



Coaltech *Colloquium* 2026

The Premier Research, Development and Innovation Platform for the Coal Industry

PROCEEDINGS DOCUMENT



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FUTURE TECHNOLOGIES

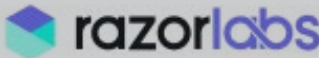
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Headline sponsors



Exhibitors





Agreenco Environmental Projects – Adrian Haagner

Agreenco Environmental Projects is an integrated environmental solutions provider specialising in ESG compliance, water-use innovation, ecological infrastructure, and land repurposing through rehabilitation.

Their team of experienced scientists, engineers, and environmental practitioners develops practical and implementable solutions to address complex environmental challenges across the mining sector.

With a strong focus on monitoring, adaptive management, and long-term sustainability, Agreenco works closely with clients and stakeholders to deliver meaningful environmental improvements to ecosystems and communities affected by mining. Their extensive track record across multiple commodities and climatic regions, combined with ongoing involvement in research, industry associations, and social upliftment initiatives, positions them as a trusted leader in environmental solutions.

We thank Agreenco Environmental Projects for their valued support in helping make the Coaltech Colloquium 2026 an impactful platform for collaboration, research, and innovation in the coal mining industry.



HEADLINE SPONSOR – Agreenco Environmental Projects | **Adrian Haagner**

COALTECH COLLOQUIUM 2026 AGREENCO SERVICE OFFERINGS

Action Environmental Results

ADRIAN HAAGNER
DIRECTOR



AGREENCO

People · Planet · Progress



Industry challenges



Advancing the Future of Sustainable Coal

Complex environmental, regulatory and operational challenges demand integrated, science-based solutions



Short-term procurement paradigm

Procurement of sustainability remains a fallacy – focus on cost, not long-term outcomes.



Regulatory uncertainty

Evolving DWS TAN, pit lakes, closure & financial provision regulations create uncertainty and compliance risk.



Break in the implementation chain

Lack of flow-through from design intent to implementation to eventual sign-off and acceptance.



Closure provisions vs. enterprise needs

Application of closure provisions can activate reactivation and create enterprise gaps.



Sustainability outcomes

Need for solutions that optimise expenditure, reduce uncertainty and advance true sustainability.

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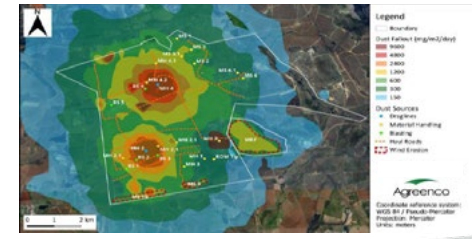
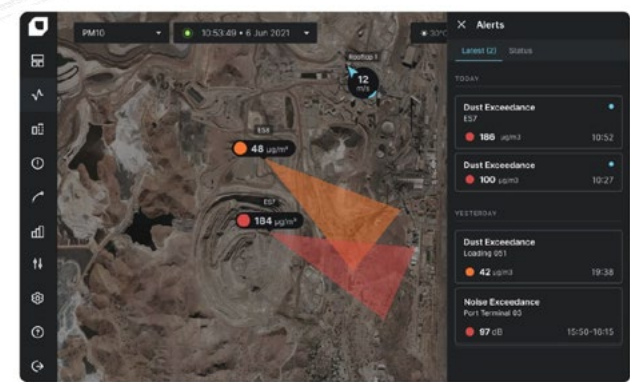
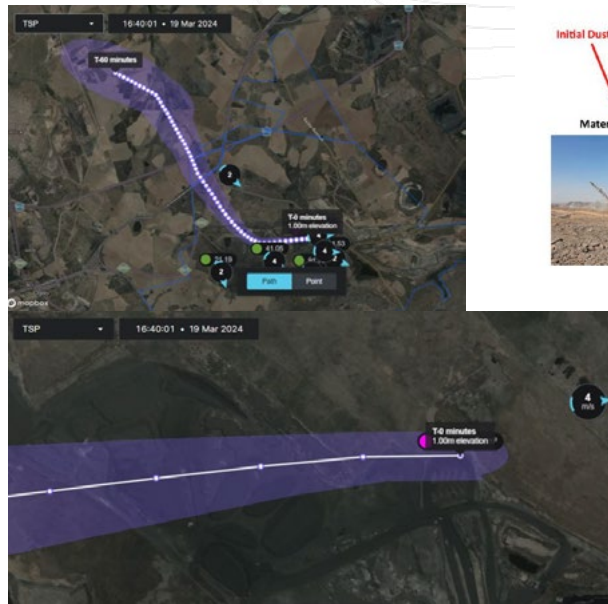


Air quality services



Advancing the Future of Sustainable Coal

- Design & audit of monitoring programmes, including real-time monitoring, forecasting & exceedance investigations
- Updated Highveld Priority Area & updated NDCR (2026) ERMP & periodic reporting



Turning data into action.
Mitigating risk.
Delivering compliance.
Protecting operations.

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Air quality services



Advancing the Future of Sustainable Coal



Undertake designs & implementation for:

- haul roads (trucks vs sprinklers),
 - materials handling, stockpiles, transfer points,
- linked to ERMPs and monitoring- NDCR (2026)



Effective design.
Proven implementation.
Measurable results.

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Air quality services



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Reduction and elimination of in-pit sponcom



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Water management services



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Full Irrigation Layout

System Composition

- Proposed 3 phased approach (Trial; P2 and P3)
- Cannon Emitters- 263 Units;
- Main line- MPVC 355mm (C116) (9200 m)
- Main line- MPVC 250mm (C112) (2460 m);
- Manifold lines- MPVC 200mm (C112) (18700 m);
- Suggested Pump- Curro LTS 125/150 (3 stage) (x10);
- Paired Motor- WEG premium 75 kW (x10);
- Temporary water storage units – 780 m³ (x4)

System Operation

- Total flow rate- 1450 m³/hr;
- Velocity = < 2,5 m/s;
- Friction loss threshold: <1,5%
- Total Area- 354 Ha;
- Maximum Water Usage – 13 050 m³/day;
- Mean Water Usage- 6 300 m³/day;
- Cycle- 10 cannons for 45 min stand time (20 hours/ 2,2 days);

- A- Trial area & Pump Station location (light blue);
- B- Phase 2 area & Pump Station location (Dark blue);
- C- Phase 3 area & pump Station location (Purple)



- Irrigation- licensing & specialist studies,
- Integrated design for:
 - rehab irrigation
 - crop or biocrop irrigation
 - dust management irrigation,
- Excess water evaporation,

All linked to total water make.

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Water management services



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Recharge & seepage management via:

- enhanced vegetation performance,
- afforestation, interception, evapotranspiration,
- integrated engineering designs.

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Water management services



Advancing the Future of Sustainable Coal



	AMD Stage 3 Oxidised Decant	AMD Stage 2 Reduced Decant	AMD Stage 1 Saline Decant
pH	<3.2	3.2 - 4.5	>4.5 mg/l
SO ₄	2000 - 6000	2000 - 10000	(No Na) 200 - 2600 mg/l
Fe	50 - 1000	or 100 - 5000	or <100 mg/l
Al	10 - 500	10 - 100	<20 mg/l
Mn	10 - 500	10 - 300	<10 mg/l

Treatment	
Lime:	Crushed Recycled Concrete and Slag
Organic Material:	Alien Vegetation Woodchips / Sewage Biosolid Mix
Liming Plant	FeO(OH), Al(OH) ₃
Sludge:	CaCO ₃ , SiO ₂ , CaSO ₄

Output:
Clay: Geothite - FeO(OH), Gibbsite - Al(OH)₃, Gypsum - CaSO₄
Used for Rehabilitation

Water Outflow:
pH>5.5
SO₄ <400mg/l
Fe<1mg/l
Al<1mg/l
Mn<1mg/l

In situ remediation of seepage or shallow groundwater via:

- microbial degradation
- anaerobic bioremediation
- pH adjustments for precipitation

Often integrated with vegetation

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Biodiversity services



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- Aquatic and terrestrial biodiversity monitoring, with BAP/BMP.
- Invasive plant delineation, management plans & monitoring, invasive plant eradication (conventional & drone) via PCOs, permitting.
- Nuisance vegetation management- pipelines, fencelines, conveyors, roadways, firebreaks, security. Chemical, burning, green breaks, mechanical.

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Biodiversity services



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- TOPS delineation,
- Monitoring,
- Relocation plans & services,
- Nurseries,
- Permitting.

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Biodiversity services



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- Afforestation- for recharge reduction & seepage control, carbon sequestration
- Design, monitoring, permitting, economic feasibility
- Implementation and maintenance

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Biodiversity services



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- Wetland rehabilitation:
 - Design,
 - implementation,
 - offsets,
 - permitting.
 - For direct rehabilitation or nature-based treatment solutions.
- Wetland delineation and monitoring

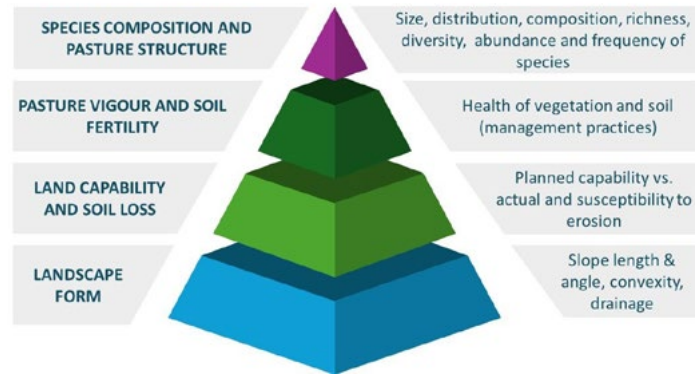


Land management services



Advancing the Future of Sustainable Coal

THE REHABILITATION HIERARCHY



- Rehabilitation performance assessments
- Rehabilitation maintenance plans



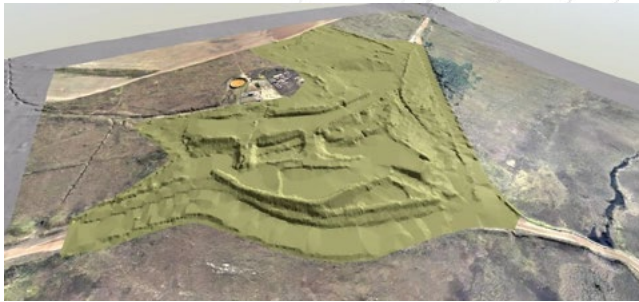
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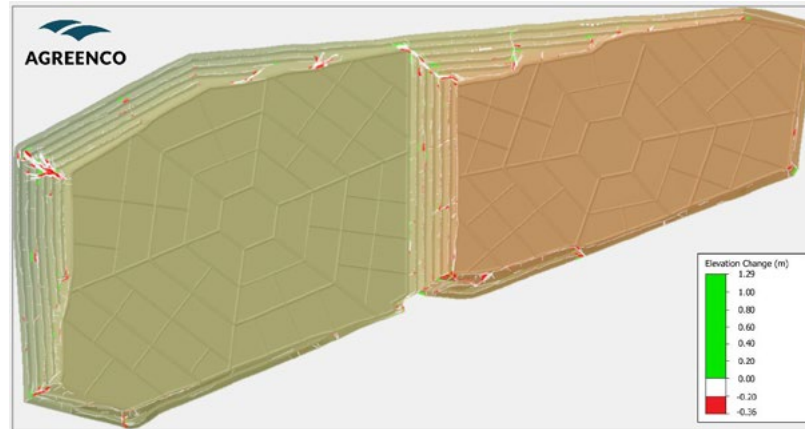
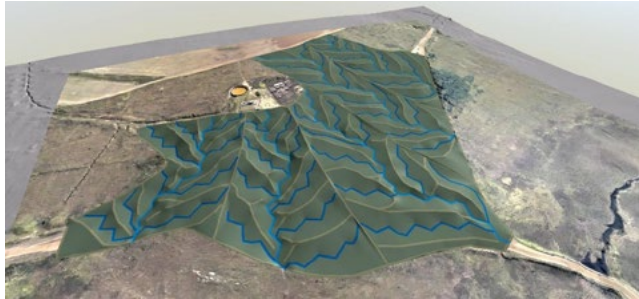
Land management services



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- Rehabilitation designs
- Rehabilitation plans



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Land management services



Advancing the Future of Sustainable Coal



- Rehabilitation implementation
- Rehabilitation maintenance

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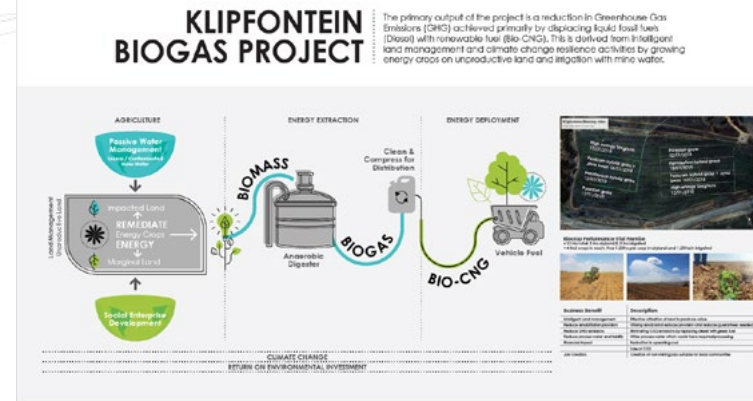


Land management services



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Integrated land stewardship



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Thanks



Advancing the Future of Sustainable Coal



- For complex situations requiring interdisciplinary specialists
- For a proven track record
- For cost-effective high value services
- For “scientific contractors”
- For value-added compliance to true sustainability
- For innovative partnerships

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FlowCentric Mining Technology - Charles Bothma

FlowCentric Mining Technology supports the coal industry with practical solutions built for real operational challenges. At the centre of its offering is FlowCentric Heatshield™, a long-term solution developed to help prevent, control, and extinguish self-heating and spontaneous combustion in coal.

The product is designed for both proactive and reactive treatment, helping operations manage one of the sector's most persistent safety and resource risks.

Alongside FlowCentric Heatshield™, the company also provides mechanical wastewater evaporation solutions for mine dewatering, as well as a full range of industrial dust control and stabilisation services for roads, tailings, and material processing areas.

As the Coaltech community comes together to share research, insight, and progress across the sector, the support of organisations such as FlowCentric Mining Technology helps strengthen the shared drive towards a safer, more efficient, and more sustainable coal industry.

Thank you to FlowCentric Mining Technology for supporting the Coaltech Colloquium 2026 as one of the two Headline Sponsors.





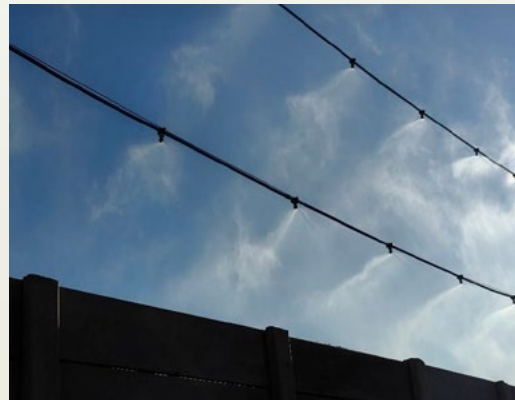
FlowCentric Mining Technology



Sustainable Mining Technology
For A Cleaner Future



Dust Management



www.flowcentric-mining.com

Industrial Waste Water Evaporation



www.flowcentric-mining.com

Spontaneous Combustion Management



Mine Water Management



www.flowcentric-mining.com

Current R&D Projects

Recovering lanthanides (rare earth metals) and transition metals from chemically treated landfill leachate using integrated advanced and conventional processes.

Rare Earth Elements
by Geology.com

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La-Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt									
Lanthanides																	
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																	
Actinides																	
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																	





MINING

This session concentrates on managing immediate operational risks by enhancing measurement, testing, and understanding of underground conditions.

- **Coal Dust Explosibility – Kloppersbos Testing Capability**
 - ◊ Presenter: Riaan Bergh (CSIR) – (20 Minutes)
- **Stress Measurement for Fall-of-Ground Prevention**
 - ◊ Presenter: Johan Hanekom (CSIR) – (20 Minutes)

“

Improved stress measurement is the key to preventing fall-of-ground incidents and saving lives ”





*“Keeping People Safe
and Operations Stable”*



**Presenting -
Coal Dust Explosibility, Kloppersbos Testing Capability**

Riaan Bergh

Mechanical Engineer | CSIR

Riaan Bergh brings 25 years of structural mechanics and performance testing experience to the coal sector. He leads the CSIR's Mining Testing and Training impact area, which includes the Cottesloe Mining Laboratories and the Kloppersbos mine fire and explosion testing and training facility. His presentation covers South Africa's coal dust explosibility testing capability and what it means for operational safety standards underground. The work is directly relevant to every underground coal operation in the country: if dust explosibility thresholds are not properly understood and tested, the safety protocols built on top of them are unreliable.



COALTECH COLLOQUIUM 2026

MINING

RESEARCH FOCUS AREA

THEME

*Keeping People Safe
and Operations Stable*



Advancing the Future of Sustainable
Coal



Kloppersbos explosibility laboratory upgrade

Riaan Bergh

CSIR

Project Number: M2020-2 | Presented: May 2026

WORK IN PROGRESS COMPLETED





CONTEXT & RESEARCH PROBLEM



20-litre explosion vessel being charged with a coal dust sample

Why does this matter?

Accurate determination of coal dust explosibility is a key input to manage the risk of catastrophic dust explosions.

Unverified equipment: The 40-litre explosion vessel has lacked independent calibration verification for years, raising a question about validity of test results.

Standardisation gap: While the 20-litre apparatus is the international standard and independently calibrated, its correlation with local historical data had not been established.

Real world disconnect: Standard laboratory testing occurs under laboratory ambient conditions, failing to account for the heat, humidity, and methane of real mines.

40-litre apparatus

Local standard for coal explosibility, used in early research

20-litre apparatus

Wide adoption globally and annually calibrated through round robin testing





RESEARCH OBJECTIVES

*What did this project
set out to achieve?*

MINING
RESEARCH FOCUS AREA



01

Investigate the feasibility of replacing the 40-litre test method with an equivalent test using the international standard 20-litre apparatus.

02

Establish the relationship between explosibility test results obtained in the 40-litre apparatus vs. the 20-litre apparatus.

03

Evaluate the impact of variation in temperature, humidity and the presence of methane on coal dust explosibility results.

04

Recommend the appropriate equipment and test method for future explosibility testing.





RESEARCH APPROACH & METHODOLOGY



1

Scoping & Literature

Literature review of local and international dust explosibility practice

Samples were taken from various underground coal mines

2

Laboratory experimental work

Coal samples were collected from underground mines, prepared and tested in the Kloppersbos laboratory

Sample Size
16

3

Data Analysis

*Relationship established between results of two apparatuses.
Effect of atmospheric conditions quantified.*

Samples were collected and tested over 12 months

4

Validation & Outputs

*40-litre results compared with historical database.
20-litre results compared to calibration values.*

Test methods according to the equipment manufacturer's manuals





KEY FINDING

The relationship between explosibility indices of the two laboratory apparatuses was established as
 $K_{max} = 0.97 \times K_{ex}$

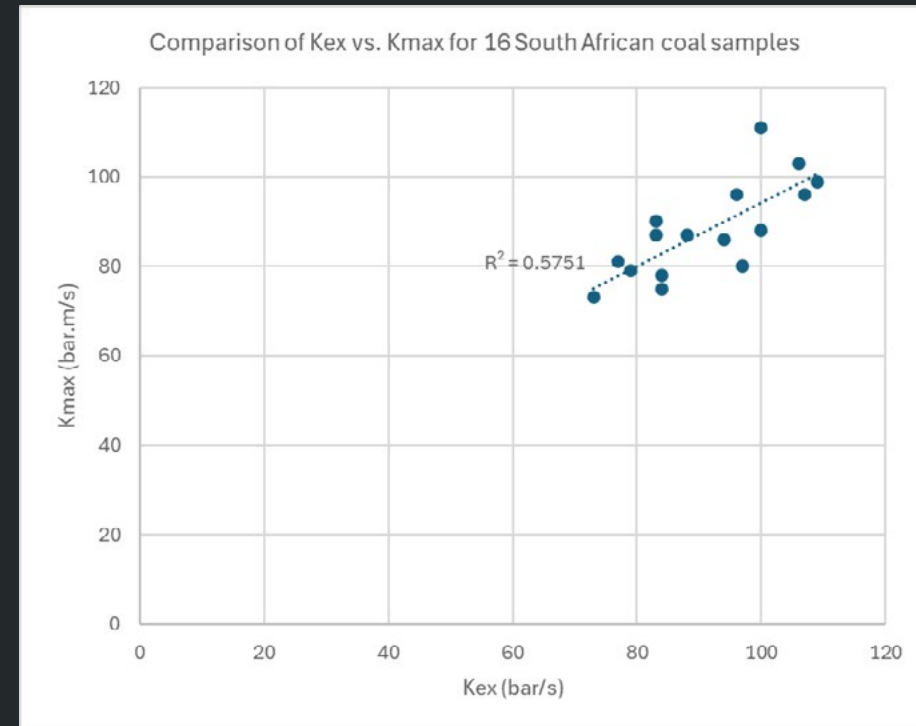
PRELIMINARY INDICATIVE CONFIRMED

WHY THIS MATTERS:

Coal explosibility can be determined using the internationally accepted and calibrated 20-litre explosion apparatus



SUPPORTING EVIDENCE



Comparison of explosibility indices measured using 40-litre and 20-litre apparatuses





APPLICATION ILLUSTRATION

Category	Kex Range	Kmax Range	Implication
Non-Explosive	≤ 70	≤ 68	Considered non-explosive and will not propagate an explosion under laboratory test conditions.
Transition	70 - 95	68 - 93	Uncertain behavior. Do full-scale gallery testing, or treat as likely to propagate an explosion.
Propagating	≥ 95	≥ 93	High risk. Will sustain and propagate an explosion.

Established explosibility classification in terms of Kex range (40-litre apparatus) and equivalent Kmax range (20-litre apparatus)

KEY FINDING

The established coal dust explosibility classification can be expressed in terms of the Kmax parameter, determined using the 20-litre explosion vessel.

