TITLE:

The Case for a CFBC Pilot Plant in South Africa

Proposal compiled by:
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MOTIVATION

• **ROLE OF COAL IN THE POLICY ADJUSTED IRP2010 –**
  • Hydrocarbons (predominantly COAL) are set to decreases from 86% to 57%, BUT they actually increase from 37 990 MW to 50 771 MW in the period to 2030. **This requires urgent attention to develop newer, cleaner and more sustainable technologies**

• **Current dependence on coal** – 93% electricity, 30% liquid fuels, 95% reductants, high income from foreign exchange through exports

• **Reducing coal qualities** – 20-60% ash

• **Inability to beneficiate further** – ash too finely distributed to extract/liberate so cannot produce good quality coal

• **Highly variable lower qualities** – run-of-mine, blends, different sources on offer in the market place

• **Inability to use lower grades and inconsistent qualities of coal effectively** in all current boiler plants in SA – large scale pulverised boilers and industrial plants

• **IRP 2010 carbon cap and impending Carbon TAX** - due to be implemented shortly

• **Stringent emissions control** – SOx, NOx, PM (including fine PM), trace elements, radionuclides .....
POLICY ADJUSTED IRP 2010

The size and mix of the South African power generation capacity – 2010 to 2030
The draft IEP 2012’s proposed and estimated contributions to South Africa’s energy generation-mix.

Most of the installed capacity is more than 30 years old.
COAL QUALITIES IN THE REMAINING COAL RESERVES IN SOUTH AFRICA

NB: THE PROPORTIONS OF COALS IN INCREASING RANGES OF ASH CONTENT

(after Petrick; Horsfall, 1977)

Up to 65% ash in coals are being mined and included in market products today

Very little left
COAL QUALITIES FROM DIFFERENT REGIONS

NB: VARIATIONS IN ORGANIC COMPOSITION

>15% variation in coal quality and consistency causes problems in combustion: ignition, flame control, burnout and boiler efficiency
FLAME PROPAGATION VELOCITY AT FIXED PARTICLE CONCENTRATION

- **Coal C (SA):** VM=21%, Ash=31%
- **Coal A (SA):** VM=20%, Ash=44%
- **Coal B (SA):** VM=25%, Ash=37%
- **Coal E (SA):** VM=25%, Ash=16%
- **Coal F (Australian):** VM=31%, Ash=15%
- **Coal D (US):** VM=44%, Ash=6%

Normalized flame propagation velocity, Sb (-)

Volatile matter, dry basis (%)
EFFECT OF REDUCING COAL QUALITIES (HIGH ASH AND INERT ORGANIC MATTER) ON CO\textsubscript{2} EMISSIONS.

Rise in CO\textsubscript{2} in Eskom over 10 years

Eskom grid emission factor

<table>
<thead>
<tr>
<th>Year</th>
<th>t CO\textsubscript{2e} / MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>0.90</td>
</tr>
<tr>
<td>2003</td>
<td>0.90</td>
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<tr>
<td>2005</td>
<td>0.92</td>
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<tr>
<td>2007</td>
<td>0.92</td>
</tr>
<tr>
<td>2009</td>
<td>0.93</td>
</tr>
<tr>
<td>2011</td>
<td>0.95</td>
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POOR EFFICIENCY ~
SUSTAINABLE COAL TECHNOLOGY TO ALLOW CONTINUED USE OF COAL IN SOUTH AFRICA

OBJECTIVES:

To ensure continued sustainable use of indigenous coal by aiming to achieve high efficiency and low emissions (HELE) in all South African coal-fired conditions

