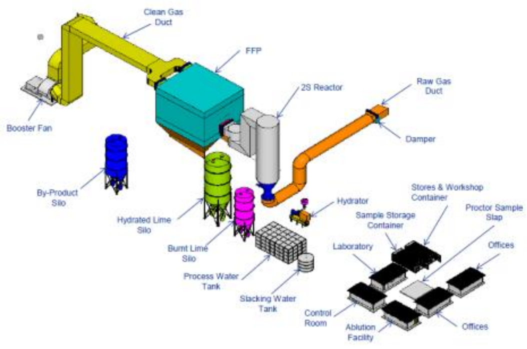


Maturity

- Technologies range from commercially available to demonstrated and bench scale
- Commercially available normally does not require demonstration

Control of SOx and NOx, Mercury and Particulates
CFB FGD Demonstration Plant at Kendal Power Station

Technology Description



Post combustion technology that utilses fluidisation technology to capture SO_2. The fluidised bed reactor is located downstream of the air pre-heater before a particulate control device. Flue gas containing SO_2 and fly ash enters the reactor and accelerates through a venturi into a fluidized bed.

The fluidized medium consists of hydrated lime, ash and recycled by-product. Water is injected separately into the absorber to humidify the flue gas and further facilitate the reactions. The hydrated lime converts SO_2 and SO_3 in the flue gas to $CaSO_4$ and $CaSO_3$. Upon exiting the reactor the flue gas is passed through an FFP to remove the combined mixture of by-products (unreacted hydrated lime, calcium carbonate and fly ash).
The FFP provides additional reaction residence time on the filter cake of bags to improve SO_2 capture. A fraction of the by-product/ are recirculated back into the reactor to reuse the unreacted hydrated lime and maintain the required fluidisation medium.

Technology Benefits

Low Water Use	A semi-dry technology operates with reduced water consumption of up to 30 % less than conventional wet FGD.
Operational Flexibility	Capable of handling ranging variation of sulphur in fuel making it more flexible than other technologies.
Multi-pollutant Control Capability	Co-benefit of capturing other acid gases and mercury - supports future air quality control requirements.
Low CAPEX	CFB FGD retrofit is a cost effective and feasible solution for Eskom. The design of the CFB FGD can be optimised to realise major cost saving which will make the technology more competitive.
Range of Lime Quality	Capable of utilisating low quality sorbent in scrubbing process hence reducing OPEX; Demo plant will provide insight on the range of lime quality that can be utilised.

Technology Timeline

- CRA (Nov 2018)
- DRA (Dec 2019)
- ERA (Apr 2020)
- Demo Plant (June 2021)
- On-hold – awaiting DEFF

Maturity

- Currently single train flue gas cleaning units of large capacity power plants are commercially available with operating reference on coal–fired power plants of over 420 MWe
- Reference plants treat 3 500 000 m^3/h flue gas (proposed retrofit would treat 4 700 000 m^3/h)

Control of SOx and NOx, Mercury and Particulates

Dual Flue Gas Conditioning Demonstration

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Technology Description

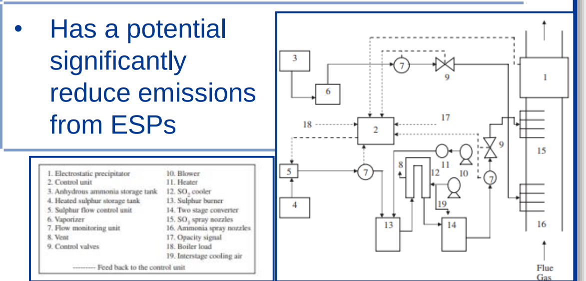
With the MES requiring a maximum emissions of 50 mg/Nm^3, a number of Eskom coal-fired stations will have to undergo a series of upgrades. ESP's on certain plants are incapable of meeting the MES. The options to improve ESP performance include upgrade of ESPs, addition of FGC and installation of HFTs failing which the ESPs will have to be retrofitted with FFPs. Dual FGC was identified as a technology that can significantly improve ESP performance incurring lower capital expenditure.