PRELIMINARY INDICATIVE CONFIRMED

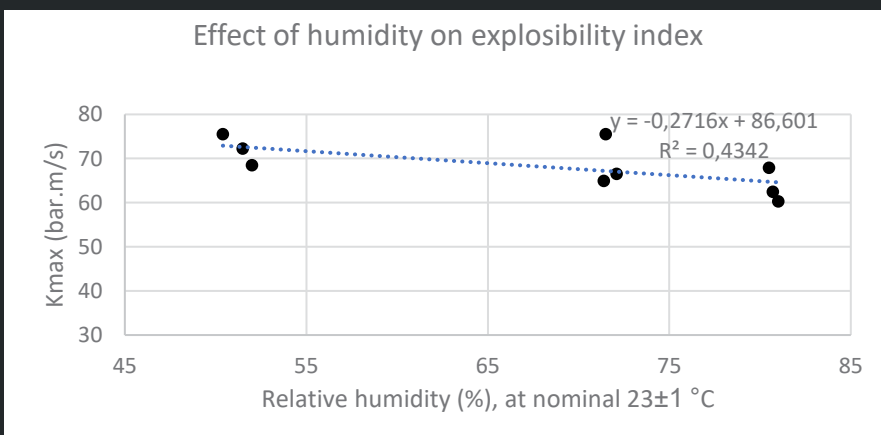
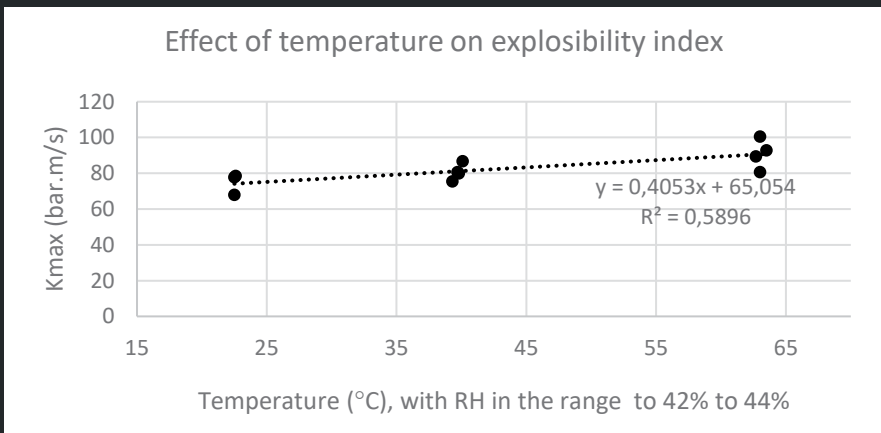
WHY THIS MATTERS:

Well-known explosibility risk categories remain valid when adjusting ranges to suit 20-litre vessel results.





SUPPORTING EVIDENCE



Effect of temperature (top) and humidity (bottom) on explosibility index



KEY FINDING

Temperature and humidity of the atmosphere change the explosibility behaviour of coal dust.

[] PRELIMINARY [X] INDICATIVE [] CONFIRMED

WHY THIS MATTERS:

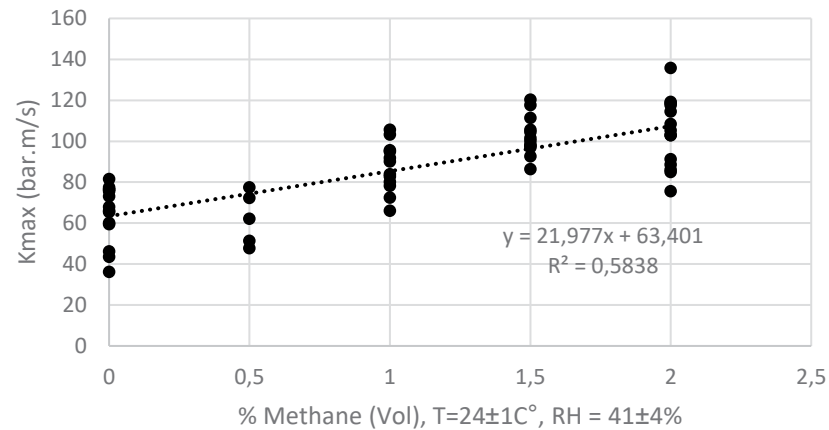
Accurate assessment of explosibility risk should consider in-mine atmospheric conditions.





SUPPORTING EVIDENCE

Effect of % methane on explosion index, Kmax - Test series M2 to M6



Effect of methane on explosibility index

KEY FINDING

Presence of methane in the atmosphere has a dramatic effect on the explosibility behaviour of coal dust.

PRELIMINARY INDICATIVE CONFIRMED

WHY THIS MATTERS:

Methane concentration can change the risk category of the mine's coal dust.





RESULTS & DATA



Temperature effect: +0.4

Bar/s increase in Kmax per 1°C above 22 °C

Humidity effect: -0.3

Bar/s decrease in Kmax per 1%RH above 45%RH

Methane effect: +22

Bar/s increase in Kmax per 1% CH₄

Calculation Formula

$$K_{max}_{mine} = K_{max}_{lab} + (\Delta T \times 0.4) - (\Delta RH \times 0.3) + (CH_4\% \times 22)$$

Example calculation

Lab Result	Temperature	Humidity	Methane
69	28°C	60%	0.5%
Kmax (Baseline)	+6°C vs Lab	+15% vs Lab	Low Concentration

69	+	2.4	-	4.5	+	11.0	=	77.9
Base Kmax		Temp (6×0.4)		Humid (15×0.3)		CH ₄ (0.5×22)		Adjusted Kmax

Key Take-away

Atmospheric conditions in the mine, especially the concentration of methane, may have a dramatic effect on the explosibility of the coal dust. Taking atmospheric conditions into account requires in-mine measurements and a simple calculation.





WHAT THIS MEANS FOR MINING



Practical takeaways — what should your organisation do with these results?

1

Mine Operations

*Test coal dust explosibility regularly and update explosion risk controls as necessary.
Review and update SOPs - dust explosibility must take mine atmospheric conditions into account.*

2

Workforce Safety

*Adjust dust explosibility test results based on measured atmospheric conditions in your mine.
Assess explosion risk based on the adjusted explosibility classification.*

3

Digital & Technology

Consider continuous monitoring of temperature, humidity and methane concentration to track and report the combined effect of in-mine conditions on explosion risk.

4

Planning & Design

Consider the impact of methane concentration on dust explosibility during planning and design to provide adequate fresh air ventilation for dilution of methane.





CONCLUSIONS & RECOMMENDATIONS

*The key outputs from
this research and
what to do next.*

CONCLUSIONS

- C1** Coal dust explosibility can be tested using the international standard 20-litre explosion apparatus.
- C2** Coal dust explosibility classification can be expressed in terms of K_{max} .
- C3** Coal dust explosibility lab results should be adjusted to take in-mine atmospheric conditions into account.

RECOMMENDATIONS FOR INDUSTRY

- R1** Sample and test coal from production sections at regular intervals and have it tested to classify the explosibility risk.
- R2** Monitor atmospheric conditions in underground mines and adjust explosibility lab results to take in-mine conditions into account.





*“Keeping People Safe
and Operations Stable”*



**Presenting -
Stress Measurement for Fall-of-Ground Prevention**

Johan Hanekom

Chief Rock Engineer | CSIR

Johan Hanekom is a rock engineer with 36 years of experience spanning AngloGold Ashanti, SRK Consulting, and the University of Pretoria's Mining Engineering Department. He held the Harmony Chair in Rock Engineering and Numerical Modelling at the University of Pretoria from 2015 to 2018 and has operated as an independent specialist consultant before joining the CSIR as Chief Rock Engineer in 2023. His presentation addresses how improved stress measurement techniques can prevent fall-of-ground incidents, the leading cause of fatalities in South African underground mining. The research targets practical, deployable measurement approaches that mines can integrate into existing ground control programmes.



COALTECH COLLOQUIUM 2026

MINING

RESEARCH FOCUS AREA

THEME

*Excavation stability and
worker safety*



Advancing the Future of Sustainable
Coal



Stress Measurements to Confirm Stress Field Components for FOG Prevention in Complex Geological Areas

JWL Hanekom

Council for Scientific and Industrial research

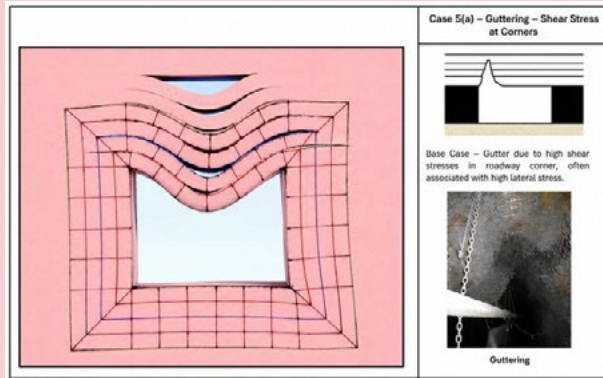
M2025-2 | Presented: May 2026

PROJECT PHASE COMPLETED





RESEARCH PROBLEM



Potential impact of high horizontal stress in Coal Mines (Seriti Power)

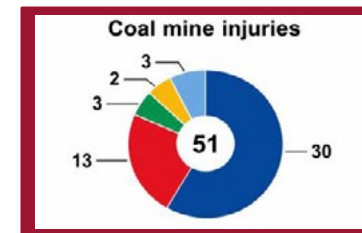
The concern

A higher horizontal field stress component can result in shear failure in the roof (directional shear failure) or at excavation corners (guttering). Whilst substantial geotechnical data is gathered on most operations, the local stress field components are usually estimated from regional or unknown. This lack of local stress data is critical when the magnitude and orientation of the major horizontal stress component appear to be variable, which is more prevalent when the geology in the planned mining area is complex.

Recent falls-of-ground on some of the collieries highlighted the need to be able to have improved understanding of the field stress component magnitudes and orientations in areas accessed for mining.

Currently, designs for the mining of an area applies regional stress field data and augmented that with observational data from surrounding areas. No data is available from the area where mining is planned. Unforeseen stress field changes can thus be missed.

Safety data courtesy of MCSA (5 Year data summary), dated 4 May 2026)





CONTEXT



Compact Conic-ended borehole overcoring (CCBO)

- (1) BX pilot drilling (Must stop at 10m; up-plunge) with a normal BX crown. Must use stabilizers and 1m rods.
- (2) Conically shape the b/h bottom with a special conic bit. Must use stabilizers. (Low gear; high rotation as used in bull-nose drilling)
- (3) Inspect with a b/h camera
- (4) Clean the b/h bottom
- (5) Glue a shorter-nose strain cell (16 strain gauges) with minimal adhesive.
- (6) Over coring (Low gear; slowest) Must use a thin BX bit and stabilizers
- (7) Break the core with a pinch bar



A special conic bit (NX) We use a BX one.



A 16-element strain cell (BX)

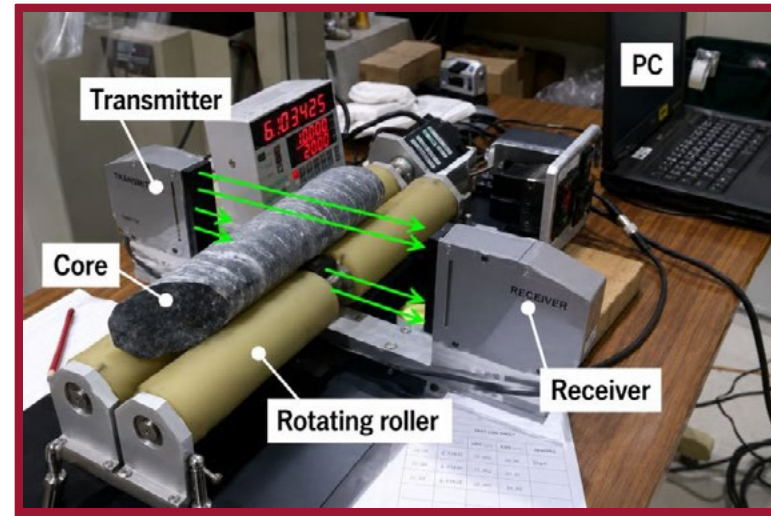
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CCBO method description

The methods applied

The CCBO method measures rock deformation at the borehole-ends using strain gauges. During the process of over-coring the strain gauges, the strain relief OR 'rock expansion' is measured and converted to stress values.

The DCDA method takes core drilled and removed from a borehole, places it on rollers that accurately measure the diameter (and thus shape) of the core. From this 'new' shape, the strain relief OR 'core expansion' is measured and converted to stress.



DCDA method description

2





RESEARCH OBJECTIVES

Measurement of the stress field components as mining approaches a geologically complex area will **contribute to quantify the impact** of these structures on the magnitude and / or orientation of the field stress components and allow **remedial action to be implemented timeously**.

Hypothesis

The DCDA method, using the deformation of core samples, can provide sufficient information on local in-situ stress fields, to correlate results with the field stress components provided by traditional, proven, over-coring methods.

MINING
RESEARCH FOCUS AREA



01

Stage Gate 1: Initial assessment of the ability of the DCDA method to indicated field stress components and magnitudes in the Coal environment

02

Stage Gate 2: Execute control measurements with over-coring method (CCBO) in underground sites

03

Performing DCDA measurements at the same sites, using core drilled from the over-coring boreholes and correlate the findings with CCBO results

04

Conclude on the ability of the DCDA method to measure appropriate stress components and recommend a way forward.

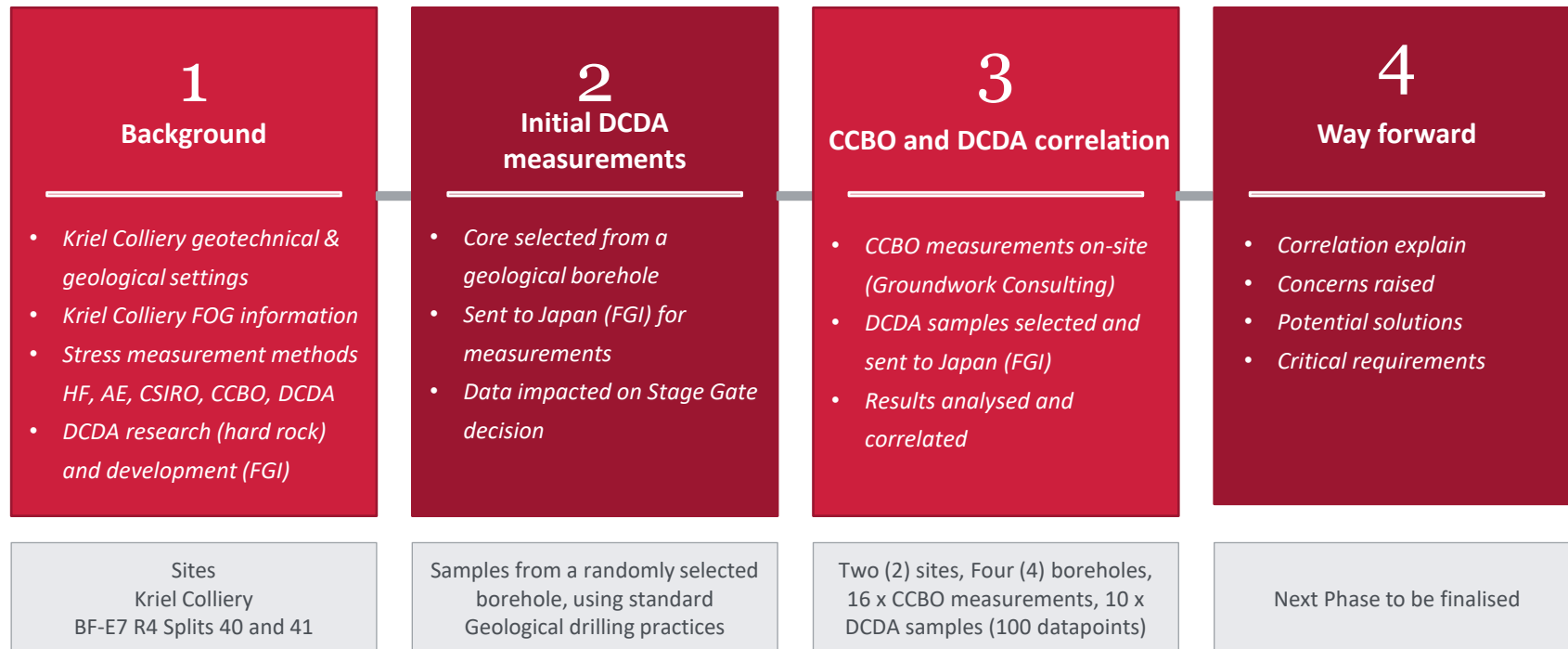




RESEARCH APPROACH



Correlation between DCDA and the more conventional CCBO results, indicates that DCDA is a potential more cost-effective solution to the need for more regular stress measurements. Correlation also supports the value of further development of this method into an operational tool.





KEY FINDINGS

1

Initial DCDA measurements

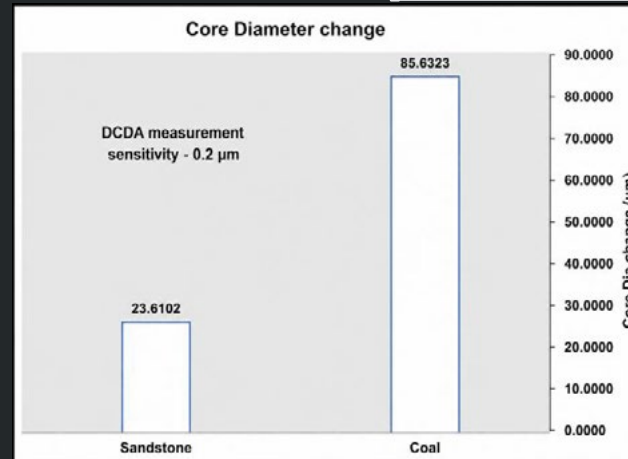
Assumptions:

- Historic stress components include a vertical and horizontal component that align with σ_3 and σ_1 respectively
- The borehole direction will not be critical to the initial decisions

Results are INDICATIVE of sufficient potential to continue

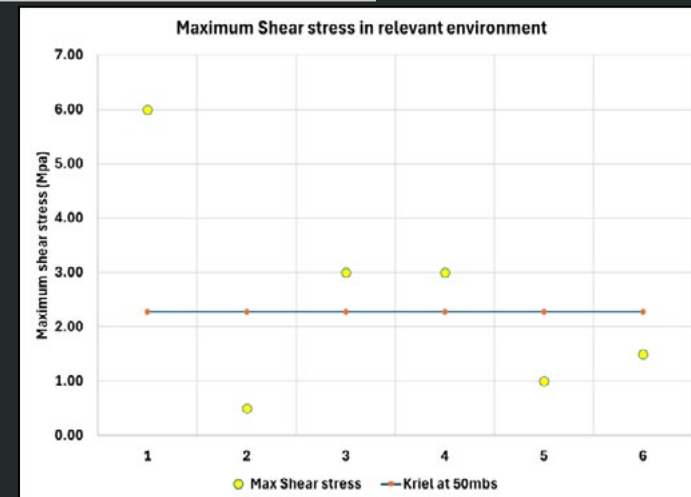
THIS FINDING WAS IMPORTANT:

Stage Gate 1: Unacceptable results → Terminate project



Expected diameter change

DCDA results vs Historical data





KEY FINDINGS

2

CCBO Measurements

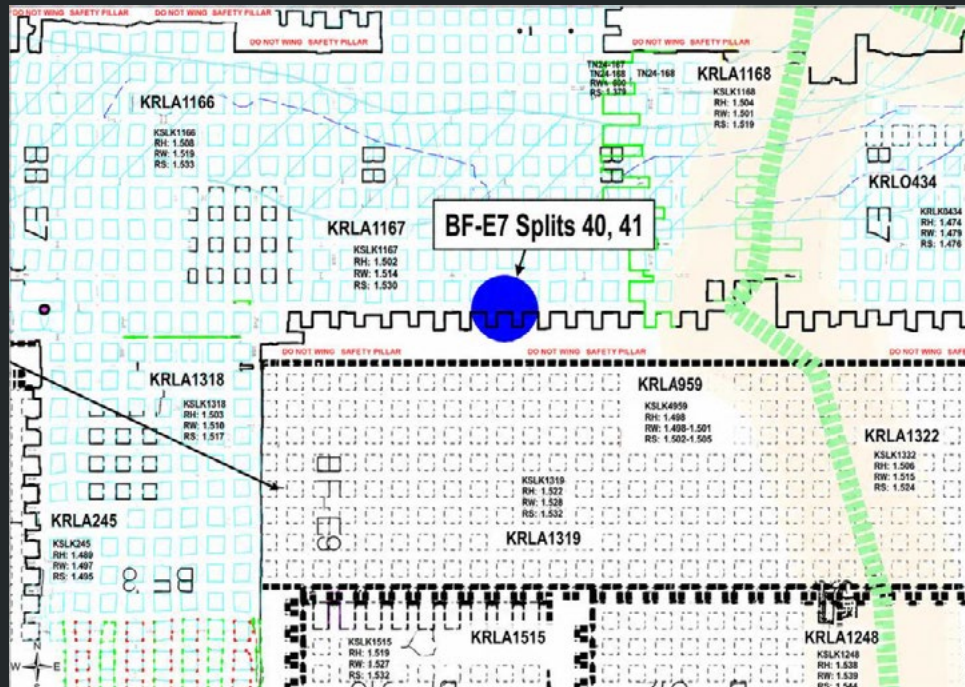
- Site selection
- Instrumentation
- Data collection
- Results achieved (Orientation / Magnitudes)

Data was CONFIRMED through analysis

WHY THIS MATTERS:

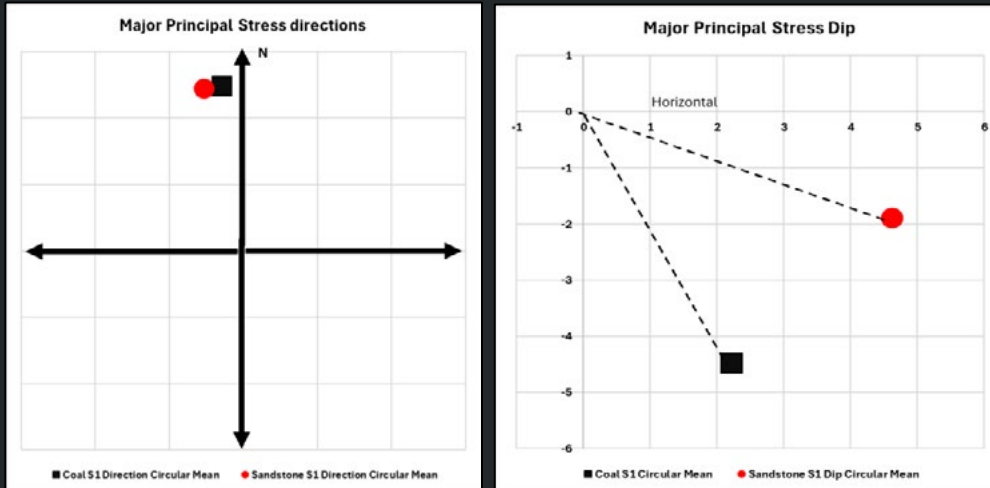
Unacceptable CCBO results (control data) makes project continuation unnecessary

6

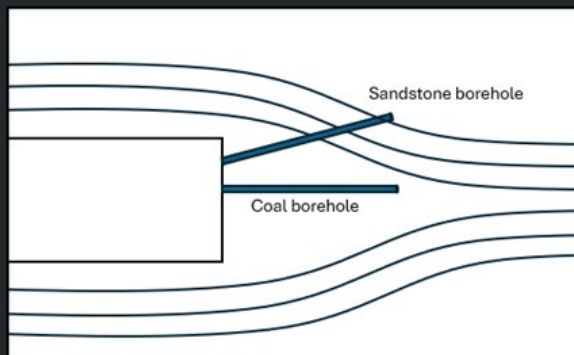


Kriel Colliery Site BF-E7





Major Principal Stress Orientations



KEY FINDINGS

2

CCBO Measurements

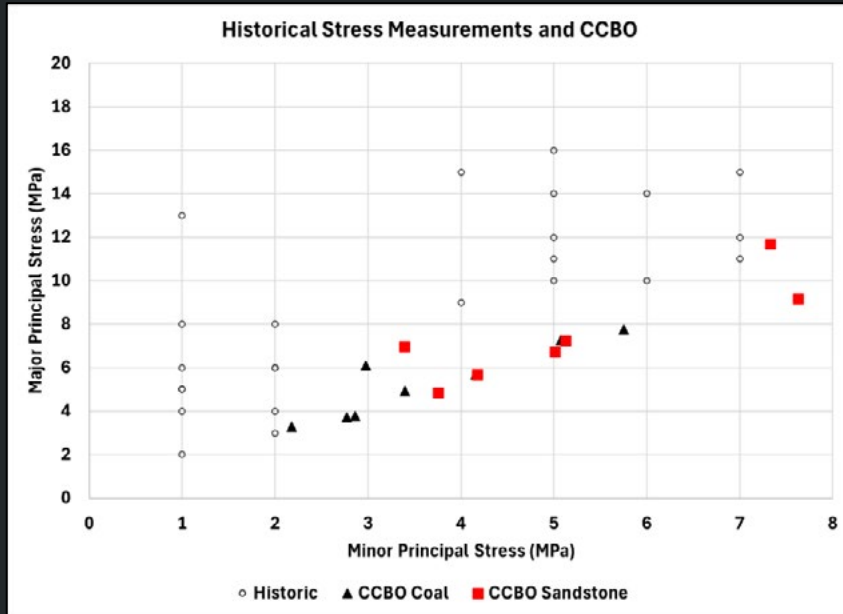
- Site selection
- Instrumentation and Data collection
- Results achieved (Orientation / Magnitudes)

Data was CONFIRMED through analysis

WHY THIS MATTERS:

Unacceptable CCBO results (control data) makes project continuation unnecessary





Major Principal Stress Magnitudes



KEY FINDINGS

2

CCBO Measurements

- Site selection
- Instrumentation
- Data collection
- Results achieved (Orientation / Magnitudes)

Data was CONFIRMED through analysis

WHY THIS MATTERS:

Unacceptable CCBO results (control data) makes project continuation unnecessary

6





KEY FINDING

3

DCDA measurements

- *Samples and measurements*
- *Results achieved (Orientation / Magnitudes)*

Data was CONFIRMED through analysis

WHY THIS MATTERS:

DCDA results are indicative of the potential for this method



Core quality

Site	Sample No.	Core condition	Max length (cm)	Targeted for measurement
Site1	Sandstone 1	Allernating layers of sandstone and mudstone	9	
	Sandstone 2	Core surfaces are uneven	11	Yes
	Sandstone 3	Mudstone layers are indented	17	Yes
	Sandstone 4	Bedding dip: approximately 50°	10	
	Sandstone 5		7	
	Sandstone 6	Easily fractured at bedding planes	21	Yes

5





KEY FINDING

3

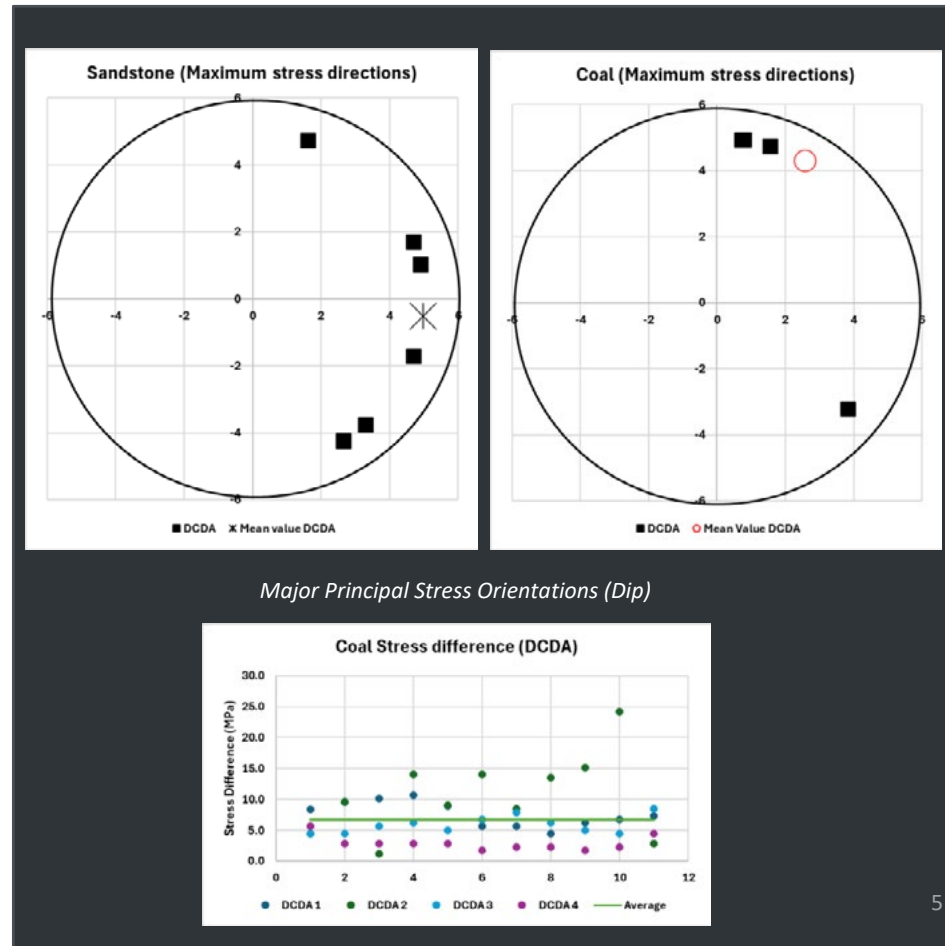
DCDA measurements

- Samples and measurements
- Results achieved (Orientation / Magnitudes)

Data was CONFIRMED through analysis

WHY THIS MATTERS:

DCDA results are indicative of the potential for this method





CORRELATION APPROACH

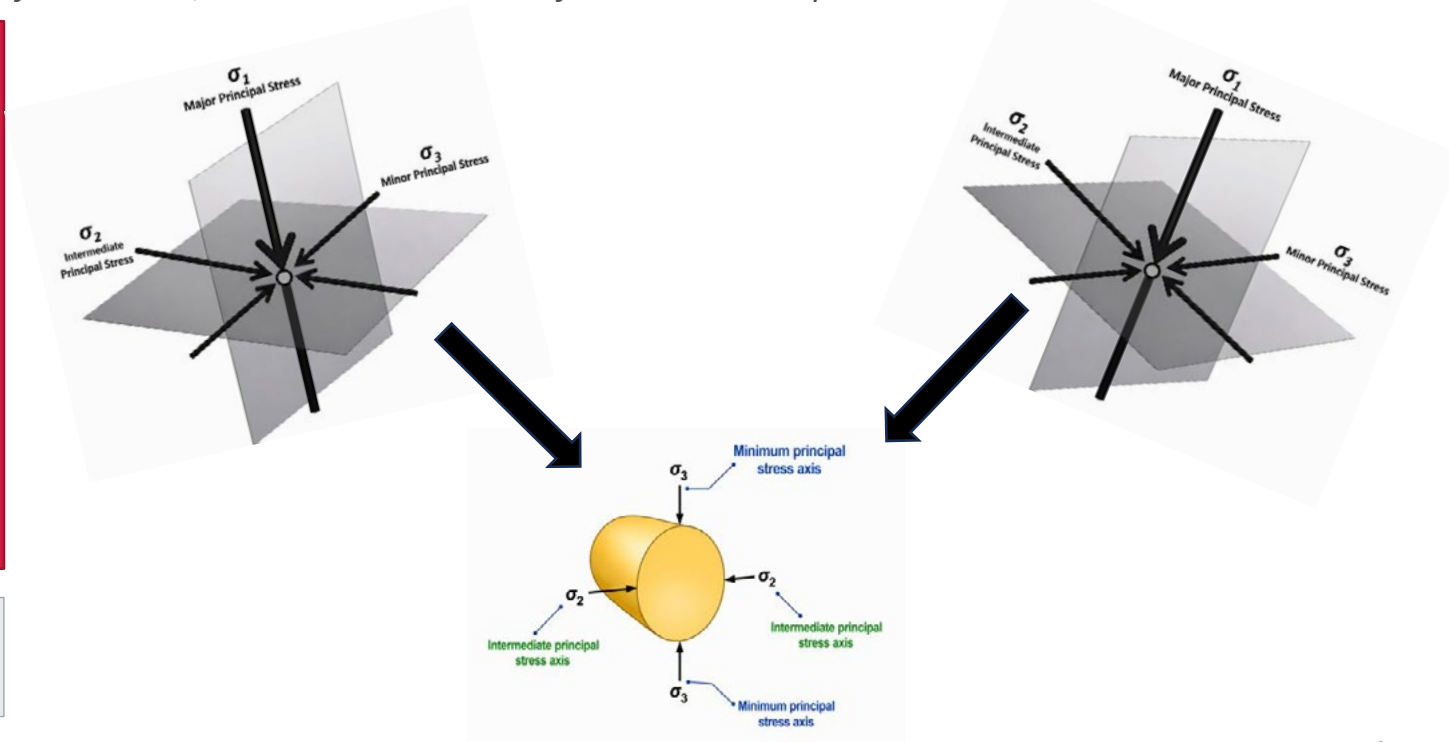


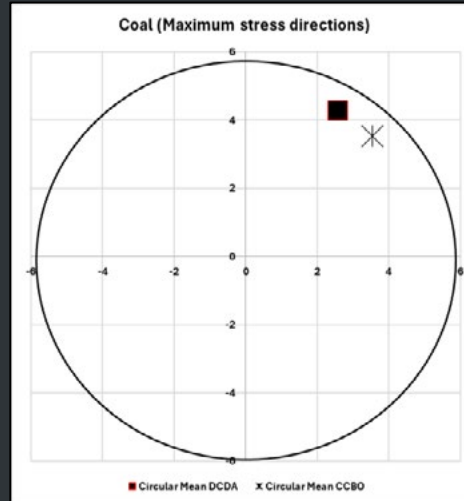
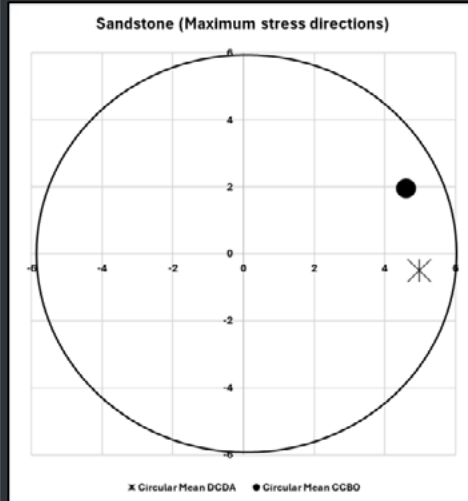
The CCBO stress field components are provided in a full 3-dimensional space. The DCDA field stress results are provided as the 'difference' between the two (2) stresses acting perpendicular to the core sample, in 2-dimensions. To allow correlation or comparison of the results, the stress results must fall in the same space.

CCBO results transformed

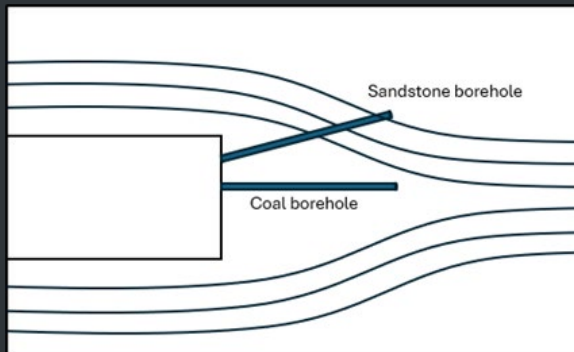
- Assuming isotropic, elastic material property behaviour
- Transformation equations rotate stresses from one coordinate system into another
- Hooke's Law relate stress, strain and rock elastic constants

The 'difference' between the stresses perpendicular to the cross-section plane is determined and compared





Major Principal Stress Orientation correlation



KEY FINDING

4

Correlation

- Orientations
- Magnitudes

Data was CONFIRMED through analysis

WHY THIS MATTERS:

Correlation indicate method's ability to provide similar results, improving potential for application

6





KEY FINDING

4

Correlation

- Orientations
- Magnitudes

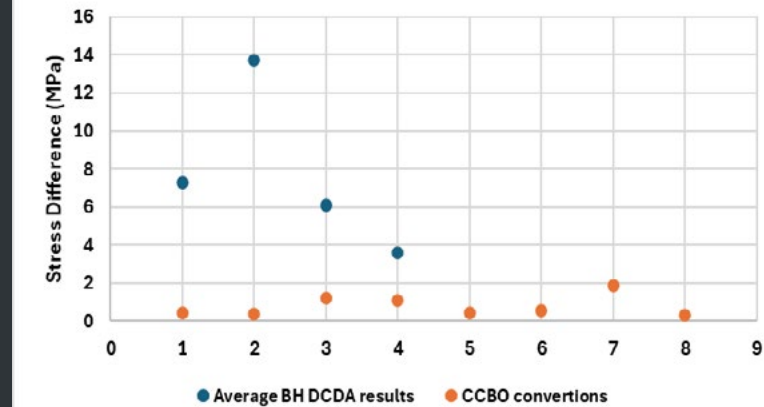
Data was CONFIRMED through analysis

WHY THIS MATTERS:

Correlation indicate method's ability to provide similar results, improving potential for application

6

Coal (Stress difference on BH Plane)



Major Principal Stress Magnitude correlation





RESULTS & DATA



CCBO

Measurements 'appropriate'

Orientations not as 'expected' but can be explained

Magnitudes slightly higher than expected but within historical ranges

DCDA

Measurements 'partly appropriate'

Orientations not as 'expected' but correlates with CCBO

Magnitudes substantially higher than expected

Correlation

*Orientation = Good correlation
Magnitudes = Poor correlation*

Key Take-away

DCDA continues to show substantial promise in being able to indicate Major Principal Stress orientation changes, but work is required on :

- Improving core quality
- Catering for anisotropy
- Calculating full stress field components

- Core quality is essential
- Elastic behaviour seem to control orientations
- Anisotropy seem to affect magnitudes
- Continued development feasible ?





WHAT THIS MEANS ?



1

Mine Operations

Mine design changes to cater for stress field component changes to **improve stability and safety of workers**.

2

Workforce Safety

Mine design changes to cater for stress field component changes can be planned and implemented before the impacts materialise.

3

Digital & Technology

Fall-of-ground prevention due to reduced impact of unexpected stress field changes.

4

Planning & Design

This technology is still in its research phases in both RSA and Japan. If successful, its use could become **standard practice** before new, different ground control districts are approached, to allow appropriate designs to be made.





CONCLUSIONS & RECOMMENDATIONS



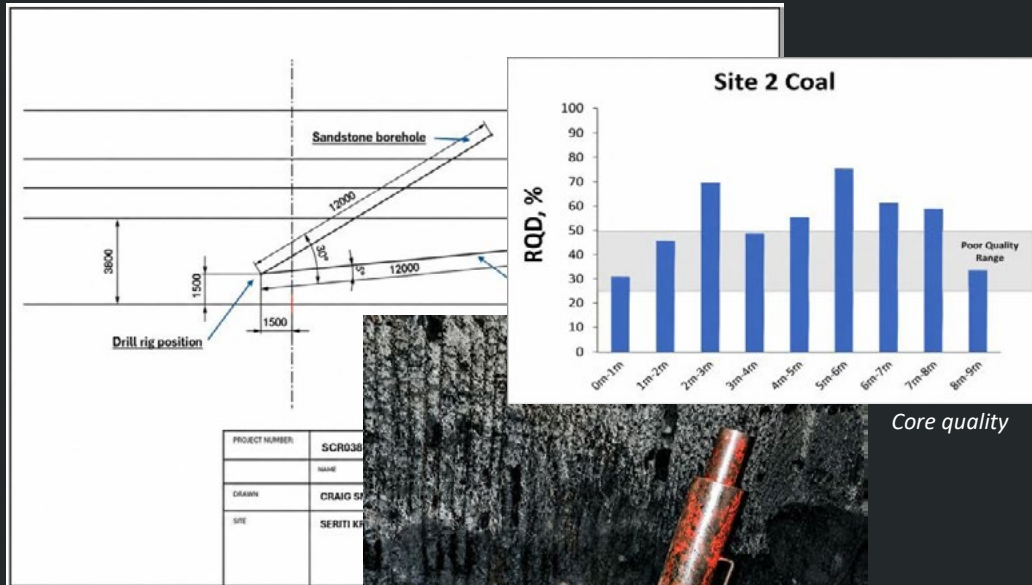
CONCLUSIONS

- C1** DCDA stress orientation results correlate with CCBO, but not magnitudes
- C2** DCDA appears to have the ability to indicate Major Principal Stress orientation changes compared to an 'expected' orientation
- C3** Core quality and anisotropy makes firm recommendations difficult

RECOMMENDATIONS FOR INDUSTRY

- R1** Continue with research into ensuring core quality and anisotropy
- R2** Develop the required methodologies to calculate more appropriate field stress component details





Core quality

Drilling layout / equipment

KEY FINDINGS

2

CCBO Measurements

- Site selection
- Instrumentation
- Data collection
- Results achieved (Orientation / Magnitudes)

Data was CONFIRMED through analysis

WHY THIS MATTERS:

Unacceptable CCBO results (control data) makes project continuation unnecessary





SURFACE ENVIRONMENT

This session delves into integrated approaches for mine water treatment, land rehabilitation, and carbon management.

- **Mine Water Treatment: From Liability to Productive Use**
 - ◊ Biological Treatment of Brines – Ryan Merckel (Mintek) – (20 Minutes)
 - ◊ Irrigation Using Treated Mine Water – Lesego Madiseng (University of Pretoria) – (20 Minutes)
- **Carbon Farming on Rehabilitated Coal-Mined Land**
 - ◊ Presenter: Wayne Truter (University of Pretoria) – (20 Minutes)
- **Carbon Capture & Energy Recovery Using Algae**
 - ◊ Presenter: Sue Harrison (University of Cape Town) – (20 Minutes)

“

Biological processes offer a sustainable alternative for treating concentrated industrial brines”





*“Managing Water, Land
and Carbon as Systems”*



**Presenting -
Biological Treatment of Brines**

Dr Ryan Merckel

Bioprocess Specialist | Mintek, Biometallurgy Division

Dr Ryan Merckel is a chemical engineer and bioprocess specialist with experience spanning academia, applied research, and industry. He has been affiliated with the University of Pretoria and Mälardalen University and has worked in the forestry, energy, and chemicals sectors before joining Mintek’s Biometallurgy Division. His work focuses on biological process development for industrial and environmental applications, particularly mine water treatment, biological sulphate reduction, sulphide management, and the biological treatment of brines. At the Colloquium, he presents research on how biological processes can offer more sustainable alternatives for treating the concentrated brines that conventional mine water treatment systems produce.