To achieve this by

• Comparing best boiler plant and operating processes for future boiler plants, i.e. comparing
  • Pulverised coal (PC) versus fluidised bed Combustion (FBC)
  • Within the FBC category, Bubbling FBC (BFBC) versus Circulating GBC (CFBC)
• Introducing co-firing of coal with biomass in new FBC boilers and existing PC boilers
• Investigating fuel flexibility for CFBC with a wide range of alternative fuels/waste matter
• Researching new methods to reduce GHG (CO$_2$) and pollutant emissions (SOx, NOx, PM)
• Increasing coal-fired thermal efficiency and thereby lowering emissions in current boiler plant
# PULVERISED COAL (PC) VERSUS FLUIDISED BED COMBUSTION (FBC)

<table>
<thead>
<tr>
<th></th>
<th>PC</th>
<th>FBC</th>
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<tbody>
<tr>
<td>Particle Size</td>
<td>&lt;75μm</td>
<td>1-5cm</td>
</tr>
<tr>
<td>Operating temperatures</td>
<td>&gt;1400°C</td>
<td>&lt;900°C</td>
</tr>
<tr>
<td>Burnout time</td>
<td>&lt;2 sec</td>
<td>As long as needed</td>
</tr>
<tr>
<td>SOx sorbent</td>
<td>Limestone* +FGD</td>
<td>Dolomite*/Limestone* in-bed</td>
</tr>
<tr>
<td>Fuel requirement</td>
<td>Pulverised coal</td>
<td>Coal / flexible fuels</td>
</tr>
<tr>
<td></td>
<td>Consistent quality</td>
<td>Variable qualities</td>
</tr>
<tr>
<td>Water consumption</td>
<td>High with FGD</td>
<td>No water required for FGD</td>
</tr>
</tbody>
</table>

* Limestone severely limited in SA
+ Dolomite abundant in SA

<900°C prevents NOx, slagging
## BFBC vs CFBC

<table>
<thead>
<tr>
<th>Differentiator</th>
<th>BFBC</th>
<th>CFBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form of bubbling bed</td>
<td>Compact, shallow</td>
<td>Extended, re-circulating</td>
</tr>
<tr>
<td>Bed density</td>
<td>High density</td>
<td>Low density</td>
</tr>
<tr>
<td>Commercial operating scale</td>
<td>&lt;60 MW</td>
<td>60-460 MW</td>
</tr>
<tr>
<td>Steam conditions</td>
<td>Sub-critical</td>
<td>Sub- to Super-critical</td>
</tr>
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</table>
# OPPORTUNITY FUELS FOR CO-FIRING IN FBC