Dual FGC is the addition of two chemical additives into the flue gas to enhance particulate capture in an ESP. This demonstration is specifically considering the use of ammonia and SO_3, simultaneously. The efficient operation of an ESP depends largely on the resistivity of the ash. SO_3 conditioning helps to reduce the resistivity of the fly ash by creating a sulphuric acid film on the surface of the ash, whereas ammonia conditioning helps to improve the surface charge hence enhancing the particle agglomeration and cohesiveness minimizing the re-entrainment of particles into the flue gas.

The dual conditioning skid is designed in a semi-mobile configuration, enabling application on multiple sites. The skid will inject SO_3 and ammonia at rates equivalent to 25 and 20 ppm respectively, on units ranging from 400-670 MWe. The skid will run continuously for 3 months.

Technology Benefits

CAPEX	• Significantly lower CAPEX than having to retrofit an ESP with and FFP.
Outage Duration	• Eliminates the need for a lengthy outage required for an FFP retrofit. • Installation of the Dual FGC only requires a short opportunity outage to install.
Roll-out Period	• Full station rollout can be done in a relative short period and is not dependant on General Overhaul to install.
Enhanced ESP Performance	• Has a potential significantly reduce emissions from ESPs



Technology Timeline

- DRA (2017)
- Installation (Aug 2020)
- CRA (2016)
- ERA (Apr 2018)
- Current Optimisation at Tutuka U6

Maturity

- The technology is commercially available, however the expected emissions reduction gains can not be accurately predicted without physical testing

Carbon Abatement
Carbon Capture, Transport, Utilization and Storage

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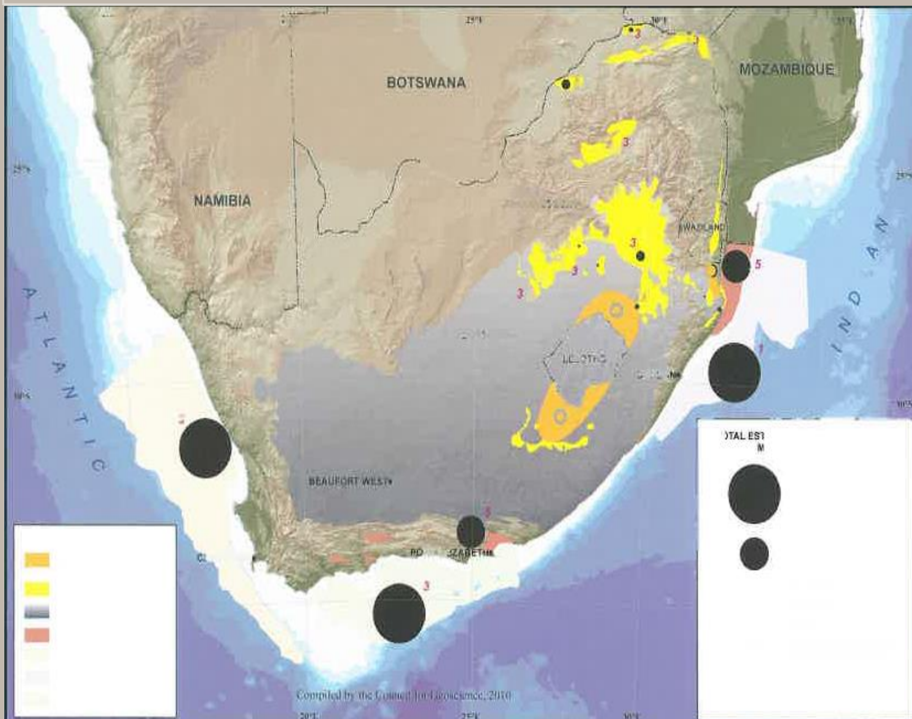
Technology Landscape



Technology Status

- The pre-requisite for carbon capture is either utilisation of storage, as Eskom Eskom has participated at a national level with the South African Centre for Carbon Capture and Storage (SACCCS) has been investigating the technical feasibility of CCS in South Africa, since its inception in 2009.
- SACCCS' milestone of the PCSP involves the injection, storage and monitoring of 10 000-50 000 t CO_2 with the aims of demonstrating CO_2 handling, injection, storage and monitoring in South African geology. The Zululand Basin in KZN and the Algoa Basin in the Eastern Cape are possible areas.
- Eskom has conducted techno-economics of the capture technology through the EC 7th Framework Programme.
- Referring to the CO2 storage landscape in the map beside, the predominant source of CO2 is inland and major storage options are either off-shore or coastal, hence the transportation pipeline cost of between 2-6 USD/tCO_2/250 km (IEA 2020), is highly cost prohibitive.