COALTECH COLLOQUIUM 2026

**SURFACE
ENVIRONMENT**
RESEARCH FOCUS AREA

THEME

*Managing Water, Land
and Carbon as Systems*



Advancing the Future of Sustainable
Coal



Biological Treatment of Brines: *The Life of Brian*

Dr Ryan Merckel & Kerri du Preez

Mintek

E2024-2 | Presented: May 2026

COMPLETED





CONTEXT & RESEARCH PROBLEM



mining-influenced water



reverse osmosis plants



hyper-saline brine ponds



Chemical treatment



Concentration



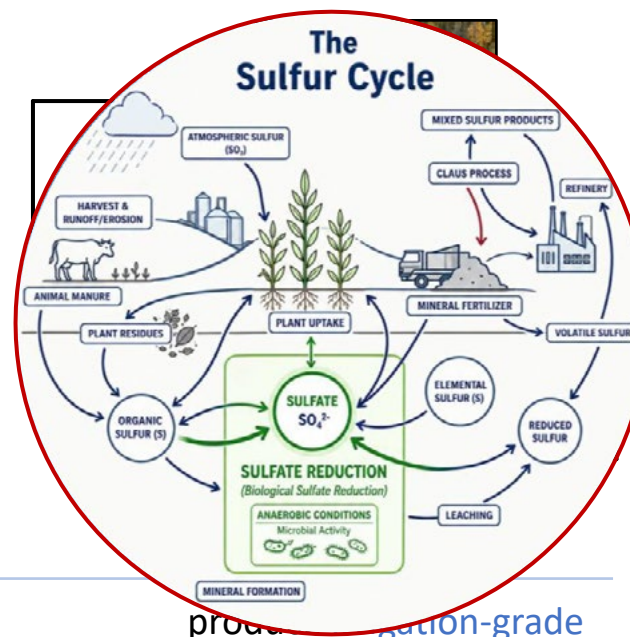
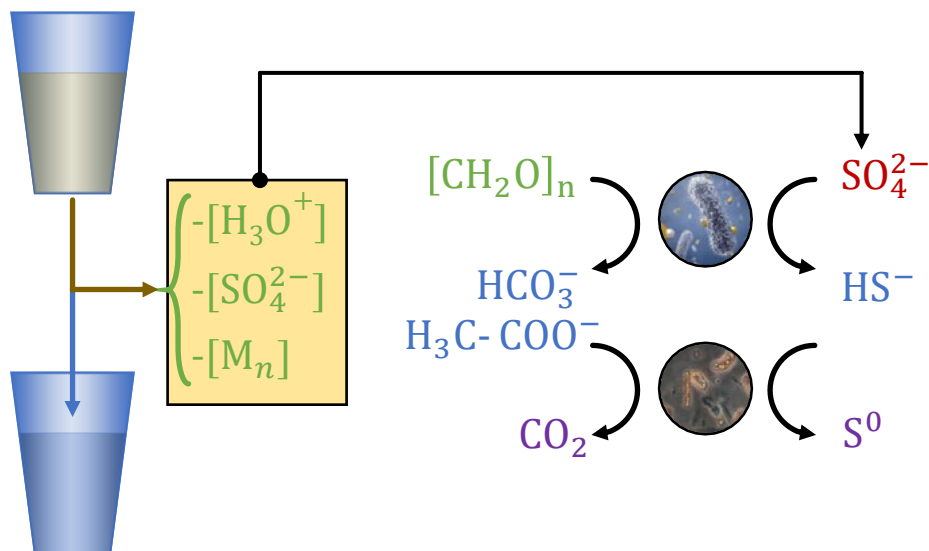
Ongoing liability





CONTEXT & RESEARCH PROBLEM

[Institution Logo]



improve water quality

employ passive processes

produce irrigation-grade water for agricultural use

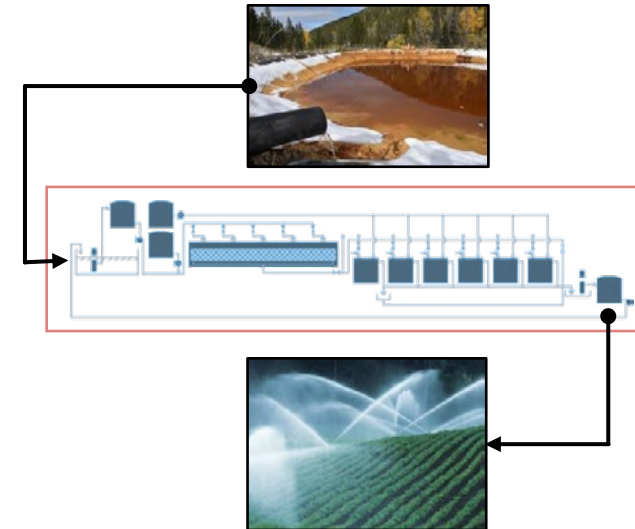
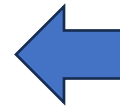




CONTEXT & RESEARCH PROBLEM



cloSURE[®] demonstration plant,
EWRP





CONTEXT & RESEARCH PROBLEM



Field observations:
H₂S presence at brine ponds





RESEARCH OBJECTIVES

SURFACE ENVIRONMENT
RESEARCH FOCUS AREA

01

Investigate applicability of **biological sulfate reduction** to **hypersaline brines**

02

Develop bench-scale **biological sulfate reduction**

03

Evaluate technical **viability**, process **performance**, and microbial **resilience**

04

Recommend pathway to **pilot demonstration**





RESEARCH APPROACH & METHOD



1

Scoping &
Literature

State of the art
BSR already established at pilot &
demonstration scales

1.1

Local precedent:

- Rhodes bioSURE Process® / vitaSOFT
- Thungela VCC bio-neutralisation plant
- Mintek cloSURE® Process

1.2

Key question:

- Can hypersaline conditions support bio-SO₄²⁻ reduction?

1.3

Baseline:

- Review BSR reactor kinetics
- Review microbial ecological and inhibitory factors





RESEARCH APPROACH & METHOD



2

Fieldwork & shake-flask studies

Study Sites
EWRP brine pond, Thungela

2.1

Sampling site:

- Thungela eMalahleni Water Reclamation Plant
- Brine Pond

2.2

Brine composition & inoculum:

- Perform compositional analysis of brine
- Generate enriched cultures from brine

2.3

Assess microbial activity:

- Confirm wild microbial activity
- Cultivate inoculum for further bench-scale test work





RESEARCH APPROACH & METHOD



3

Bench-scale work & Analyses

Main focus
Continuous bench-scale BSR
testwork

3.1

Empirical approach:

- Prioritise bench validation
- Recommend predictive modelling study for future work

3.2

Shake flask screening:

- Feasibility, kinetics, inhibition thresholds and limitations
- Initial microbial characterisation

3.3

Continuous BSR study:

- Construct and commission bench-scale reactor
- Assess process parameters and monitor stability





RESEARCH APPROACH & METHOD



4

Process validation & design parameters

[How were results checked/validated?]

Outcomes
Piloting is a possibility

4.1

Biological sulfate reduction:

- Achievable
- Sustainable

4.2

Design parameters:

- H₂S management key
- Include stripping column to off-gas H₂S continuously

4.3

Outputs:

- Validated process with process design parameters
- Pilot-ready technology with pathways to resource recovery





KEY FINDING

1 OF 3

Continuous biological sulfate reduction achievable, but with caveats

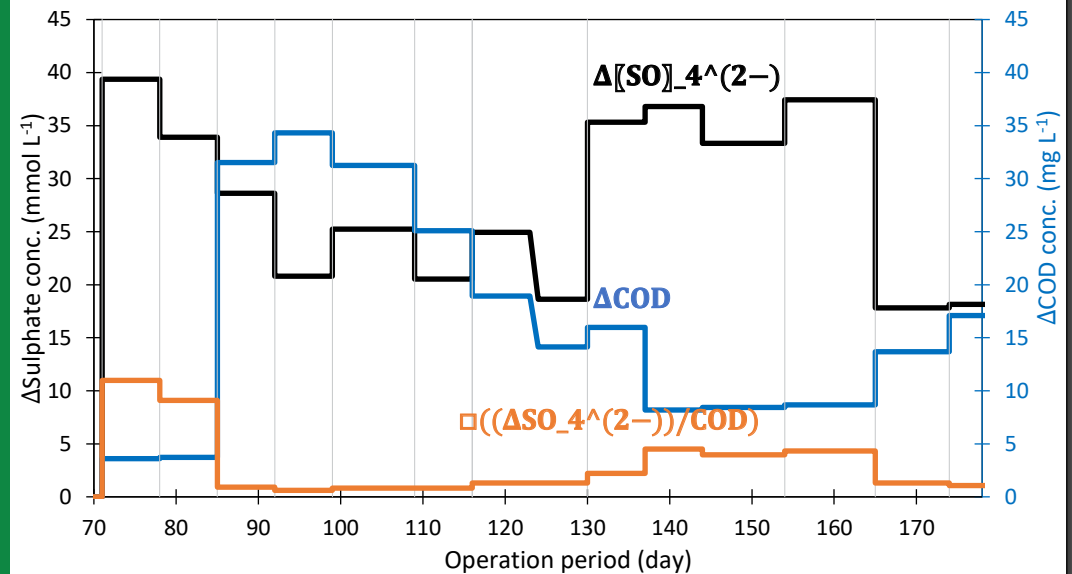
CONFIRMED

WHY THIS MATTERS:

Biological sulfate reduction is a viable option to address reverse osmosis liabilities, especially w.r.t. mine closures



SUPPORTING EVIDENCE





SUPPORTING EVIDENCE

Mineral	Neat Brine (%)	Treated Brine (%)	Precipitate (%)
Thenardite [Na ₂ SO ₄]	75.0	21.5	16.1
Gypsum [CaSO ₄ · 2H ₂ O]	-	30.5	-
Monohydrocalcite [CaCO ₃ · H ₂ O]	-	15.5	-
Calcite [CaCO ₃]	-	-	15.2
Halite [NaCl]	-	-	23.5
Apatite [Ca ₅ (PO ₄) ₃ (F, Cl, OH)]	2.9	4.7	25.8
Titanite [CaTiSiO ₅]	14.5	-	-

<minor mineralogy has been excluded from this presentation>

KEY FINDING

2 OF 3

Selective sulfate removal with mineral recovery possible

CONFIRMED

WHY THIS MATTERS:

Hypersaline brine transformed from pure liability to source of co-products.





KEY FINDING

3 OF 3

Presence of sulfate-reducing bacteria confirmed (*Desulfomicrobium*, *Desulfococcus*) with halotolerant and heterotrophic consortia presence

CONFIRMED

WHY THIS MATTERS:

Validates that hypersaline brines contain native competent microbes for biological treatment



SUPPORTING EVIDENCE

Desulfomicrobium baculatum

Desulfococcus multivorans

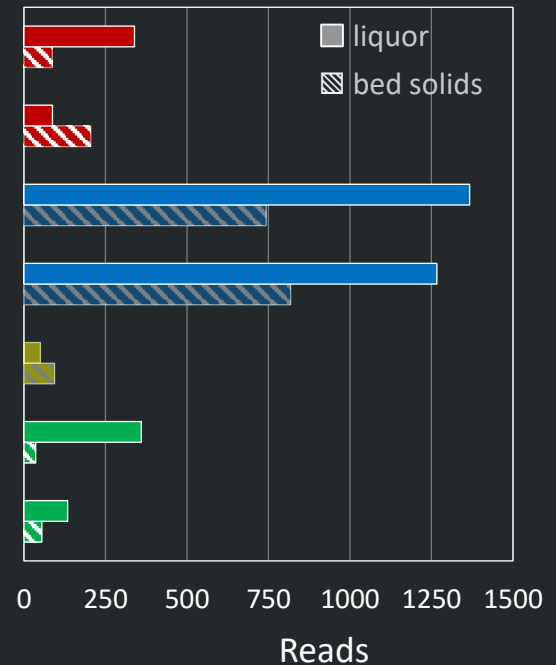
Marinobacterium iners

Uncultured *Trichococcus*

Sulfurovum mangrovi

Klebsiella oxytoca

Pseudomonas spp. (combined)



- Heterotrophs, not SRBs, seem to be rate-limiting
- Uncultured *Trichococcus* seems to be holding the consortia together



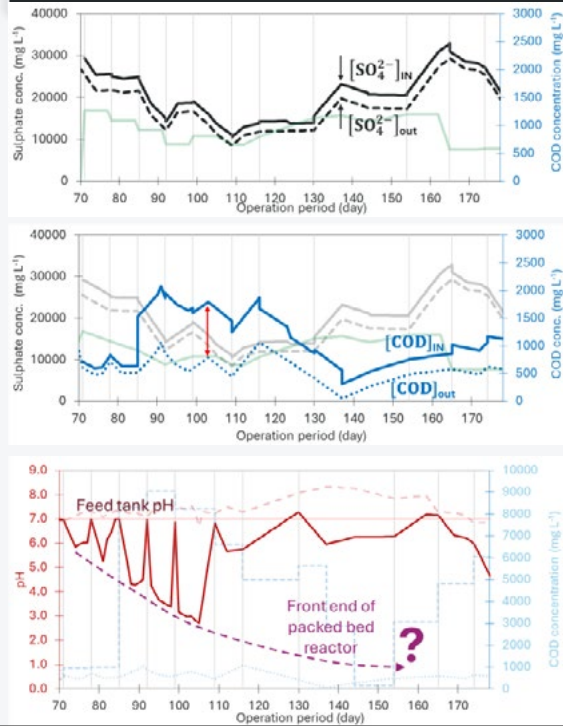


RESULTS & DATA



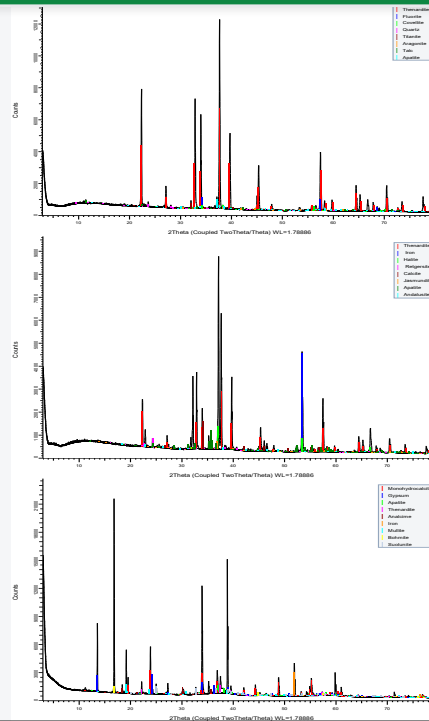
Process Operational

Process design parameters established



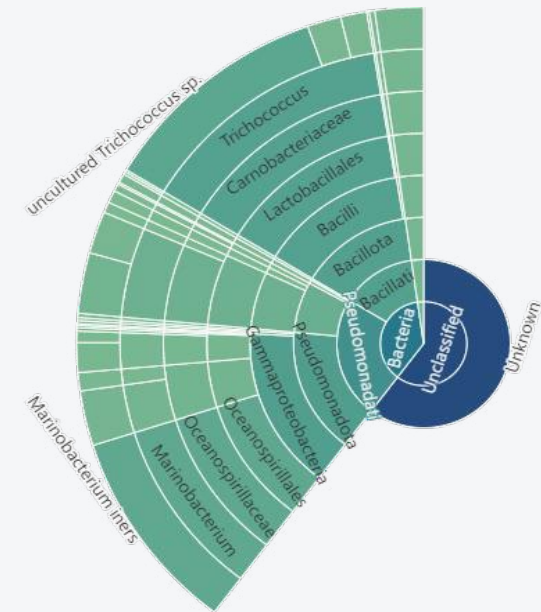
Mineralogy Characterised

Possibility for resource recovery



Microbiota Characterised

Hypersaline consortia viable





WHAT THIS MEANS FOR SURFACE ENVIRONMENT



Practical takeaways — what should your organisation do with these results?

1

Water Management

- 1. Eliminates perpetual RO brine ponds.
- 2. Treated water for discharge, reuse, or mineral recovery.

2

Land Rehabilitation

- 1. Potentially frees evaporation pond footprint for post-closure rehabilitation.

3

Carbon & Climate

- 1. Energy consumption and operational expenditure are considerably reduced.
- 2. Carbon-neutral COD feedstocks also aid in valorising other biological wastes.

4

Compliance & Closure

- 1. Converts 30-year brine liability into 5-year engineering problem.
- 2. Reduces liabilities.





CONCLUSIONS & RECOMMENDATIONS

*The key outputs from
this research and
what to do next.*



CONCLUSIONS

- C1** Biological sulfate reduction is technically proven on hypersaline brines at bench scale over 110 days.
- C2** Native competent SRBs and halotolerant microbes exist in brines; no exotic inocula required.
- C3** Consortium is robust and stable under variable feed. Scaling pathway is clear.

RECOMMENDATIONS FOR INDUSTRY

- R1** Pilot this technology at an operating coal mine closure site within 12–18 months.
- R2** Characterise uncultured *halotolerant microbes* to unlock consortium optimisation and staged-treatment design.





*“Managing Water, Land
and Carbon as Systems”*



**Presenting -
Irrigation Using Treated Mine Water**

Lesego Madiseng

PhD Candidate in Agronomy | University of Pretoria

Lesego Madiseng is an environmental and agricultural scientist with more than five years of experience in mine water irrigation research. She holds a BSc (Hons) in Environmental Soil Science and an MSc Agric in Agronomy, and is currently completing her PhD in Agronomy at the University of Pretoria. She has worked as an environmental consultant in the mining industry, specialising in rehabilitation and mine closure planning. Her presentation covers the work undertaken by the University of Pretoria's Mine Water Irrigation Research group to facilitate the acceptance and adoption of irrigation as a mine water management strategy through evidence-based decision-making. The goal is to turn treated mine water from a disposal problem into a productive agricultural resource.





COALTECH COLLOQUIUM 2026

SURFACE ENVIRONMENT

RESEARCH FOCUS AREA

THEME

*Managing Water, Land
and Carbon as Systems*



Advancing the Future of Sustainable
Coal



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YUNIBESITHI YA PRETORIA

FACILITATING IRRIGATION AS A MINE WATER MANAGEMENT STRATEGY IN THE MPUMALANGA COALFIELDS

**Lesege Madiseng, John Annandale, Phil Tanner,
Siboniso Magwaza, Panayotis Patoussias, Sakhiwo Sukati**

University of Pretoria

Project Number: E2025-2 | Presented: May 2026

Work in Progress





CONTEXT & RESEARCH PROBLEM



Maize irrigated with circumneutral calcium and sulphate-rich mine water (Middelburg, December 2024)

Why does this matter?

- Interest in using irrigation to manage mine waters is increasing
- Modelling and past practical experience show mine water irrigation can be productive and sustainable
- However, regulators and practitioners concerned about large-scale, long-term irrigation

≈ 360 000 m³/day
Mining influenced water from the MP Coalfields





CONTEXT & RESEARCH PROBLEM



Crops on rehab land irrigated with circumneutral calcium and sulphate-rich mine water (Middelburg, March 2025)

Why does this matter?

- Large areas of rehabilitated mined land close to mine water sources
- Land under control of collieries
- Offsite impacts expected to be minimal
- However, most rehab land has complex soils with low potential
 - Extreme spatial variability
 - Physical limitations

> 10 000 ha
Rehabilitated mined land in the MP Coalfields





RESEARCH OBJECTIVES

SURFACE ENVIRONMENT
RESEARCH FOCUS AREA



01 Demonstrate long-term commercial-scale irrigation

02 Identify key factors for successful irrigation of rehabilitated land

03 Model environmental impacts of irrigation with mine waters on rehabilitated land

04 Screen food, fodder and industrial crops to increase cropping system options for mine water irrigation

05 Evaluate and revise best-practice guidelines for mine water irrigation on unmined and rehabilitated land





RESEARCH APPROACH & METHODOLOGY



Three study focus areas were identified based on > 20 years of research supported by WRC, MWCB, Coaltech and industry at large

Irrigation of rehabilitated land

- Productivity and environmental impact
- Guidance on rehabilitation for irrigation

Crop screening

- Crop and soil responses to irrigation with acidic and circumneutral mine waters
- Industrial crops to address food safety concerns

Demonstration of commercial-scale irrigation with mine water

- Address concerns regarding long-term commercial-scale irrigation





RESEARCH APPROACH & METHODOLOGY



Demonstration of commercial-scale irrigation with mine water



19 ha centre pivot on unmined land in Middleburg

Maize irrigated with untreated circumneutral void mine waters rich in Ca and SO_4^{2-}

- pH: 7.2–8.8
- EC: 110–440mS/m
- SO_4^{2-} : 1000–2500mg/L

8 consecutive seasons of monitoring

- Productivity (crop growth and yield)
- Profitability
- Food safety
- Environmental impact (soil quality, surface and ground water quality)

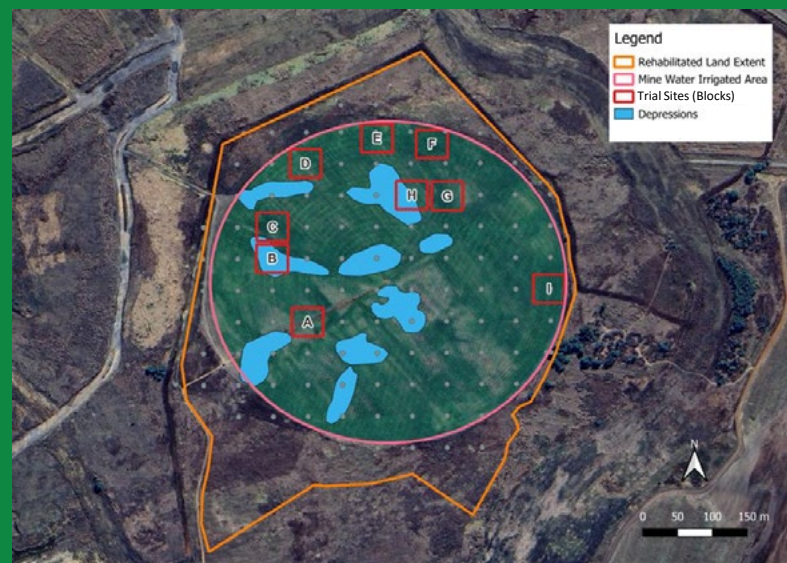




RESEARCH APPROACH & METHODOLOGY



Irrigation of rehabilitated land



20 ha centre pivot on rehabilitated land in Middleburg

- Nine sites selected based on soil physical properties and position in microlandscape
- Irrigated with untreated circumneutral void mine waters rich in Ca and SO_4^{2-}
- 1 season of monitoring and analysis
 - Productivity (yield and biomass production)
 - Soil physical properties (texture, bulk density)
 - Water movement through the profile





RESEARCH APPROACH & METHODOLOGY



Crop screening



Small plot trials at eMalahleni

- Food, fodder and industrial crops
- Irrigated with a range of mine waters, including:
 - Acid mine drainage (AMD) on **limed soil**
 - High-density sludge (HDS) treated AMD
 - Biological sulphate reduction (BSR) treated AMD
- Crops planted on a constructed platform of subsoil covered with 10-15cm of topsoil





RESEARCH APPROACH & METHODOLOGY



Crop screening



450 m² /block (water quality)