<table>
<thead>
<tr>
<th>Agricultural</th>
<th>Peach wood</th>
<th>Cotton stalks</th>
<th>Walnut shells</th>
<th>Paper sludge</th>
<th>Hardwoods</th>
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<tbody>
<tr>
<td></td>
<td>Pear wood</td>
<td>Cow manure</td>
<td>Walnut wood</td>
<td>Oil soaked clay</td>
<td>Railroad ties</td>
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<tr>
<td>Alfalfa seed straw</td>
<td>Peat</td>
<td>Cubed garlic</td>
<td>Wheat midds</td>
<td>PET/Glycol liquid</td>
<td>Saw dust</td>
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<tr>
<td>Almond brush</td>
<td>Pecan shells</td>
<td>Figulls</td>
<td>Wheat straw</td>
<td>Petroleum tanker sludge</td>
<td>Softwoods</td>
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<tr>
<td>Almond shells</td>
<td>Pistachio shells</td>
<td>Fig wood</td>
<td>Petroleum coke</td>
<td>Zinc borate OSB waste</td>
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<tr>
<td>Almond wood</td>
<td>Pistachio wood</td>
<td>Garlic and onion skins</td>
<td>Polyolefins</td>
<td>Board plan waste</td>
<td></td>
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<tr>
<td>Apple wood</td>
<td>Plum wood</td>
<td>Grape canes</td>
<td>Sontara</td>
<td>Planer shavings</td>
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<tr>
<td>Apricot wood</td>
<td>Poultry derived fuel</td>
<td>Grape pomace</td>
<td>Grease, scum and screenings</td>
<td>Tyre derived fuel</td>
<td></td>
</tr>
<tr>
<td>Barley straw</td>
<td>Prune pits</td>
<td>Grape scaffolds</td>
<td>Cardboard sludge</td>
<td>Unburned fuel</td>
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<tr>
<td>Bean straw</td>
<td>Prune wood</td>
<td>Grass straw</td>
<td>Auto shredded residue</td>
<td>Slander dust</td>
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<tr>
<td>Cherry pits</td>
<td>Race track shavings</td>
<td>Lignin cake</td>
<td>Cellulose absorbent</td>
<td>Slash</td>
<td></td>
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<tr>
<td>Chicken litter</td>
<td>Race track straw</td>
<td>Manure + wheat straw</td>
<td>Carpet scraps</td>
<td>Urban wood waste</td>
<td></td>
</tr>
<tr>
<td>Citrus trees</td>
<td>Rice hulls</td>
<td>Nectarine wood</td>
<td>Char</td>
<td>Woodex pellets</td>
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<tr>
<td>Coffee grounds</td>
<td>Rice straw</td>
<td>Oat straw</td>
<td>Cellulose acetate</td>
<td>Refused derived fuel</td>
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<td>Corn cobs</td>
<td>Safflower stalks</td>
<td>Olive pits</td>
<td>Distillation bottoms</td>
<td>Wastewater treatment sludge</td>
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<tr>
<td>Corn kernels</td>
<td>Sunflower hulls</td>
<td>Orange peel and pulp</td>
<td>Charcoal</td>
<td>Anthracite</td>
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<tr>
<td>Corn stalks</td>
<td>Swine solids</td>
<td>Paunch manure</td>
<td>Hospital waste</td>
<td>Coal dust</td>
<td></td>
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<tr>
<td>Cotton gin wastes</td>
<td>Tobacco sludges</td>
<td>Peach pits</td>
<td>Dried paper sludge</td>
<td>Subbituminous</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bituminous</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lignite</td>
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SCALE UP OF CFBC BOILER CAPACITY SINCE 1994

(Lockwood, 2013)
CURRENT FACILITIES FOR COMBUSTION TESTING IN SOUTH AFRICA:

- Eskom DTF and Pilot scale PC test facilities, and a BFBC/BFBG test facility that is not currently in use
- CSIR BFBC/BFBG laboratory scale facilities (mostly for gasification)

CURRENT COMBUSTION TESTING LIMITATIONS

- No adequate facilities for testing CFBC combustion characteristics anywhere in (Southern) Africa
- No training facilities for research and skills/capacity building for new CFBC IPPs
- International testing of coals precludes training and research in this country
- Exchange rate fluctuations impact significantly on cost of sending SA coals internationally for testing in CFBC pilot scale facilities
- CFBC IPPs now being established in Southern Africa using international CFBC technologies
- International CFBC technologies are not confirmed as suitable for local coals and conditions
Fuel characterisation tests are a common input required for scale up designs.

Combustion
- Combustion profile (heat release), fuel reactivity
- Unburned carbon (UBC)

Emissions
- Main component such as CO₂, O₂, CO, H₂O, SOx, NOx
- Trace elements such as HCl, HF, N₂O, NH₃, CₓHᵧ, Hg

Ash
- Ash composition and split: bottom ash vs fly ash
- Agglomeration, fouling and corrosion tendency

Sorbents
- Reactivity
- Estimated sorbent dosage to reach the emission limits

Optimal combustion conditions: furnace dimensions; heat transfer surfaces; material selection; emission control system; ash removal system and utilisation; plant location (fuel and sorbent selection); training and research
CONCEPTUAL CFBC TEST FACILITY (100-150 kW)

(VTT – Finland)
Project stakeholders

- **Government** (DST, DMR, DEA, DoE, SANEDI)
- **SA Power Producers** (Eskom, IPPs and others)
- **OEMs** (various)
- **Academia** (Wits, NWU, UJ .....)
- **Science Councils** (CSIR, MINTEK...)
THE PROPOSAL