South African Centre for carbon capture & storage

2004
Assessment of the potential for CCS in South Africa

2010
Development of a South African CO_2 Geological Storage Atlas

2017
Commencement of a PCSP (10s thousand t/y)

Current – SACCCS relinked with CGS - Current review of storage options includes UCG site

Carbon Abatement

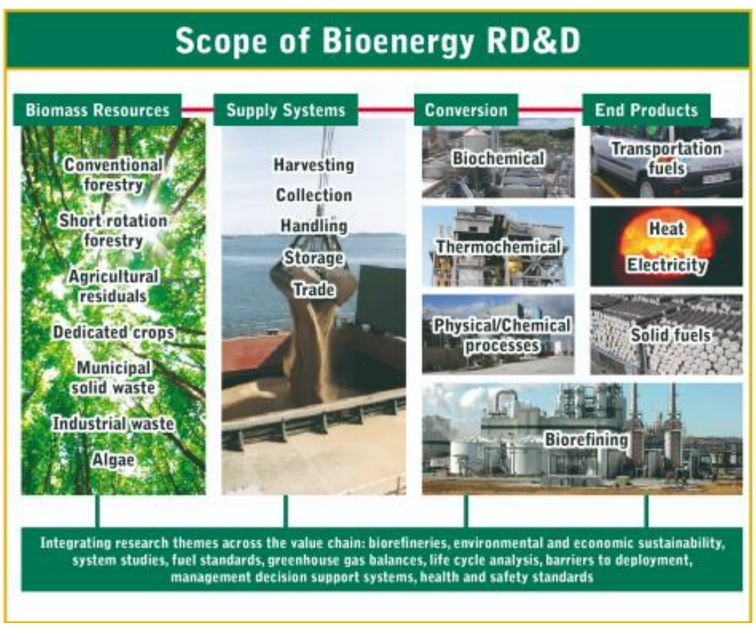
Fuel Substitution: IEA Bioenergy Task 32 and BAPEPSA

IEA Bioenergy Task 32

IEA Bioenergy

Biomass Combustion and Co-firing

- Within the IEA Bioenergy agreement, Task 32 works on further expansion of the use of biomass combustion for heat and power generation, with special emphasis on small and medium scale CHP plants and co-firing biomass with coal in traditional coal-fired boilers.
- This is done by generating and disseminating information on technical and on non-technical barriers and anticipated solutions.



BAPEPSA

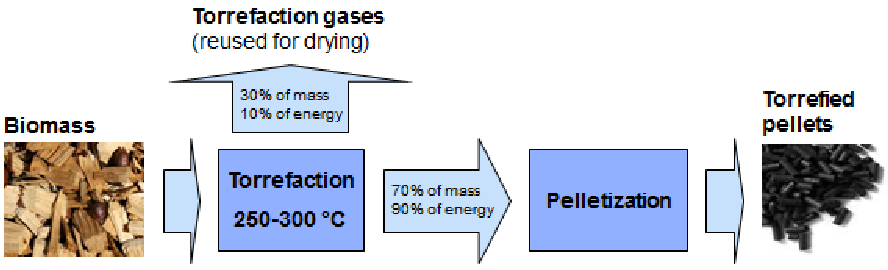
Biomass Action Plan for Electricity Production in South Africa

- Biomass resource quantification;
- Evaluation of utilisation technologies for woody and agricultural biomass use and fuel upgrading;
- Overview of markets for electricity and heat generation;
- Assessment of cost aspects of electricity and heat production from biomass in small, medium and large-scale Installations;
- Overview of the regulatory framework for biomass in South Africa;
- Formulation of barriers, identification of solutions and actions for biomass implementation in South Africa;
- Formulation of biomass targets for electricity and heat production in South Africa for 2020 and 2030.