	AMD	HDS treated	BSR treated
pH	≈3	≈8	≈ 7
EC (mS/m)	≈430	≈325	≈360
SO ₄ ²⁻ (mg/L)	≈2800	≈2500	≈800
Alkalinity (mg/L)	≈5	≈21	≈1500

- 4 cropping systems replicated 4 times per block
- 1 season of monitoring
 - Crop productivity and quality
 - Soil quality





KEY FINDING

Successful irrigation with circumneutral Ca & SO4-rich mine water demonstrated on a commercial scale over medium-long term

CONFIRMED

WHY THIS MATTERS:

Success at this site has been key in promoting regulatory consideration of mine water irrigation and facilitating water use license applications



SUPPORTING EVIDENCE: PRODUCTIVITY AND PROFITABILITY

Season	Yield (t/ha)		Profit / Loss per ha	
	Irrigated	Dryland	Irrigated	Dryland
2017/18	13,5	4,5	R10 390	R6 540
2018/19	11,6	5,5	R14 990	R790
2019/20	14,3	4,9	R15 340	R5 690
2020/21	12,2	8,4	R22 200	R10 890
2021/22	14,2	8,7	R35 920	R15 980
2022/23	12,4	8,1	R19 210	R6 900
2023/24	12,6	8,5	R30 180	R15 950
2024/25	12,1	8,6	R20 460	R10 960





KEY FINDING

Not all arable land is irrigable

- *Profile hydraulic properties are a key factor for successful irrigation of rehab*
- *Poor drainage below the root zone due to subsurface compaction during rehab - major limitation to irrigability*

INDICATIVE

WHY THIS MATTERS:

Subsurface physical soil limitations are more difficult and expensive to ameliorate than surface limitations



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SUPPORTING EVIDENCE



Sorghum growing on a well-drained site vs on a site prone to ponding due to poor drainage





KEY FINDING

Not all mine waters are suitable for irrigation

- *Some level of treatment may be required*
- *Environmental impacts may not be acceptable*
- *Productive use of the water may not be possible*

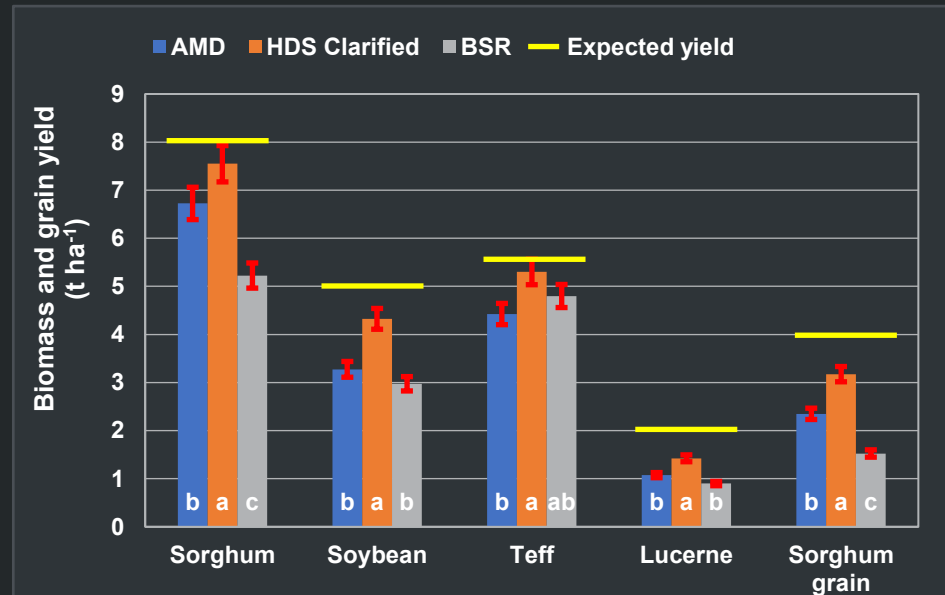
PRELIMINARY

WHY THIS MATTERS:

Irrigation with unsuitable mine water can result in financial losses and poses serious environmental and food safety risks



SUPPORTING EVIDENCE: CROP PRODUCTIVITY



Aboveground biomass and grain yield of crops irrigated with untreated AMD on limed soil, HDS-treated AMD and BSR-treated AMD





WHAT THIS MEANS FOR SURFACE ENVIRONMENT



Practical takeaways — what should your organisation do with these results?

1

Water Management

Suitable mine waters can be responsibly used for irrigation. This option makes productive use of mine water and is cost-effective compared to preferred treatment technology (Reverse Osmosis).

2

Land Rehabilitation

Good rehabilitation that prevents deep soil constraints and supports plant growth will have long-term socio-economic benefits and prevent latent environmental effects that are expensive to remediate.

3

Carbon & Climate

Irrigation with mine water is energy-efficient compared to RO treatment and is expected to contribute less to carbon emissions.

4

Compliance & Closure

Rehabilitated land that supports irrigation and agricultural productivity is more likely to achieve regulatory acceptance, successful handover, and community value.





CONCLUSIONS & RECOMMENDATIONS



CONCLUSIONS

- C1** Irrigation with circumneutral Ca & SO₄-rich mine water on a commercial scale over medium-long term is sustainable
- C2** Rehabilitated land can be productive and irrigable, but care must be taken during the rehab process to avoid subsurface compaction
- C3** Certain mine waters are not suitable for irrigation

RECOMMENDATIONS FOR INDUSTRY

- R1** Sustainable and responsible mine water irrigation requires informed decision-making and careful planning
- R2** Careful material selection and placement, as well as prevention of subsoil compaction during rehab, are critical for ensuring productivity and irrigability of rehab land





*“Managing Water, Land
and Carbon as Systems”*



**Presenting -
Carbon Farming on Rehabilitated Coal-Mined Land**

Prof Wayne Truter

Full Research Professor | University of the Free State, Green Futures Hub

Prof Wayne Truter holds a PhD in Integrated Agricultural and Environmental Sciences from the University of Pretoria. He is currently employed by the University of the Free State as Full Research Professor in the Faculty of Natural and Agricultural Sciences, Centre of Mineral Biogeochemistry, and serves as the Executive Manager of the Green Futures Hub. He is also a Research Programme Specialist Advisor at Enterprises University of Pretoria. His specialisation focuses on establishing the most sustainable, economical, and practically feasible regenerative land use management systems in disturbed and rehabilitated environments. He is a founding member and past president of LaRSSA (Land Rehabilitation Society of Southern Africa). His presentation explores how carbon farming can turn post-mining landscapes into carbon sinks rather than liabilities.





COALTECH COLLOQUIUM 2026

**SURFACE
ENVIRONMENT**
RESEARCH FOCUS AREA

THEME

*Managing Water, Land
and Carbon as Systems*



Advancing the Future of Sustainable
Coal



Carbon Farming Model for Rehabilitated Coal Mine Land

Prof Wayne Truter, Dr Emmanuel Cele and Albert van Zyl

Enterprises University of Pretoria (AF₄RICA Lab) | FPLRI RTI Institute

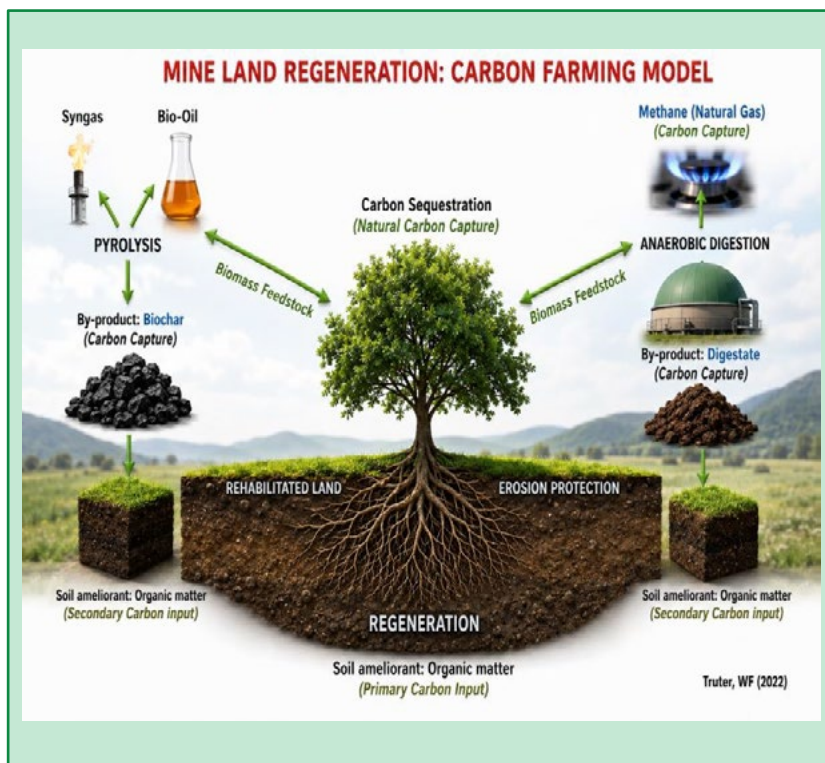
Project Number: E2023-1 | Presented: May 2026

COMPLETED





CONTEXT & RESEARCH PROBLEM



Conceptual framework of the Mine Land Regeneration Carbon Farming Model integrating biomass production, renewable energy generation, carbon sequestration and soil regeneration on rehabilitated coal mine land.

Why does this matter?

- Thousands of hectares of rehabilitated coal mine land remain underutilised, **creating environmental liabilities, erosion risks** and **declining soil quality**.
- Increasing pressure exists on the mining sector to reduce carbon footprints, support mine closure obligations and enable a just energy transition.
- **The Carbon Farming Model** integrates soil regeneration, biomass production, renewable energy generation and circular carbon management into a unified rehabilitation framework.
- **High-biomass, deep-rooted vegetation systems** are used as primary carbon inputs, while **biochar and digestate** function as secondary carbon inputs to accelerate soil regeneration and carbon sequestration.
- Biomass produced on rehabilitated land can be converted into renewable energy through **anaerobic digestion** and **pyrolysis**, producing **methane, bio-oil, syngas** and **carbon-rich soil ameliorants**.
- Research demonstrates that rehabilitated mine land can be transformed into a **productive, regenerative** and **revenue-generating asset** supporting **renewable energy production, carbon sequestration, erosion protection** and **community enterprise development**.

Thousands of hectares of **rehabilitated coal mine land remain underutilised** and require sustainable post-closure land-use solutions.

~2 728 m³ CH₄ ha⁻¹ Potential biomethane yield achieved **by annual sorghum** within the Carbon Farming Model trials.





RESEARCH OBJECTIVES

What did this project set out to achieve?

SURFACE ENVIRONMENT
RESEARCH FOCUS AREA

01

Investigate - Quantify the current soil organic carbon status and carbon mass balance of rehabilitated coal mine soils over spoils.

02

Develop - A model to evaluate high-biomass vegetation species for their soil regeneration potential (Carbon input value), **biomass production** and **renewable energy value**

03

Evaluate - Assess the role of biochar and digestate as secondary carbon inputs to improve **soil quality**, **carbon sequestration** and **rehabilitation performance**

04

Recommend - Develop and validate a circular Carbon Farming Model that transforms rehabilitated mine land into a productive post-mining asset supporting **renewable energy**, **carbon storage** and **community enterprise development**.





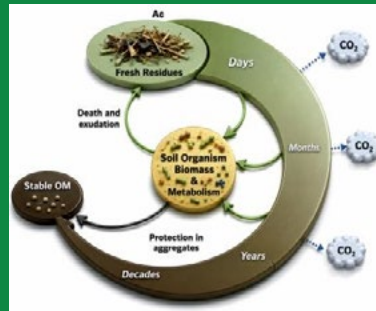
RESEARCH APPROACH & METHODOLOGY





KEY FINDING

1 OF UP TO 3



- Rehabilitated mine land can be transformed into a productive regenerative system that simultaneously **rebuilds soil organic carbon (SOC)**, produces **renewable energy feedstock** and improves long-term land functionality through integrated biological and **circular carbon processes**.
- Trials demonstrated that **biochar** and **digestate** treatments consistently improved SOC levels and plant productivity relative to untreated controls.

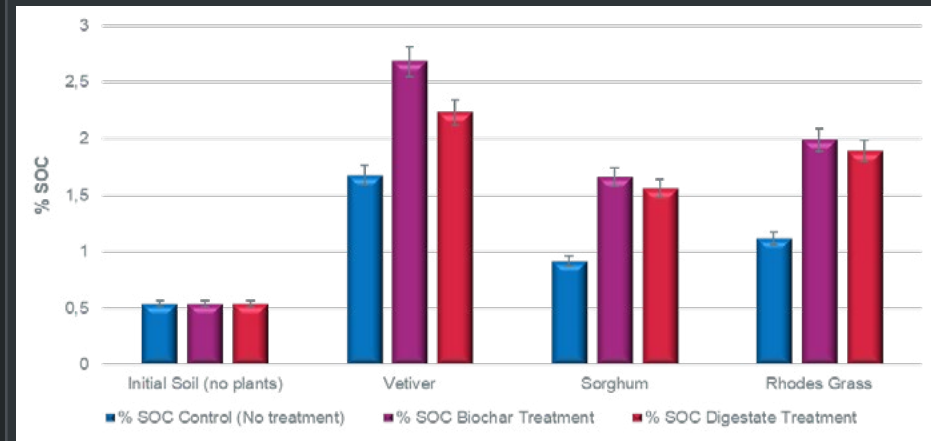
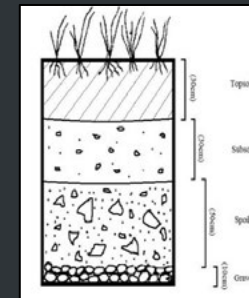
CONFIRMED

WHY THIS MATTERS:

This provides the coal sector with a practical pathway to convert post-mining rehabilitation liabilities into **carbon-sequestering, revenue-generating and environmentally sustainable land-use systems** aligned with mine closure and just transition objectives.



SUPPORTING EVIDENCE



Soil organic carbon (% SOC) response of rehabilitated mine soil under control, biochar and digestate treatments across Vetiver, Sorghum and Rhodes grass systems. Biochar and digestate significantly increased SOC accumulation compared with untreated controls.





SUPPORTING EVIDENCE



PARAMETER	VETIVER	ANNUAL SORGHUM	RHODES GRASS	INTERPRETATION
BMP (mL CH₄ g⁻¹ VS)	232 ± 4.5	325 ± 4.6	281 ± 2.6	Sorghum highest due to high VS % and low lignin
VS (% of TS)	86 ± 0.6	89.6 ± 0.5	86.9 ± 0.3	Higher volatile solids - higher biodegradable fraction
C:N Ratio	32.7	28.2	30.9	Sorghum near optimal (25–30) for anaerobic digestion
Lignin (%)	14.2	9.3	10.8	Vetiver’s lignin limits degradability
CH₄ Yield (m³ ha⁻¹)	1 742	2 728	2 093	Sorghum’s superior energy potential

Comparative biomethane production potential and lignocellulosic characteristics of vetiver, annual sorghum and Rhodes grass grown on rehabilitated mine land. Annual sorghum achieved the highest methane yield (~2 728 m³ CH₄ ha⁻¹) due to lower lignin content and favorable anaerobic digestion properties.



KEY FINDING

2 OF UP TO 3

*Annual sorghum demonstrated the **highest renewable energy production potential** among the tested species, producing the **greatest biomethane yield** due to its favorable lignocellulosic composition, high volatile solids content and optimal carbon-to-nitrogen ratio for anaerobic digestion.*

CONFIRMED

WHY THIS MATTERS:

*This confirms that rehabilitated mine land can serve as a **viable biomass feedstock platform for renewable energy generation**, supporting carbon reduction strategies, alternative energy production and post-mining economic diversification within the coal sector.*





RESULTS & DATA



2 728 m³ CH₄ ha⁻¹

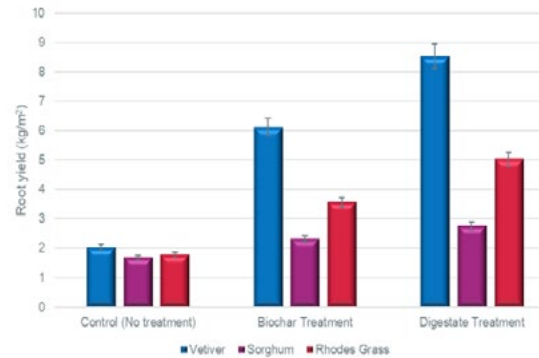
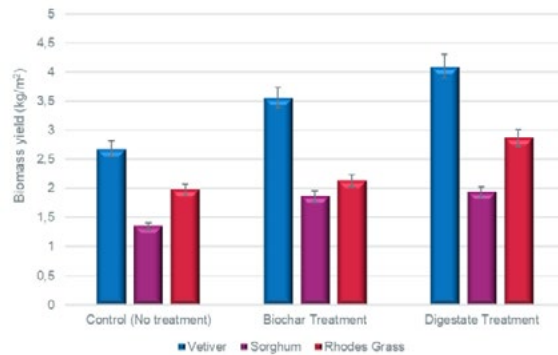
Highest biomethane yield achieved by annual sorghum

Highest SOC accumulation

Observed under vetiver systems combined with biochar and digestate treatments.

Highest Root to Shoot ratio

Observed under vetiver systems combined with digestate treatments



Comparative biomass production and root biomass response of vetiver, annual sorghum and Rhodes grass under control, biochar and digestate treatments on rehabilitated coal mine land. Results demonstrate the regenerative potential of integrated biological and circular carbon systems.

Key Take-away

- The results demonstrate that rehabilitated coal mine land can simultaneously support soil regeneration and renewable energy feedstock production when managed using integrated carbon farming principles.
- Biochar and digestate consistently improved soil organic carbon levels and plant productivity across treatments.
- **Vetiver** contributed strongly to long-term soil carbon accumulation through extensive root biomass production, while **annual sorghum** achieved the highest biomethane production potential.
- These findings confirm the technical feasibility of transforming post-mining land into a regenerative **carbon-sequestering** and renewable energy-producing system.





WHAT THIS MEANS FOR SURFACE ENVIRONMENT



1

Water Management

- Integrated vegetation systems and improved soil organic carbon enhance **soil structure**, **infiltration** and **water-holding capacity** on rehabilitated mine land.
- The use of biochar and digestate can further improve **moisture retention** and **reduce erosion risk**, supporting more resilient post-closure landscapes.

2

Land Rehabilitation

- Rehabilitated mine land can be converted into productive regenerative systems using high-biomass species such as **vetiver**, **sorghum** and **Rhodes grass**.
- These systems support **soil regeneration**, **erosion control**, **biomass production** and **improved long-term land functionality** while reducing rehabilitation liabilities.

3

Carbon & Climate

- The Carbon Farming Model provides a practical biological carbon sequestration pathway through **vegetation growth**, **soil carbon accumulation** and **carbon-rich by-products** such as **biochar** and **digestate**.
- Biomass-to-energy systems further support **renewable energy production** and **carbon footprint reduction strategies** within the coal sector.

4

Compliance & Closure

- The model supports mine closure objectives by transforming rehabilitated land from a long-term liability into a productive post-mining land-use system aligned with **just transition** and **ESG objectives**.
- The approach creates opportunities for **carbon markets**, **community enterprise development** and **sustainable post-closure land stewardship**.





CONCLUSIONS & RECOMMENDATIONS

*The key outputs from
this research and
what to do next.*



CONCLUSIONS

- C1** The research confirmed that **rehabilitated coal mine land** can be transformed into a **productive regenerative system** capable of simultaneously supporting **soil carbon sequestration**, **biomass production** and **renewable energy generation**.
- C2** **Biochar** and **digestate** were validated as **effective secondary carbon inputs** that improve soil **organic carbon levels**, **plant productivity** and **long-term soil regeneration performance** on rehabilitated mine soils.
- C3** Different vegetation species provide complementary benefits within the **Carbon Farming Model**, with **vetiver** contributing strongly to **soil regeneration** and **annual sorghum** demonstrating superior **biomethane production potential**.

RECOMMENDATIONS FOR INDUSTRY

- R1** Mining companies should **integrate carbon farming** and **biomass-to-energy systems** into **mine closure** and **post-closure land-use planning** to reduce rehabilitation liabilities and create regenerative value streams.
- R2** Further **large-scale demonstration projects** and **industry partnerships** should be established to validate the **commercial, environmental** and **carbon market potential** of regenerative mine land systems under operational conditions.





*“Managing Water, Land
and Carbon as Systems”*



**Presenting -
Carbon Capture & Energy Recovery Using Algae**

Karen Ssekimpi

Scientific Officer | Centre for Bioprocess Engineering Research (CeBER), University of Cape Town

Karen Ssekimpi holds both a Bachelor’s and a Master’s degree in Chemical Engineering from UCT. She has several years of experience in microalgal biotechnology, with a particular interest in developing sustainable and scalable solutions to environmental challenges. Her current work at CeBER focuses on advancing microalgal-based systems for wastewater treatment and resource recovery, integrating biological processes to improve water quality while generating value-added products. Her research includes the use of microalgal polycultures to remediate mine-impacted wastewater, coupled with carbon capture. At the Colloquium, she presents work highlighting the potential of these systems for addressing both water treatment and climate-related challenges for the coal sector.





COALTECH COLLOQUIUM 2026

SURFACE ENVIRONMENT

RESEARCH FOCUS AREA

THEME

*Managing Water, Land
and Carbon as Systems*



Advancing the Future of Sustainable
Coal



UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Micro-algal Systems for Carbon Capture and Energy Recovery from Mine Waters

Karen Ssekimpi, Juarez Amaral Filho and Nodumo Zulu,
Sue Harrison

University of Cape Town – Centre for Bioprocess Engineering
Research

P2020-4 | May 2026

WORK IN PROGRESS





CONTEXT & RESEARCH PROBLEM



Severe example of effects of AMD

Why does this matter?