• To establish:
  • A **pilot scale CFBC test facility** for testing the combustion (or co-combustion) of coal and a wide range of biofuels and other waste materials in a location which could become a **Centre for Research in Sustainable Coal (and other materials) Combustion**
  • A **virtual National Centre of Excellence comprising key parties** (academia, industry and science councils), all sharing the use of the CFBC test facility;
  • A **Manager/Management team from one organisation responsible for operating and maintaining the CFBC test facility** but overseen by an executive committee comprised of other interested bodies
  • **Adequate analytical laboratory equipment** (locally or on-site) to support the centre and its facility

• To do so in a location:
  • **Accessible for parties**: university staff, researchers, science council and industrial personnel, and all others wishing to use the Centre and CFBC facility for research, teaching, operational training, testing, trials and diagnostic reasons
  • **Permissible in terms of legal and environmental legislation**
  • **Accessible for the transport in, and storage of, feed materials**: coals, biofuels/biomass, sorbents and other waste materials
**THE PROPOSAL**

For the purposes of

- **Testing a wide range of feed materials:** coals, biofuels, agricultural off-cuts, industrial and municipal waste materials for their combustible properties and steam or heat generating capabilities, **singly or co-fired with coal**

- **Establishing the suitability of feed materials and blends** for in-coming new technologies (CFBCs for IPPs)

- **Researching methods to reduce GHG (CO₂) and pollutant emissions** (SOx, NOx, PM),

- **Researching SOx in-bed de-sulphurisation** by various Ca-rich sorbents

- **Establishing the suitability of dolomite** instead of scarce limestone resources for in-bed SOx reduction

- **Establishing the ash slagging and corrosion propensities** of coals and waste materials

- **Researching the nature and use of combustion by-products** (ash, gypsum, CO₂, major and trace elements)

- **Providing research and development opportunities as well as operational training and skills development for employment in establishing IPPs** (certificated training is legally required for any operation of this nature)
OUTCOMES AND BENEFITS

• Technical and scientific understanding of own coals, biomass and waste materials for own use (with specific application in the region of Southern Africa); and by-products

• Capacity building and skills development for employment in current and future technologies, i.e.
  • Professional scientists and engineers to acquire/adapt/develop and/or manage IPP and other plants, i.e. as “intelligent buyers of CFBC technology, and fuels/sorbents”
  • Skilled plant operators to run operations and maintain developing IPP and other plants

• Diagnosis of operational problems, whether attributable to plant design, operational issues or fuels/sorbents

• Assessments of (i) blends using different fuels/sorbents (ii) trials to reduce emissions

• Adaptation and optimisation of existing combustion technologies, with development if required

• Potential to design and manufacture own plant and processes in the longer term

• Potential to sell/provide services to the broader Southern African region
CONCLUSIONS:

• Coal has a role to play in RSA for the foreseeable future, BUT it has the challenge of ensuring it’s usage is clean and sustainable (i.t.o. fuel/sorbent suitability, cost, emissions, skills, social licence etc.)

• A National Centre for Combustion Research with a new CFBC pilot scale test facility is proposed

• A “Hub and Spoke” Centre of Excellence model for research in sustainable [clean] coal technologies is proposed, comprising academia, industry and science councils.

Fundamental philosophy to be followed is: “fast follower, slow pioneer - unless required”

NEXT STEPS:

• **Gauge interest:** Government interest and opinions

• **Feasibility study:** to determine stakeholder engagement, market needs survey, key questions, methodology and equipment, design and capability, location, infrastructure and manpower required, applicable legislation (permits, licenses and regulations), management and steering committee structure, capital and operating costs, training and education needs to be established, and suppliers of CFBC equipment

• **Business case:** this to follow subject to the first two points.
Thank you