public enterprises Department: Public Enterprises REPUBLIC OF SOUTH AFRICA
energy Department: Energy REPUBLIC OF SOUTH AFRICA
Kingdom of the Netherlands
Netherlands Enterprise Agency
sanedi
Eskom
DNV·GL
CENTRE FOR RENEWABLE & SUSTAINABLE ENERGY STUDIES
UNIVERSITEIT STELLENBOSCH UNIVERSITY
NRF National Research Foundation
SAEON South African Environmental Observation Network
WWF
SAFCOL

Carbon Abatement
Fuel Substitution: Torrefied Biomass co-firing at Arnot

Technology Description



Biomass Sourcing: SAFCOL could provide sufficient biomass to produce 80 000 t/y of pellets. Samples of SAFCOL biomass were tested to determine the suitability for torrefaction.

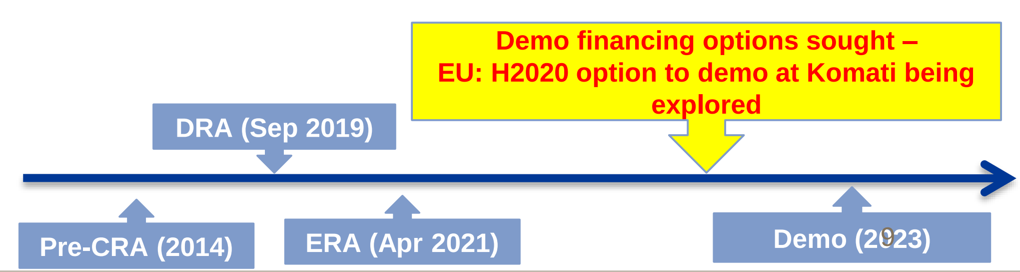
***Biomass Processing Plant*:** the site is Zebra Pellet Plant in Sabie, owned by the IDC. Blackwood torrefaction technology was chosen for the conversion of the plant and basic design study and a business case for the modification of the plant is compiled .

Biomass Utilisation: Eskom selected Arnot Power Station for co-firing evaluation, performed its laboratory capabilities assessment and performed basic engineering to determine the requirements for plant modifications to incorporate biomass co-firing and the cost associated.

Technology Benefits

Carbon Abatement	• Reduction in GHG, carbon neutral, combined with CCS co-firing results in negative GHG emissions and can offset carbon taxes.
Diversification of the Energy Mix	• Biomass is dispatchable renewable option, does not require investment for back-up power; • Offers higher capacity factors and lower CAPEX as compared to other carbon abatement/renewable technologies; • Cheaper than dedicated biomass plants. Process could see further cost reduction as it progresses.
Sustainable Electricity for All and Poverty Alleviation	• Infrastructure will provide access to electricity in rural areas and local industry creation to support the fabrication and construction of these plants; • Long term job creation in rural areas from forestry sector and biomass processing plants.
SOC Collaboration	• Eskom, SAFCOL, IDC, and DEFF (Working for Water.

Technology Timeline



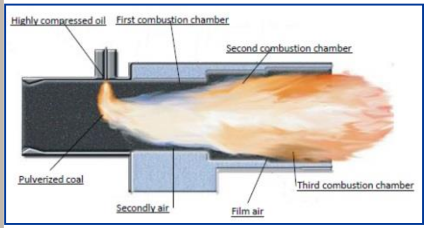
Maturity

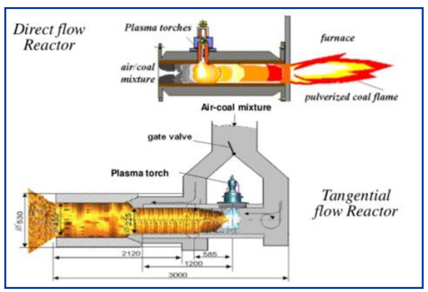
- Co-firing wood pellets is technically proven and technically feasible technology world wide, however, costs are still a major barrier to increased coal and biomass co-firing
- Co-firing torrefied biomass pellets has been demonstrated successfully through numerous different installations. In the US and Europe

Plant Performance Optimisation

Low Fuel Ignitors: Plasma Ignition and Mini Oil Guns

Technology Description: Assessment of advanced PF burner ignition systems with reduced or no fuel oil usage





- MOG is a coal ignition system that allows the immediate introduction of coal during a boiler light-up through a staged combustion process within the MOG. This resulting in a stable, high-temperature coal and gas flame. The system consists of PF burner, oil burner, air supply system, oil piping system, flame detector and control system.
- In plasma assisted coal ignition a portion of the PF is ignited by an arc plasma flame in a burner equipped with plasmatron. The air plasma flame is a source of heat and provides a high temperature medium enriched with radicals, where the fuel mixture is heated, volatile components of coal are extracted, and carbon is partially gasified. This fuel ignites the main PF flow supplied into the furnace.