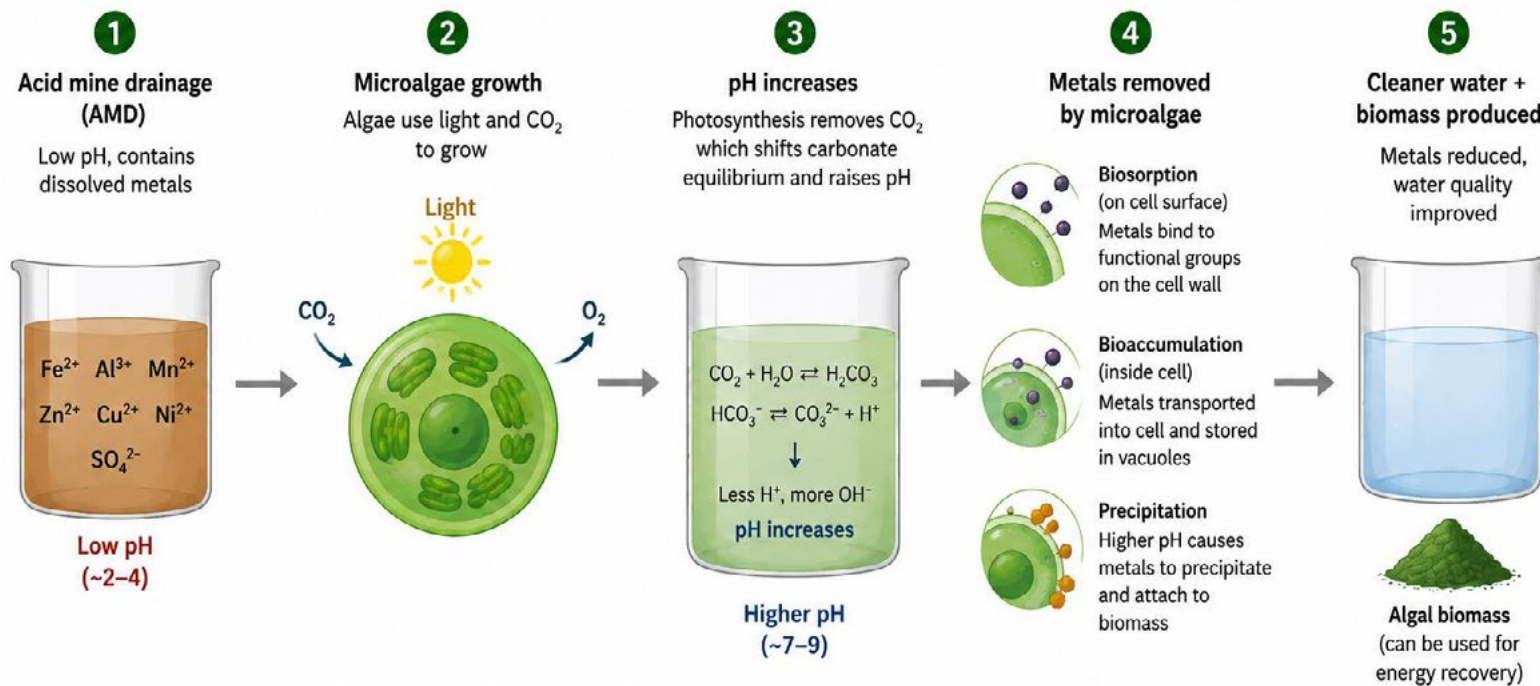
Coal mining activities generate large volumes of acid mine drainage (AMD) containing elevated concentrations of metals and sulfate. Microalgae-based treatment offers a promising alternative by simultaneously removing contaminants, neutralizing water, and producing biomass which captures carbon and can potentially be converted into bioenergy, creating a circular treatment system.

Average pH of AMD is 2.2





HOW MICROALGAE GROWS AND REMOVES METALS



AI generated image describing how microalgae grows and removes metals





RESEARCH OBJECTIVES

SURFACE ENVIRONMENT
RESEARCH FOCUS AREA

01

Investigate the growth and metal uptake of microalgae cultivated in acid mine drainage.

02

Quantify the capacity of algal systems to remove dissolved metals from AMD to neutralize and clean water.

03

Evaluate the composition of algal biomass produced during treatment to enable assessment of energy yield.

04

Recommend a continuous approach at pilot scale.

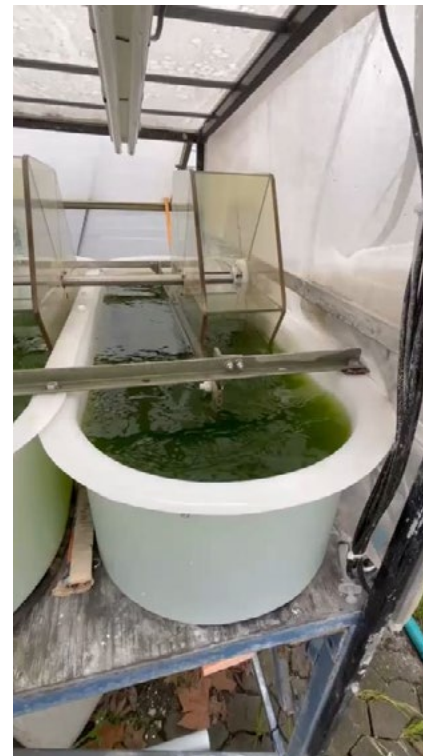




RESEARCH APPROACH & METHODOLOGY



Microalgal polycultures were cultivated in 3.2 L airlift photobioreactors and 100 L raceway ponds supplied with AMD. Growth performance, metal removal, and biomass composition were monitored to evaluate treatment efficiency and energy recovery potential.

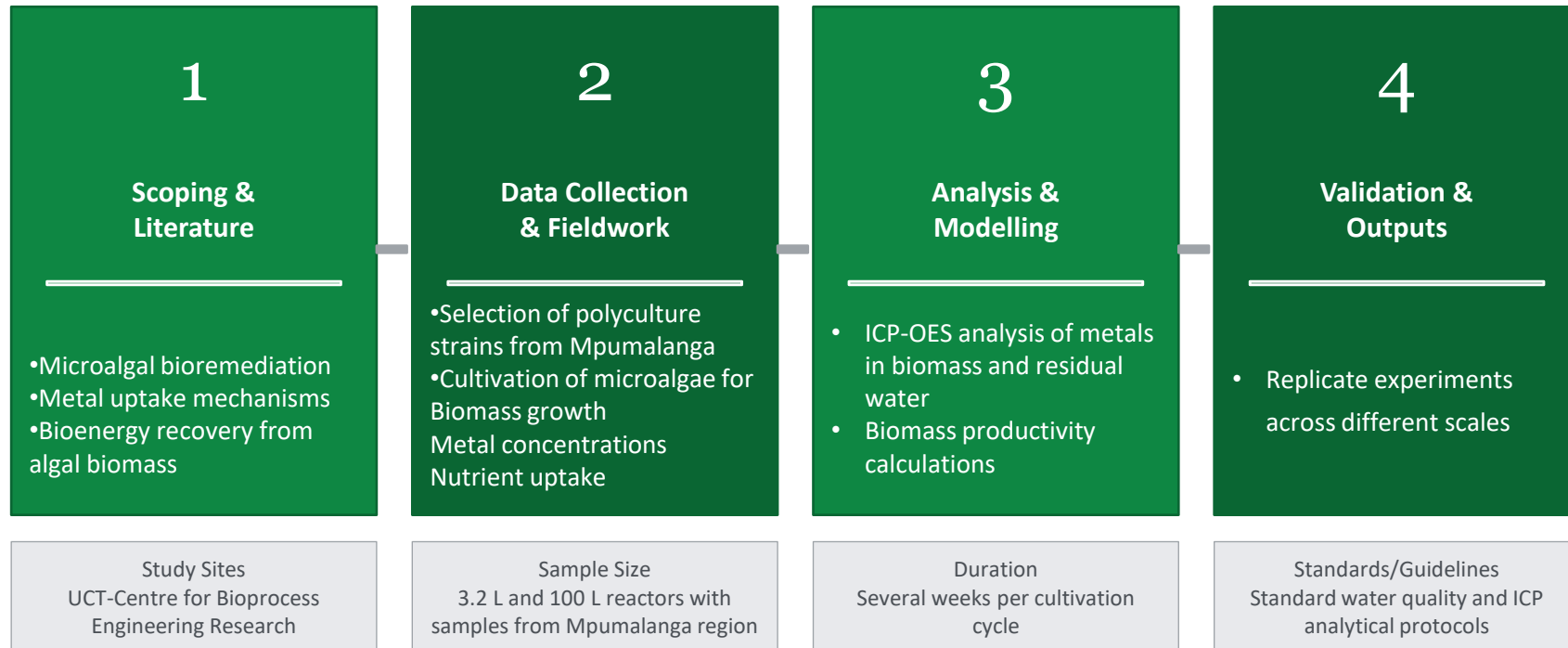




RESEARCH APPROACH & METHODOLOGY



Microalgal polycultures were cultivated in 3.2 L airlift photobioreactors and 100 L raceway ponds supplied with AMD. Growth performance, metal removal, and biomass composition were monitored to evaluate treatment efficiency and energy recovery potential.

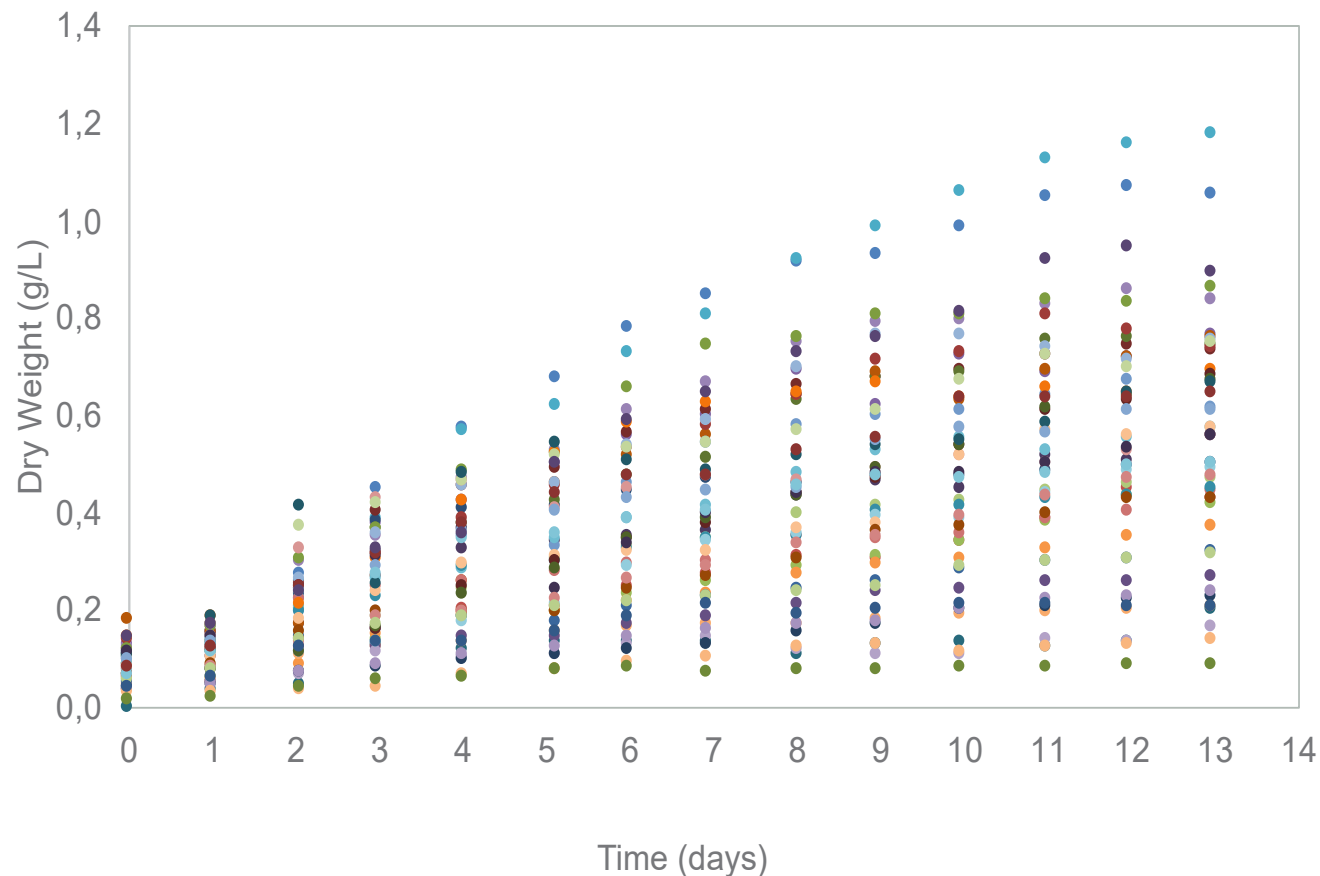




KEY FINDING 1

PRELIMINARY

SUPPORTING EVIDENCE

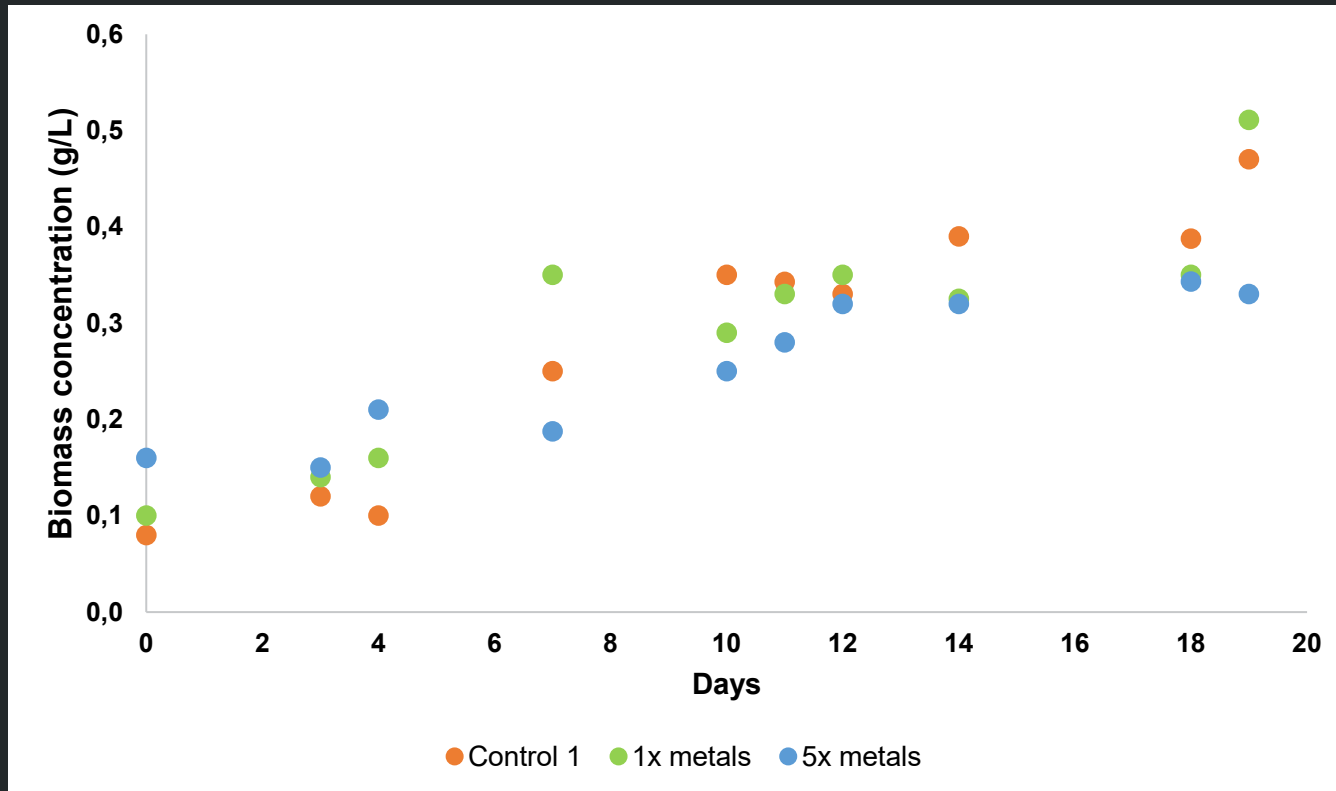


Biomass production by indigenous microalgal strains over a period of time, in the presence of metals





SUPPORTING EVIDENCE



Growth curves depicting biomass production, for the polycultures cultivated in 1x and 5x metal concentrations in the outdoor raceway ponds.

KEY FINDING 2

CONFIRMED





RESULTS & DATA



Bioconcentration Factors

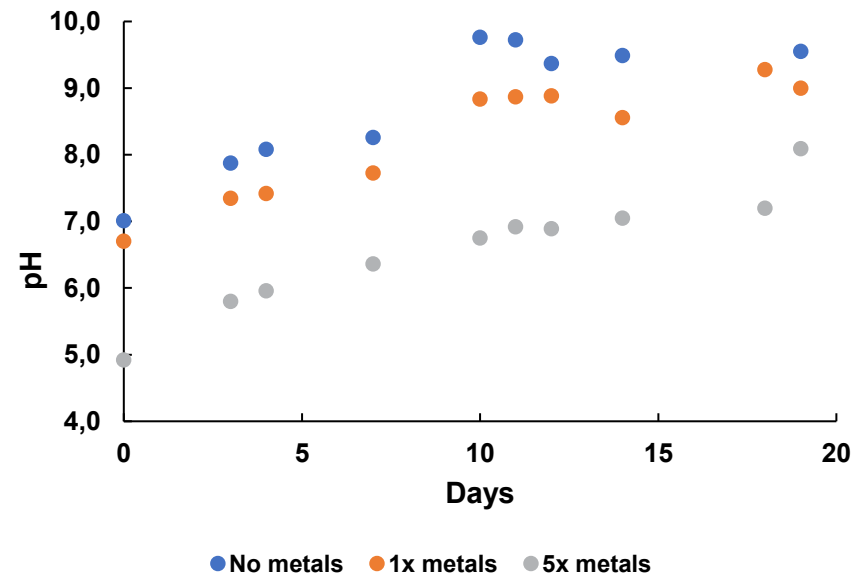
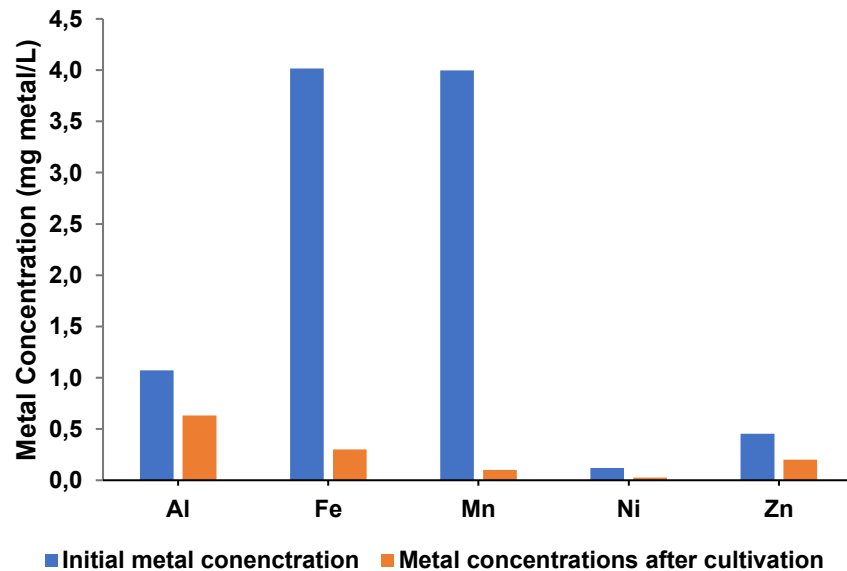
5000 for Fe, 2000 – 4000 for other metals

Metal Removal

Significant reduction in dissolved metals

Water Quality

Water improved in pH (approx.8) and metal concentration





WHAT THIS MEANS FOR SURFACE ENVIRONMENT



Practical takeaways — what should your organisation do with these results?

1

Water Management

Remediating AMD using algal biotechnology produces fit-for-purpose water without developing a sludge in waterways.

2

Land Rehabilitation

Acidification of land is reduced as AMD is treated. Improved water quality enables use for irrigation of the land.

3

Carbon & Climate

Producing energy with residual biomass acts as a carbon offset.

4

Compliance & Closure





CONCLUSIONS & RECOMMENDATIONS

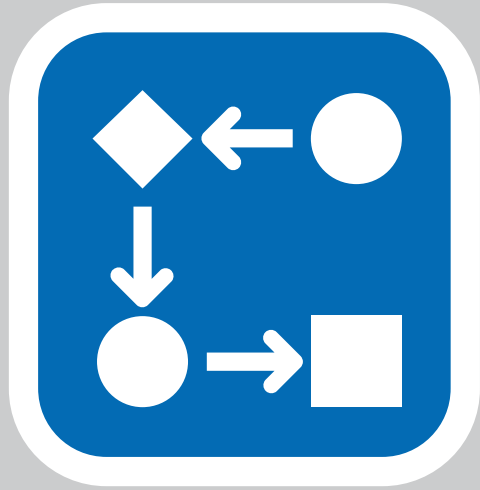
CONCLUSIONS

- c1** Microalgal polycultures can grow in AMD.
- c2** Microalgae accumulates dissolved metals from AMD during cultivation.
- c3** Algal biomass generated during treatment shows potential for bioenergy recovery given algal profiling.

RECOMMENDATIONS FOR INDUSTRY

- R1** Evaluate algal AMD treatment systems at pilot scale under continuous operation.





COAL PROCESSING

This session investigates how coal and coal-derived materials can be transformed into products of higher value.

- **Characterisation of Coal Downstream Materials for Resource Recovery**
 - ◊ Presenter: Juarez Amaral Filho (University of Cape Town) – (20 Minutes)
- **Coal-Based Circular Innovation for Asphalt Applications**
 - ◊ Presenter: Reatile Pitso (CSIR) – (20 Minutes)

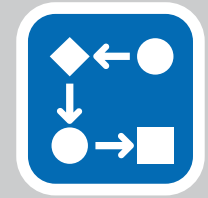
“

Detailed characterisation allows us to recover **critical minerals and create value from waste streams**”





*“Extracting New Value
from Coal and Residues”*



Presenting -

Characterisation of Coal Downstream Materials for Resource Recovery

Dr Juarez Amaral Filho

Researcher | Centre for Bioprocess Engineering Research (CeBER), University of Cape Town

Dr Juarez Amaral Filho is a researcher at UCT's CeBER whose work explores opportunities for the valorisation and repurposing of secondary resources in line with circular economy principles. His Coaltech-supported research project investigates how conventional mineral processing technologies can be applied in innovative ways to improve environmental management in the mining sector. With a particular focus on critical minerals and pyrite, the study demonstrates how detailed characterisation can support resource recovery, reduce waste-related liabilities, and create value across the coal value chain. The work is directly relevant to South Africa's strategic interest in critical mineral supply chains and the growing pressure to find productive uses for coal waste streams.