Technology Benefits

Cost Savings	Plasma and MOG technologies can reduce/eliminate the amount of fuel oil required for start-up, shut-down and low-load operations
Fast Return on Investment	Elimination of inventory of fuel oil costs (for retrofit case) or elimination of the entire supplementary fuel oil storage and handling systems (new projects)
Flexibility	Fast available ignition system supporting the flexible operation of coal- fired power plants
Fuel Flexibility	Ignition of different solid fuels like low-rank coal combustion, high volatile hard coal, coal dust or biomass

Technology Timeline

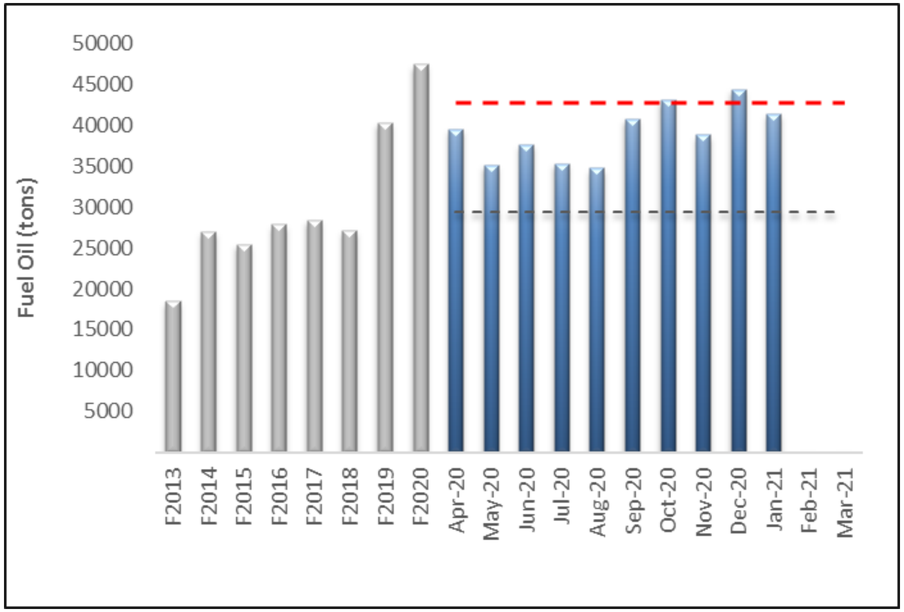
- Pre-CRA (June 2019)
- DRA (Dec 2019)
- ERA (Apr 2020)
- Current Demo Development

Maturity

- Plasma Ignition and MOG systems are widely utilised in China
- Both systems are installed in various boilers ranging in capacity from 50 to 1 000 MWe
- Utilisation of these technologies outside China are limited, with limited data available on their performance
- The technology is considered developmental

Plant Performance and Optimisation
Thermal Efficiency and Resource Utilisation

Reduction of fuel oil usage across the fleet

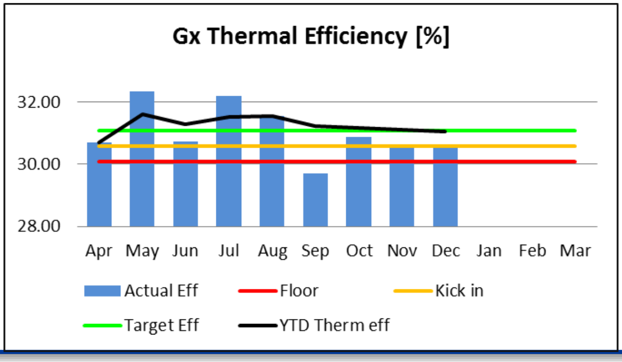


Gx has reduced FO consumption for 10 consecutive months relative to F2020 (YTD reduction by 77 764 tons)

Thermal efficiency

- New build stations are ~10% more thermally efficient than the oldest stations in the coal fleet.
- Thermal efficiency is largely dependent on the mechanical performance of the unit.
- Thermal efficiency is highest in winter due to dry coal and low ambient temperatures – warm winters and rains thus reduce thermal efficiency.

Medupi and Kusile will be included in the monthly TE dashboard once all their units have gone commercial.



Addressing coal quality according to required specification

- On line coal analysis: With instantaneous data decisions can be made and a better understanding of coal quality impact on power station is feasible.
- The aim of the project is to equip the stations with information about their coal qualities to be able to be able to specify a point in time or a period (hours or days) where their coal qualities resulted in poor unit performance.
- Research initiatives are in progress relating to fine coal and novel coal beneficiation techniques to improve coal quality further, towards Minimum Emission Standard (MES) compliance.

Plant Performance Optimisation
HORIZON 2020 Projects, IEA CCC

Eskom

Horizon 2020 Brief Profile

Horizon 2020 is the biggest EU Framework Programme for Research and Innovation with nearly €80 billion of funding available over 7 years (2014 to 2020). Agreements between the EU and individual governments have created a number of associated countries, where legal entities can participate in Horizon 2020 on an equal footing to those of EU Member States. Eskom joined the Stakeholder Community for MATChING and CapWa-Pro, this allows Eskom access to project results.

MATChING

- *Materials & Technologies for Performance Improvement of Cooling Systems performance in Power Plants* is a collaborative project which has the aim to reduce the cooling water demand in the energy sector
- A total of 9 test sites/facilities are used within the project: 2 demonstration sites (Italy, Spain), 3 pilot sites (Belgium, Italy, France) and 4 existing facilities (France, Belgium, Spain) of which two are movable to work at real power plants context

CapWa-Pro

- *Capture of Evaporated Water with Novel Membranes* is a collaborative project which is a continuation of the previously successful EU funded project (2010-2013).
- CapWa aims to produce a commercially available gas separating composite membrane modular system capable of capturing evaporated "waste" water and suitable for industrial applications.

IEA CCC

- *International Energy Agency's Clean Coal Centre* promotes best practice in all aspects of coal production, transport, processing and utilisation
- The work is focused on reducing emissions from coal use through HELE technologies.
- Conferences (Clean Coal Technologies, CCT, Multi-pollutant Emissions from Coal, MEC, Advanced USC, Co-firing Biomass with Coal).
- Webinars and technology evaluation reports.

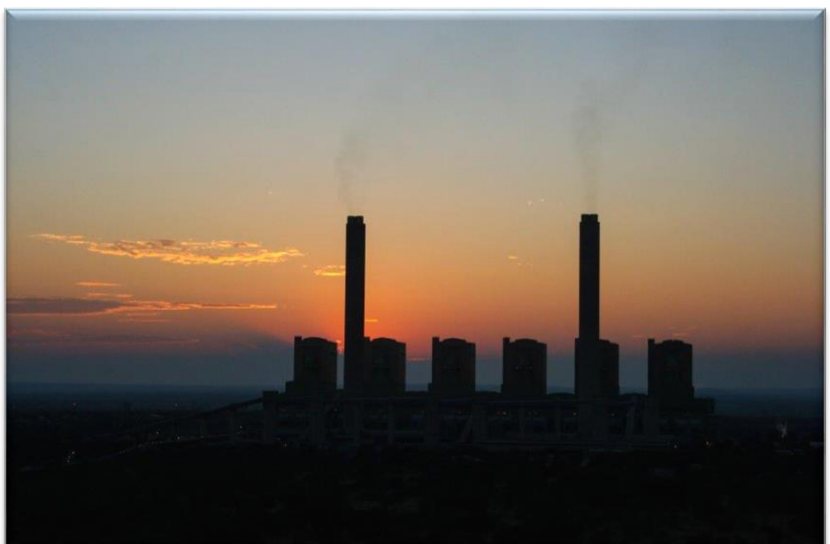
Plant Performance and Optimisation
Implementation of Dry Cooling Technology