COALTECH COLLOQUIUM 2026

COAL PROCESSING

RESEARCH FOCUS AREA

THEME

*Extracting New Value from Coal
& By-Products*



Advancing the Future of Sustainable
Coal



UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA - UNIVERSITEIT VAN KAAPSTAD

CHARACTERISATION OF COAL DOWNSTREAM MATERIALS FOR RESOURCE RECOVERY

Tinayeishe Nota, Jenny Broadhurst, Sue Harrison, Juarez Amaral Filho

University of Cape Town, Centre for Bioprocess Engineering Research

Project Number: P2025-1 | Presented: May 2026

WORK IN PROGRESS COMPLETED





CONTEXT & RESEARCH PROBLEM



AI generated image

Why does this matter?

Coal beneficiation generates significant amounts of materials with little quantitative and qualitative information.

Non-coal streams are estimated at around **60 Mt/year**, with more than **2 Gt already disposed of** in mine waste storage facilities.

Classic coal characterization tools will inform applied opportunities for further value recover with economic and socio-environmental benefits.

~1.8 Mt H₂SO₄ eq./year

~520,000 t Fe/year





RESEARCH OBJECTIVES

Characterise coal waste discards and identify applied opportunities for re-purposing/valorization/functionalization

COAL PROCESSING
RESEARCH FOCUS AREA

01

Characterise South African coal discards to determine their physical, chemical, mineralogical and environmental properties

02

Assess how conventional coal processing routes can separate discard fractions with different risks and recovery potential

03

Evaluate the potential to reduce acid rock/mine drainage risk by isolating pyrite-rich fractions before disposal

04

Identify valorization opportunities from coal discard fractions, with emphasis on pyrite derived products and critical materials.

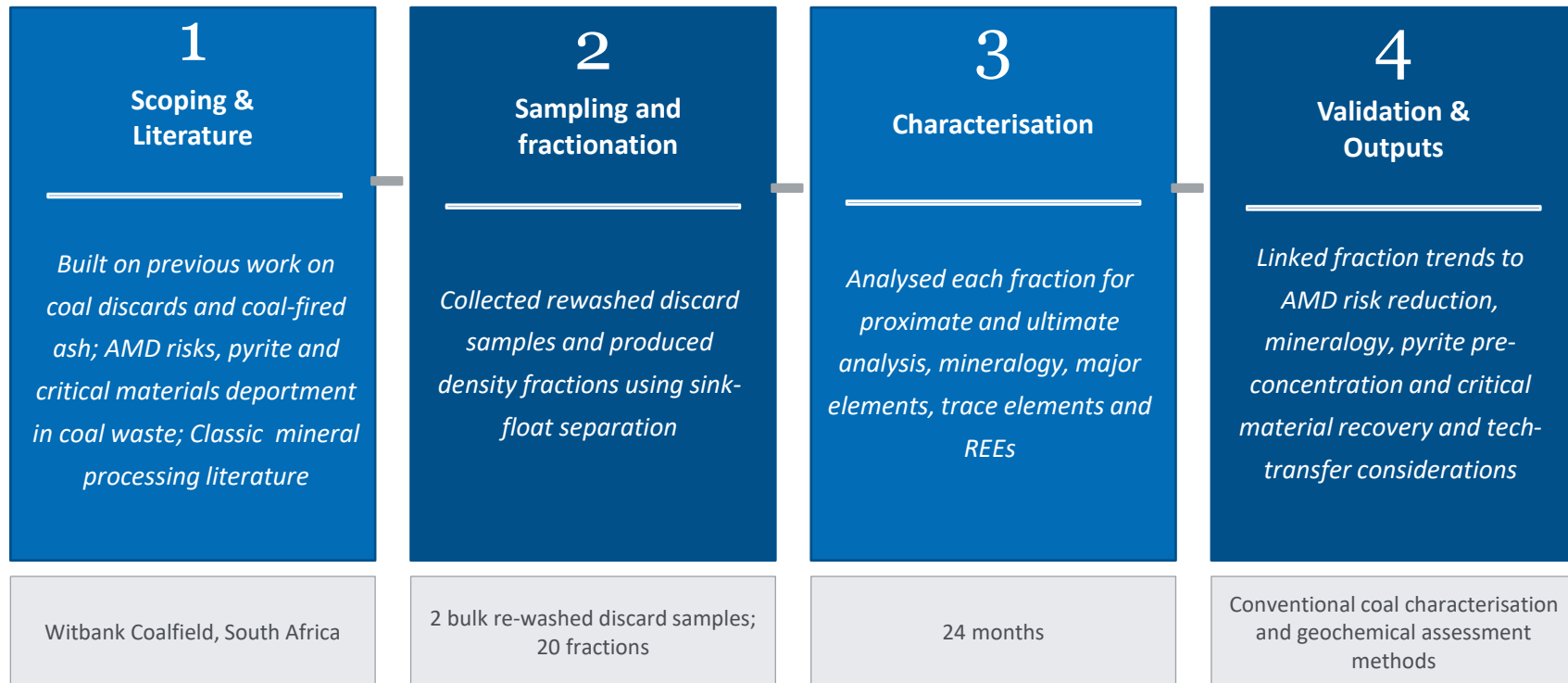




RESEARCH APPROACH & METHODOLOGY



Extended coal characterisation, including washability and geochemical methods were applied to rewashed discards to track how pyrite, REEs and other critical elements deport across density fractions. The aim was to identify fractions with different risks and circularity potential.





Key finding 1: Literature review

Bulk coal waste generates ARD/AMD, also shows weak critical-element enrichment

Coal-fired ash shows that critical materials can be enriched as they sit in non-coal phases - hard of extract

Most of the ROM gangue material reports to waste after beneficiation

Density separation concentrates ash forming and acid forming minerals in different fractions

Isolating acid and ash forming materials reduce risks and open opportunities

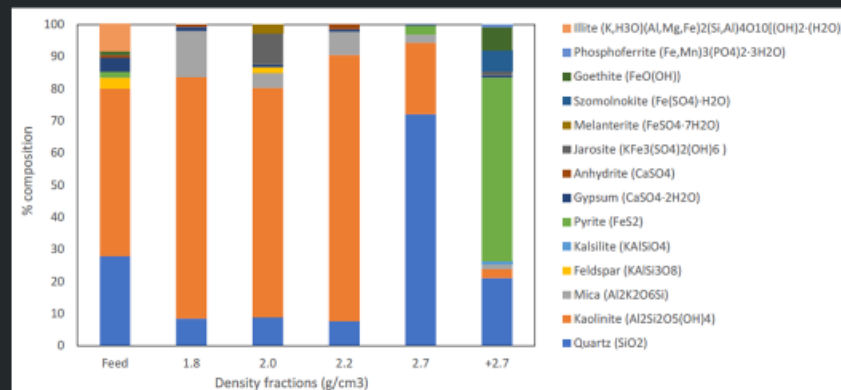
WHY THIS MATTERS:

[] PRELIMINARY [] INDICATIVE [x] CONFIRMED

This justified more detailed sink-and-float studies to test whether REEs, pyrite and other critical materials are concentrated in specific density fractions



Relative Abundance		Colliery 1	Colliery 2		Colliery 3		Colliery 4
		Slurry (1A)	Slurry (2A)	Discards (2B)	Tailings (3A)	Discards (3B)	Tailings (4A)
transition	Sc	0.25	0.66	0.56	0.26	0.42	0.74
metals	V	0.23	0.51	0.44	0.30	0.42	0.60
LREE	Y	0.43	1.01	0.89	0.44	0.68	0.96
	La	0.61	1.47	1.14	0.74	0.96	0.85
	Ce	0.64	1.51	1.20	0.73	1.11	0.90
	Pr	0.59	1.37	1.11	0.67	1.04	0.94
	Nd	0.53	1.26	0.96	0.60	0.91	0.92
	Sm	0.65	1.50	1.11	0.67	1.10	1.38
	Eu	0.46	1.06	0.86	0.52	0.75	0.93
HREE	Gd	0.70	1.48	1.22	0.72	1.08	1.53
	Tb	0.67	1.47	1.33	0.68	1.05	1.52
	Dy	0.69	1.53	1.36	0.70	1.12	1.55
	Ho	0.66	1.56	1.43	0.68	1.07	1.46
	Er	0.67	1.50	1.42	0.69	1.12	1.40
	Tm	0.71	1.67	1.67	0.75	1.24	1.50
	Yb	0.66	0.08	1.58	0.64	1.13	1.30
	Lu	0.62	1.53	1.53	0.65	1.16	1.38



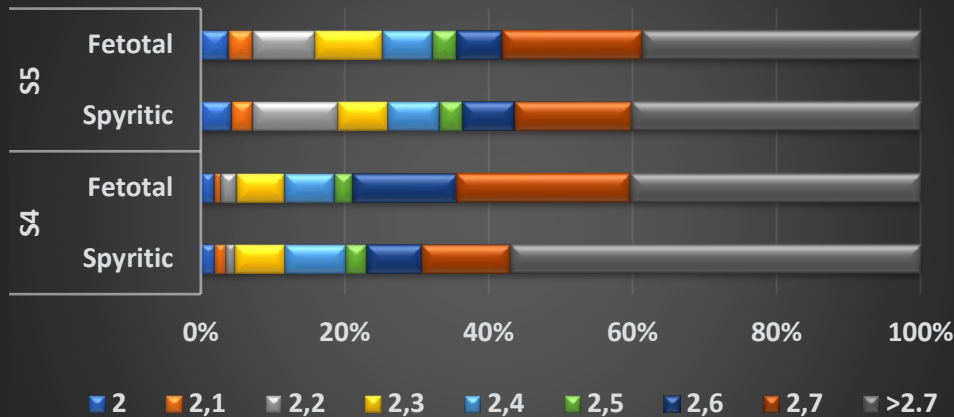
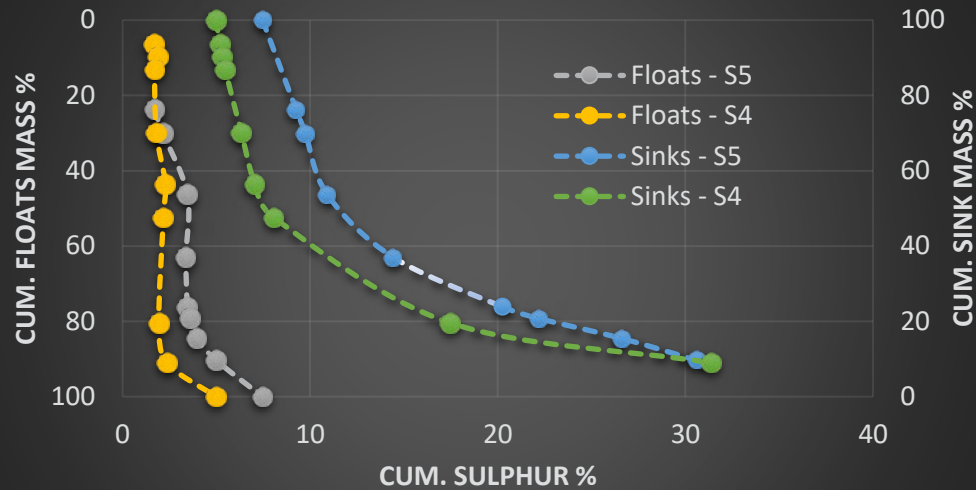
Preliminary evidence from REE enrichment patterns and DMS-based mineral separation suggests that environmental risk and material value may be concentrated in specific coal discard fractions.



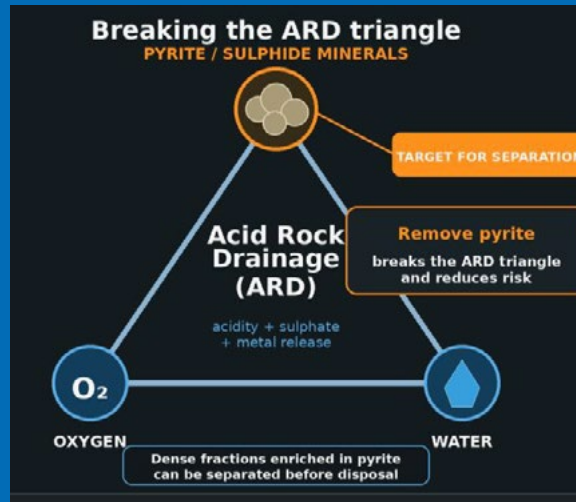


Key finding 2: Pyrite rich stream isolation

[] PRELIMINARY [] INDICATIVE [x] CONFIRMED



Pyritic sulfur and total iron department across density fractions



WHY THIS MATTERS:

A small dense fraction carries a large share of the pyrite risk, creating an opportunity to reduce AMD at source while producing a Fe-S rich stream for downstream valorisation.





Key finding 3: Considerations on Critical materials

Density separation showed where critical elements preferentially report, providing a first resource map for future recovery. The results clearly indicate that coal discards can be fractionated into streams with different environmental risks and different value-recovery potential

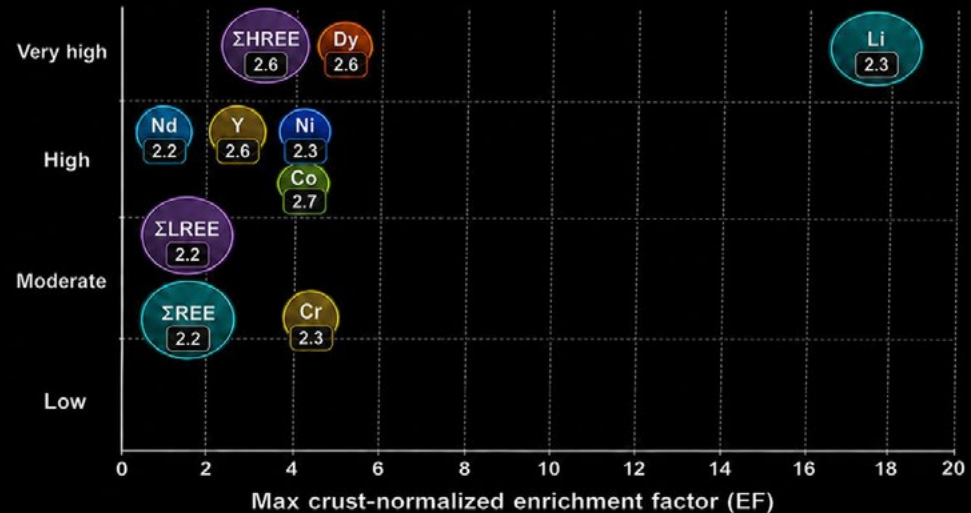
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WHY THIS MATTERS:

The same washability approach used to beneficiate coal will guide critical-material recovery by identifying priority fractions based on mineralogy, extractability, and process development.



Indicative economic / strategic relevance



Tag = best relative density (g/cm³)



Li shows the strongest enrichment (~17.7×), making it a strategic target for further investigation.



Y, Dy and ΣHREE indicate selective beneficiation potential in specific density fractions.



Economics will depend on grade, extractability, recovery potential, and processing cost offsets.





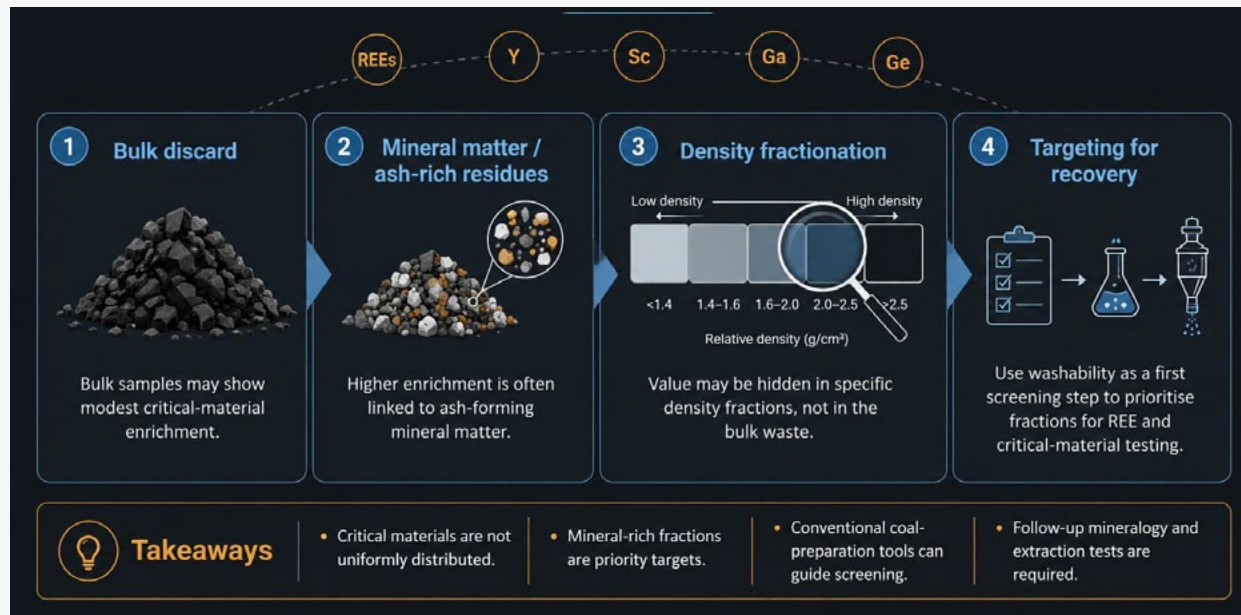
RESULTS & DATA



RD 2.0-2.2:
lower-risk zone
(~10-20% in mass)

RD 2.2-2.6: CM
enrichment zone
(~70-80% in mass)

RD >2.6: Fe-S
opportunity zone
(~10-20% in mass)



Key Take-away

Sink-and-float separation shows coal discards are not a single waste stream, but a set of fractions with different risks and opportunities. The intermediate-density fractions show the strongest critical-material signals, including Li and REE enrichment, while the high-density fraction concentrates sulfur/iron-bearing phases. This creates a practical basis for developing a more circular waste management flowsheet





WHAT THIS MEANS FOR COAL PROCESSING



Practical takeaways — what should your organisation do with these results?

1

Plant Operations

Extend routine washability tests to track pyrite, REEs and critical materials across density fractions. Non-coal fractions should be evaluated as recovery streams, not as waste.

2

Waste Management

Use fraction-specific disposal strategies. Separate pyrite-rich fractions to reduce ARD liabilities and manage lower-risk fractions more appropriately

3

Water & Energy

Reducing sulphide load at source can lower AMD treatment demand. Pyrite-rich streams will support Fe-S products recovery - e.g sulphuric acid and ferrous sulphate.

4

Capital Planning

Use the data to prioritise pilot-scale testing, cost-effective extraction and recovery research and TEA — this approach can have maximized benefits if applied in the early stages of coal mining projects





CONCLUSIONS & RECOMMENDATIONS

There is no such thing as waste



CONCLUSIONS

- C1** Conventional sink-and-float testing can transform coal discard from a disposal liability into defined streams with different environmental risks and valorisation pathways
- C2** Concentrating pyrite, is a practical route to reduce ARD risk while generating a Fe-S rich feedstock for downstream recovery
- C3** CM potential is not a bulk-discard property and not controlled only by particle size; it is also controlled by density fraction and mineral association, which creates clear targets for further testing and application

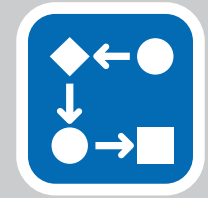
RECOMMENDATIONS FOR INDUSTRY

- R1** Coal processing operations should extend routine washability testing to include sulphur speciation, Fe department and critical-material assays across density fractions never considered before
- R2** Progress to pilot-scale fractionation, confirmation, extractability and recovery research and detailed techno-economic assessments





*“Extracting New Value
from Coal and Residues”*



Presenting -

Coal-Based Circular Innovation for Asphalt Applications

Reatile Pitso

Senior Researcher, Pavement Design and Construction Engineering | CSIR, Smart Mobility Cluster

Reatile Pitso holds a Master's Degree in Civil Engineering (Cum Laude) specialising in Transportation Engineering and is currently in the final stages of his PhD at the University of KwaZulu-Natal. He has more than 18 years of diverse experience in water supply, construction materials, pavement design, geometric design, and construction, spanning Lafarge's research operations in France and now the CSIR. His Coaltech-supported research, conducted in collaboration with the CSIR, tests whether coal waste, including coal fines, can serve as a viable substitute for natural aggregates in asphalt wearing courses. Laboratory results (Marshall Stability, Indirect Tensile Strength, Hamburg Wheel Tracking, and Four-Point Bending Beam tests) show coal waste asphalt matching or outperforming conventional mixes, with measurable cost savings where transport distances remain limited.





COALTECH COLLOQUIUM 2026

COAL PROCESSING

RESEARCH FOCUS AREA

THEME

*Extracting New Value from Coal
& By-Products*



Advancing the Future of Sustainable
Coal



Coal-Based Circular Innovation for Asphalt Applications

By

**Reatile Pitso, Johan Hanekom, Mvikeli Mpfu, Stephen Mpanamana and
Freeman Masuku**

Project No. P2024-2 | Presented 28 May 2026

RESEARCH COMPLETE





CONTEXT



South Africa's coal mining legacy generates large volumes of waste that damage land, water, and public health — demanding a sustainable reuse pathway



Coal waste impact, South Africa · Aljazeera (2015)

01

Waste at scale

Mining produces large volumes of discards and coal slurry that accumulate near operations.

02

Environmental damage

Stockpiles degrade landscape, soil and downstream water sources across mining regions.

03

Health & safety risk

Adjacent communities face elevated exposure to dust, contamination and physical hazards.





OBJECTIVE



Repurpose South African coal waste into graded asphalt wearing-course mix — turning a mining liability into a construction-grade input

01

Develop sustainable coal waste management

Design innovative, scalable approaches to managing South Africa's growing coal waste stockpiles.