Different consumption levels of wet and dry cooled technology

	Open Cycle Evaporative Cooling	Natural Draught Dry Cooled	Forced Draught Dry Cooled
Average water consumption (litres per kilowatt-hour generated)	1.90	0.12	**0.14**
For a station generating 3000MWh*	5.7 Ml / hour	0.36 Ml / hour	**0.42 Ml / hour**
	4104 Ml / month	**259 Ml / month**	**302 Ml / month**

Project Background

- Eskom has moved from wet cooling to dry cooling technology on plants since 1970's at Grootvlei and plants constructed in the 1980's including Koeberg once through sea cooled technology.
- Medupi and Kusile are dry cooled, as old plant is decommissioned total water consumption will reduce



Underground Coal Gasification (UCG)

Technology Description

UCG, a process where coal is gasified in place, was conceived in the late 1800s and has been developed in various countries across the world. A matrix of boreholes is drilled into the coal seam, sealed wells are created, the coal is ignited and air is pumped into the injection wells.

Fire is essentially used to 'mine' the coal and produce synthetic gas (syngas) which can be used directly as a fuel for power generation. UCG has synergies with conventional mining as it can make use of coal that would not normally be mined. Currently three quarters of South Africa's coal resources fall into this category. The implication is two-fold. Firstly, UCG and conventional coal mining can function in parallel without interference between sites and secondly, UCG can significantly increase the country's coal reserves. Eskom's conservative estimate is that there is an additional 45-billion tons of previously unminable coal suitable for UCG in South Africa.

Project Background

- The gas cleaning plant and condensate separation plant for a 15,000Nm3/hr co-firing demonstration have been commissioned.
- Mine production can be ramped up to provide the necessary gas flow for a co-firing demonstration in Unit 4 at Majuba Power Station.
- Initial co-firing at Majuba power station was achieved in 2010.
- Eskom not entered into many overall partnerships, and specifically of R&D to commercial technologies. UCG is one of the first in the current era.

Current Status

- The commercial and financial viability of this technology has not been assessed. This needs to be completed before further funds can be spent on UCG.
- Eskom has not entered into many overall partnerships, and specifically of R&D to commercial technologies. UCG is one of the first in the current era.
- Partnerships of R&D projects have additional complexity due to development risk allocation, and IP management in a shared partnership entity.
- Eskom, & RTD need benchmark process, experience and learnings for strategic partnership, within SPV/JV, particularly with the development, ownership and management of IP against both R&D and commercial needs.
- Invested R1,5 billion and 18 years in UCG development. RT&D assessing alternatives to SPV/JV partnership and full decommissioning.

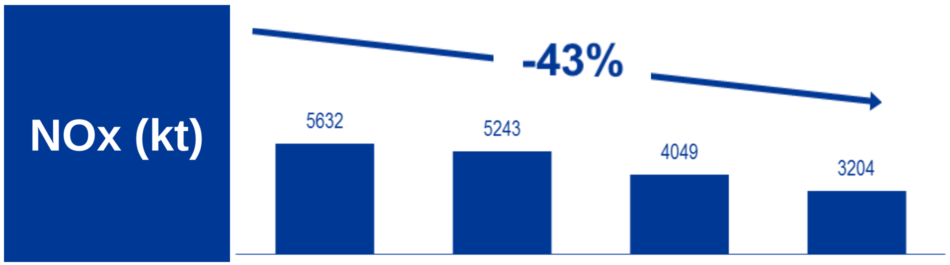
Emission Retrofit Programme

Emission Retrofit Dash-Board

Power Station	Project	Resp. Div.	2014 MES Commitment Dates	2019 MES Application Dates	Current Forecast Dates	Next Steps / Key Issues
Camden	Low Nox Burners	GCD	19/20 - 24/25	N/A	18/19 - 21/22	Equipment installation on the last unit complete.
Duvha U4-6	ESP Upgrade	Gx	18/19-20/21	20/21-24/25	20/21-24/25	Completed
	HFPS	Gx	21/22 - 23-24	21/22 - 23-24	21/22 - 23/24	Procurement process in progress - tender evaluation.
Grootvlei	FFP (Unit 2, 3, 4)	GCD	15/16 - 17/18	N/A	N/A	Complete
Kendal	ESP Upgrade	Gx	N/A	19/20 - 24/25	20/21 - 24/25	Construction on the first two units in progress.
	CFB -FGD	Gx	N/A	21/22	22/23	Definition stage complete. No funding
	HFPS	GCD	N/A	19/20 - 24/25	20/21 - 22/23	Construction on the first two units in progress.
Kriel	ESP Upgrade	GCD	19/20 - 24/25	19/20 - 24/25	21/22 - 24/25	Procurement process in progress - bid out on tender.
	HFPS	GCD	19/20 - 24/25	19/20 - 24/25	21/22 - 24/25	Procurement process in progress - bid out on tender.
Lethabo	ESP Upgrade	GCD	N/A	19/20 - 24/25	21/22 - 24/25	Procurement process in progress - bid out on tender.
	HFPS	GCD	N/A	19/20 - 24/25	20/21 - 21/22	Equipment installation on the first unit in progress.
	SO_3	GCD	N/A	19/20 - 24/25	21/22 - 24/25	Procurement process in progress - bid out on tender.
Majuba	Low Nox Burners	GCD	19/20 - 24/25	20/21 - 25/26	22/23 - 24/25	Alternative Emission Reduction Plan
Matimba	Multi-Pollutant Pilot	Gx	N/A	N/A		Project is in RFI and pre-concept phase. No funding
Matla	ESP Upgrade	GCD	20/21 - 24/25	20/21 - 25/26	21/22 - 22/23	Procurement process in progress - tender evaluation.
	HFPS	Gx	20/21 - 24/25	21/22 - 24/25	20/21 - 22/23	Procurement process in progress - negotiations.
	Low Nox Burners	GCD	20/21 - 24/25	21/22 - 26/27	22/23 - 26/27	Alternative Emission Reduction Plan
Medupi	FGD Plant	PDD	21/22 - 25/26		24/25 - 29/30	RFI evaluation in progress.
Tutuka	DFGC	GCD	N/A	N/A	2020/21	Equipment installation in progress.
	FFP (3 units)	GCD	18/19 - 23/24	21/22 - 26/27	22/23 - 25/26	Includes DHP - Tender cancellation in progress
	HFPS (3 units)	Gx	18/19 - 23/24	21/22 - 26/27	20/21 - 21/22	Equipment installation in progress.
	Low NOx	GCD	19/20 - 24/25	20/21 - 25/26	20/21- 25/26	Alternative Emission Reduction Plan

- Eskom has been implementing the emission reduction plan, the plan includes retrofitting technologies at several power station to reduce NOx, SOx, PM.

- The combination of shutting down power stations at end of life and the retrofit programme will significantly reduce emissions over the next decade and beyond



Summary – Technology Comparison
CCT Capability to Meet MES

CCT	Particulate Matter (50 mg/Nm³)	Sulphur Dioxide (1000 mg/Nm³)	Oxide of Nitrogen (650 mg/Nm³)	Impact (Cost; Efficiency; CO_2)
Wet FGD	N/A	✓	N/A	High capex
CFB FGD	N/A	✓	N/A	Medium sulphur coal (Kendal) – to be determined
DSI FGD	N/A	X	N/A	High opex
ESP + HFT	✓	N/A	N/A	Lower capex than FFP retrofit
ESP + HFT + DFGC	To be determined (Tutuka U6 Demo.)	N/A	N/A	Lower capex than FFP retrofit
Low NOx Burners	N/A	N/A	✓	Low capex; High unburnt carbon
SCR	N/A	N/A	✓	High capex and opex
SNCR	N/A	N/A	✓	High capex
Multi-pollutant	N/A	To be determined	To be determined	Potentially high capex
CCS	Pre-requisite +	Pre-requisite +	Pre-requisite +	-10% Efficiency; High capex; no proven storage
Biomass Co-firing	Biomass complies; % co-firing dependent	Biomass complies; % co-firing dependent	Biomass complies; % co-firing dependent	CO_2 reduction; high opex to coal; baseload RE option
UCG	To be determined	To be determined	To be determined	To be determined

Thank You