02

Apply a circular economy lens

Treat coal waste as a feedstock rather than disposal — close the loop on mining byproducts.

03

Produce graded asphalt-grade material

Convert coal waste into compliant wearing-course mix for direct use in construction.



Coal waste site, South Africa · Aljazeera (2015)

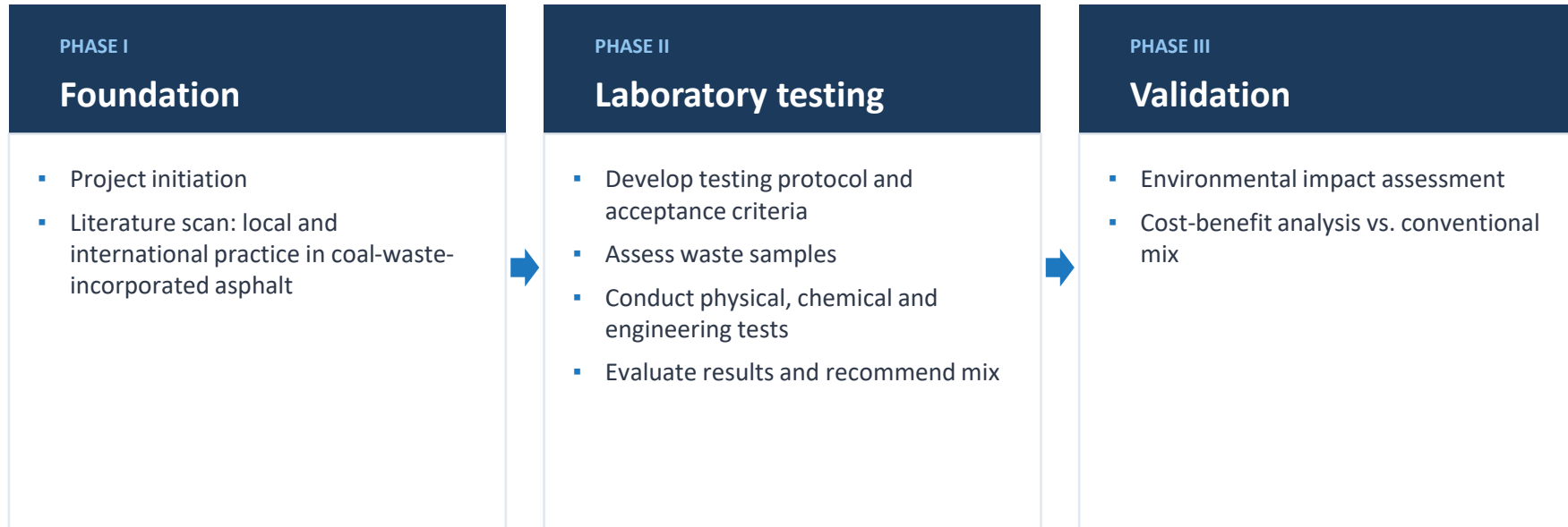




APPROACH



A three-phase programme: literature scan → laboratory testing → environmental and cost-benefit validation

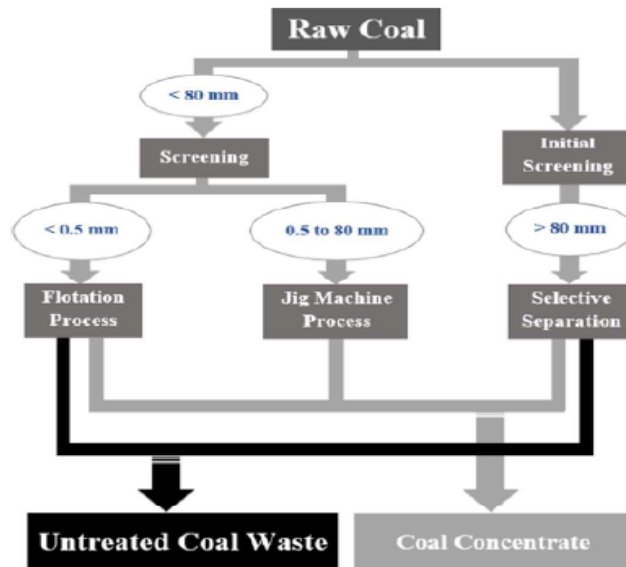




FEEDSTOCK



Three coal-waste streams sourced from beneficiation plants and power stations form the test feedstock



Coal beneficiation process · Karimaei et al. (2020)

01 Spiral discard

-5mm + 0.212mm · Coal beneficiation plants

02 Ultrafine coal waste

-0.212mm · Coal beneficiation plants

03 Coal waste fly ash

Combustion residue · Coal-fired power stations





MIX DESIGN



Three mix designs benchmarked against a conventional control across nine performance metrics



Raw materials sample

Mix Design	Conventional	Spiral Discard + Ultrafine Coal Waste (UFCW)	Reduced Lime + UFCW
Bitumen%	5.5	4.5	6
Voids in Mix%	4.2	4.5	4.6
VMA	16.5	14.8	17.1
VFB	74.8	69.7	73
Indirect Tensile Strength	698	1 184	838
Dynamic Creep	16.8	17.8	20.9
Air Permeability	0.31	0.19	0.05
Modified Lottman	0.89	0.86	0.77
Hamburg WTT@20 000 Passes (mm)	4.66	4.90	5.67





Coal waste blends increased tensile strength by up to 70% and improved rutting resistance vs. the conventional mix



Dynamic Creep test apparatus

INDIRECT TENSILE STRENGTH (ITS)

kPa — absolute tensile capacity

Conventional

698

baseline

Spiral Discard + UFCW

1,184

+70% vs control

Reduced Lime + UFCW

838

+20% vs control

DYNAMIC CREEP (RUTTING RESISTANCE)

MPa — stiffness modulus

Conventional

16.8

baseline

Spiral Discard + UFCW

17.8

stiffer mix

Reduced Lime + UFCW

20.9

stiffest

Coal waste fines boost tensile strength; ultrafine + reduced lime maximises stiffness.





Coal waste reduced permeability ~6x and held moisture resistance — except where lime was cut to 0.75%



Modified Lottman test apparatus

AIR PERMEABILITY

$\times 10^{-8} \text{ cm}^2$ — lower is better (denser, more durable)

Conventional

0.31

baseline

Spiral Discard + UFCW

0.19

-39%

Reduced Lime + UFCW

0.05

-84%

MODIFIED LOTTMAN (TSR)

Moisture susceptibility — TSR > 0.80 passes

Conventional

0.89

pass

Spiral Discard + UFCW

0.86

pass

Reduced Lime + UFCW

0.77

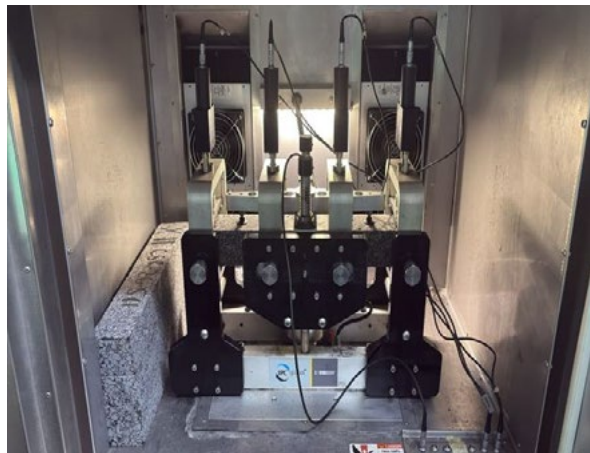
fail (lime cut)

Hamburg WTT @ 20,000 passes: all designs under 6 mm rut depth — acceptable





Fatigue life depends on strain level — at typical pavement strain (220 $\mu\epsilon$), all mixes deliver multi-year service across traffic loads



Four-Point Beam fatigue test

Strain matters more than traffic volume

Pavement design must control sub-grade strain to <250 $\mu\epsilon$ to achieve target service life

ESTIMATED SERVICE LIFE (YEARS)

Strain level ($\mu\epsilon$) vs. daily traffic load

	Light ~500/day	Moderate ~2,000/day	Heavy ~5,000/day
220 $\mu\epsilon$ <i>(low / good design)</i>	6–7 yrs	~3 yrs	1–2 yrs
300 $\mu\epsilon$ <i>(moderate)</i>	2–3 yrs	~1 yr	<1 yr
400 $\mu\epsilon$ <i>(high / under-designed)</i>	<1 yr	<1 yr	<1 yr

● Multi-year

● Marginal

● Under-designed





ENVIRONMENTAL BENEFITS



Repurposing coal waste cuts emissions, eliminates stockpiling, and closes the loop on a major mining waste stream

Carbon footprint

6–12

kg CO₂e / tonne

avoided from quarrying, crushing & transporting virgin aggregate

- Reduces emissions from conventional aggregate production
- Cuts haul distance when coal waste is co-located with road projects

Waste minimisation

–100%

stockpile

coal waste diverted from disposal into productive use

- Repurposes spiral discard and ultrafine coal waste at source
- Reduces environmental rehabilitation liability for mining operators

Circular economy



valorised

mine waste re-enters value chain as road construction input

- Creates new revenue stream from previously discarded material
- Links coal-processing and road-construction sectors





Leachate testing classifies coal waste as Pollutant Class A — safe for beneficial land use with minimal restrictions



Leachate test samples: coal waste briquettes (right) vs. conventional (left)

CLASSIFICATION

Pollutant Class A

Beneficial land use & landfill cover — minimal restrictions

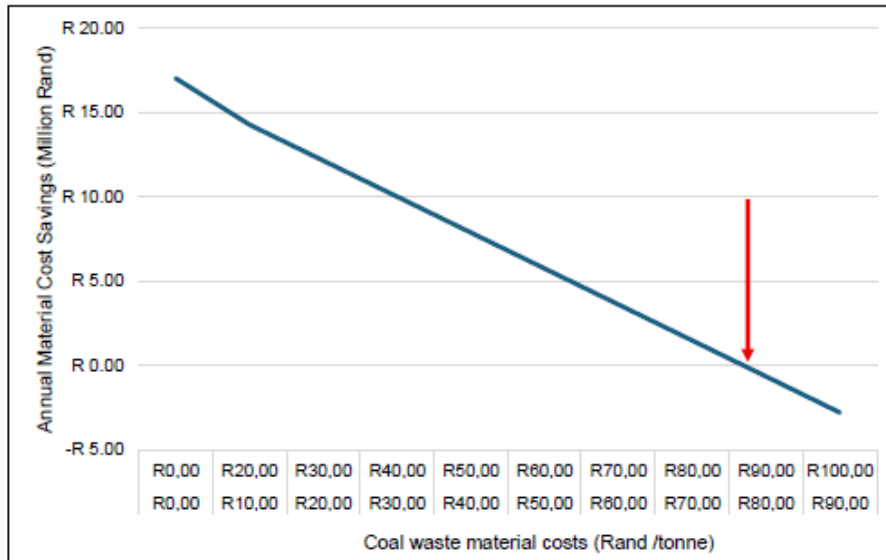
WHAT THIS MEANS

- Trace metal leaching equivalent to conventional aggregate
- Approved for use as cover material on landfill sites
- No additional environmental controls required for road construction use





Substituting 10% conventional asphalt with coal waste delivers ~R36 million in annual material cost savings



Annual material cost savings vs. coal waste material cost (Rand/tonne)

ANNUAL MATERIAL COST SAVINGS

R36 million

at 10% substitution rate

PER ROAD KILOMETRE

R6,564

road construction sector

ADDITIONAL / KM, CO-LOCATED

R5,461

if waste source near road site

Sound financial case

Savings hold for both the coal and road sectors. Co-location of waste sources near road projects amplifies the benefit.





CONCLUSIONS & RECOMMENDATION



Spiral Discard + Ultrafine Coal Waste with full lime dosage is the recommended formulation — performance, environmental safety, and cost savings align

RECOMMENDED MIX DESIGN

Spiral Discard + Ultrafine Coal Waste · full lime dosage



READY FOR PILOT TRIAL

PERFORMANCE

+70%

tensile strength vs. control

Highest ITS (1,184 kPa) with strong moisture resistance (TSR 0.86) and acceptable rut depth.

ENVIRONMENTAL

Class A

leachate classification

Safe for beneficial use; cuts CO₂ from virgin aggregate and eliminates coal waste stockpiling.

ECONOMIC

R36M

annual material savings

At 10% substitution; equivalent to R6,564/km for the road construction sector.

NEXT STEPS · Field pilot trial · Long-term performance monitoring · Cost-benefit validation at scale





FUTURE TECHNOLOGIES

This session explores emerging technologies that enhance efficiency and create new strategic opportunities.

- **High-Efficiency, Low-Emissions (HELE) Technologies**
 - ◇ Presenter: Mike Masukume (CSIR) – (20 Minutes)
- **Emissions Scope 1 & 2**
 - ◇ Presenter: Juan du Plessis (Promethium) – (20 Minutes)

“

Understanding and reporting Scope 1 and 2 emissions is now **a regulatory necessity for coal operations”**





*“The Next Frontier of
Coal Innovation”*



**Presenting -
High-Efficiency, Low-Emissions (HELE) Technologies**

Dr Mike Masukume

Principal Researcher and Project Leader | CSIR, Hydrogen South Africa and Carbon Capture and Utilisation Research Group (HySA/CCU)

Dr Mike Masukume holds a PhD in Chemical Engineering and an MSc in Project Management. He is the Project Leader for the strategic Circulating Fluidised Bed (CFB) Project at the CSIR, focused on developing a Basic Engineering Package for a 500 kW CFB plant in South Africa. The overall aim is to establish a CFB facility as an alternative to conventional coal combustion technology in order to demonstrate its fuel flexibility and emission control capabilities. He is also co-developer representing CSIR in the Mast3RBoost consortium, an international collaboration of 13 partners developing hydrogen storage technology. His presentation makes the case for HELE technology as a practical transition pathway for South Africa's coal fleet.





COALTECH COLLOQUIUM 2026

**FUTURE
TECHNOLOGIES**
RESEARCH FOCUS AREA

THEME

*The Next Frontier of Coal
Innovation*



Advancing the Future of Sustainable
Coal



HELE: Circulating Fluidized Bed Project

Mike Masukume

Council for Scientific and Industrial Research (CSIR)

Project Number: F2025-4 | Presented: 28 May 2026

FEASIBILITY STAGE | 2025/26





THE CASE FOR CLEANER COAL IN SA

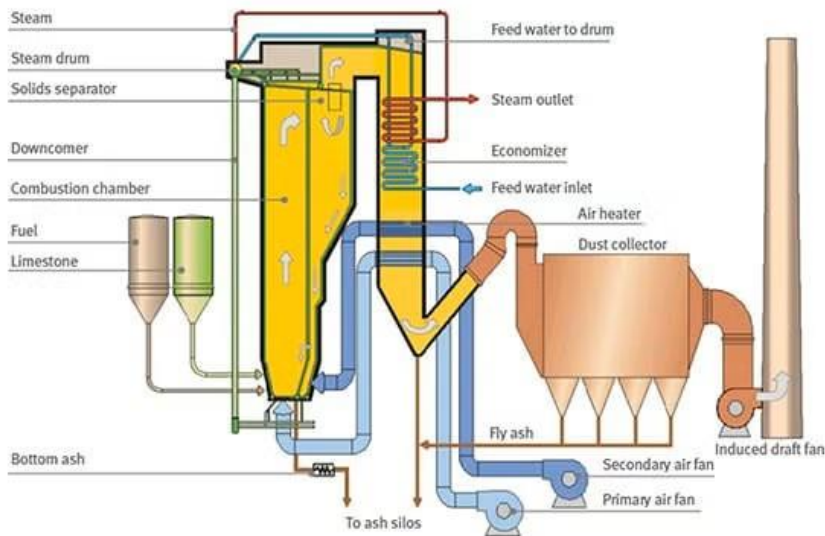


Figure 1: Schematic diagram of a circulating fluidized bed boiler (source: Amec Foster Wheeler)

Why does this matter?

Coal anchors South Africa's economy — nearly 100,000 jobs and most of the country's electricity. IRP 2025 keeps coal in the mix to 2050.

But the ageing pulverised coal (PC) fleet faces tighter emission limits, lower fuel flexibility and growing energy-security risk.

Some Eskom power stations are about to reach their end of life

An opportunity to repower the old power stations with cleaner coal technology - sustain jobs in the value chain and ensure energy security

IRP 2025 requires a clean-coal technology demonstration plant by 2030 — the window to act is now.

Circulating Fluidised Bed (CFB) combustion (left) a HELE technology of choice: Cleaner coal combustion (reduces SO₂, NO_x, CO₂ and PM) and greater fuel flexibility (can use low-grade coal, discards and biomass).

SA has 9.9 billion tons of coal reserves (Erdogan et al., 2025).

98 269 people are directly employed in the coal industry (Energy Council of South Africa report, 2025)

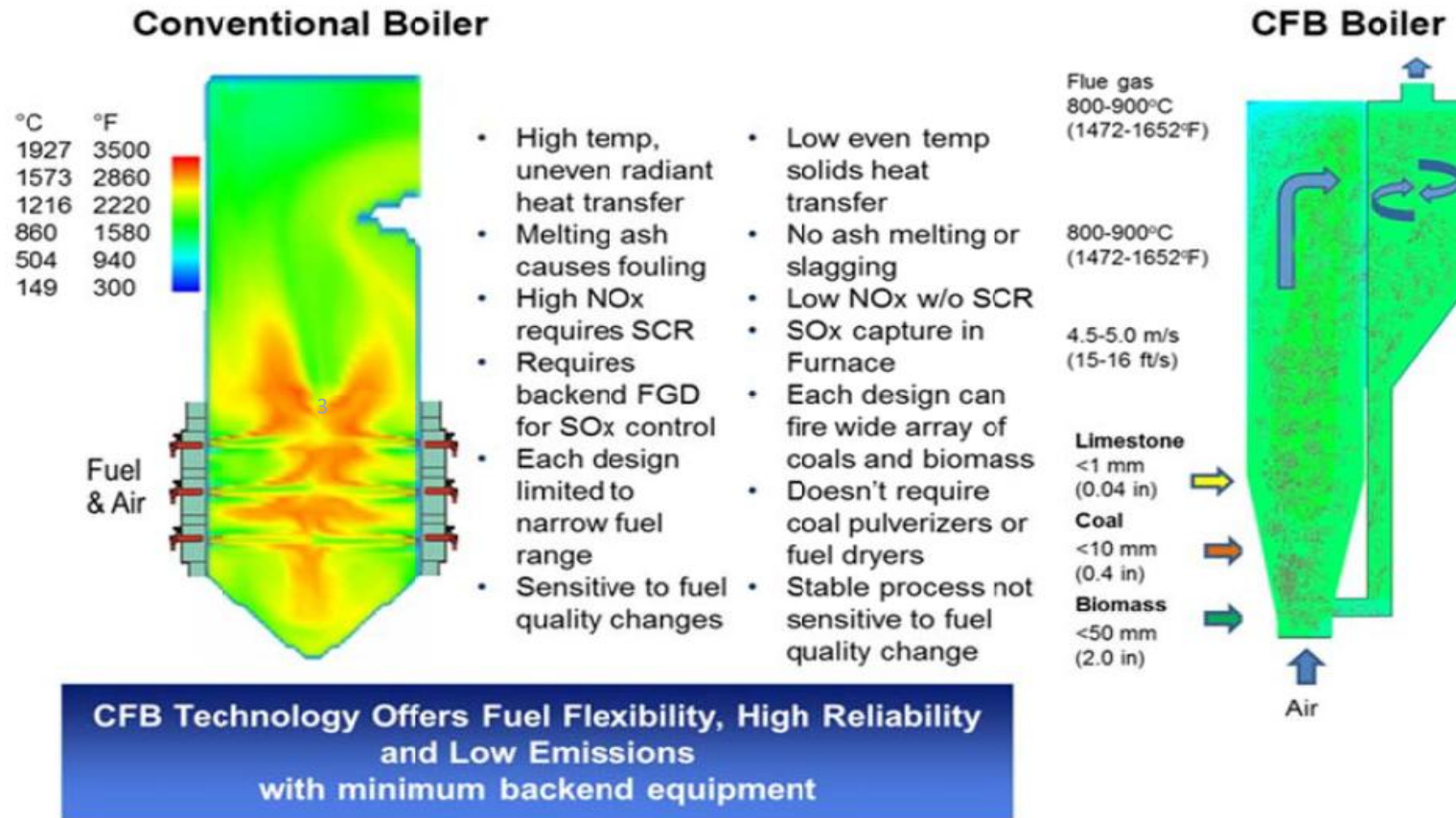
SA is the 7th largest coal producer in the world (Energy Institute, 2023). Coal remains part of the energy mix into 2050 (IRP 2025)

Up to 660 MW_e commercial CFB plant already in operation (Enterprise Asia, 2024)





PC Technology versus CFB technology



Source: Amec Foster Wheeler





WHAT WE NEED TO PROVE

*Four questions a pilot
plant must answer for SA*

FUTURE TECHNOLOGIES
RESEARCH FOCUS AREA

01

To explore the feasibility of establishing a 500-kW_t CFB test combustor in the country to demonstrate the technology's fuel flexibility and emission control capabilities under local conditions.

02

Assess the combustion performance of coals, discards and biomass

03

Test greenhouse gas and pollutants emission reduction

04

Develop local expertise, skills and capacity for future CFB commercial operations (local engineers and researchers)





FROM PILOT TEST TO POWER STATION:
THE ROADMAP



Short-term (year 1 – 2025/26)

Feasibility study and pre-EPC

Feasibility Study	
1	Technology review
2	Study - Test unit specification
3	Process Design Package - Overall facility
4	Study - Location selection
5	Special design considerations
6	Process Design Package - Unit level
7	Technol Economic Assessment Study
8	Project risk register
Pre-EPC Activities	
1	Activity and resource planning
2	Preparation of Engineering Contractor tender documents
3	Tender process including evaluation and selection
4	Early engagement with CSIR facilities
5	EIA and permitting activities

- 90% Complete
- On budget

Medium-term (years 2-3)

- To commence in Aug 2026

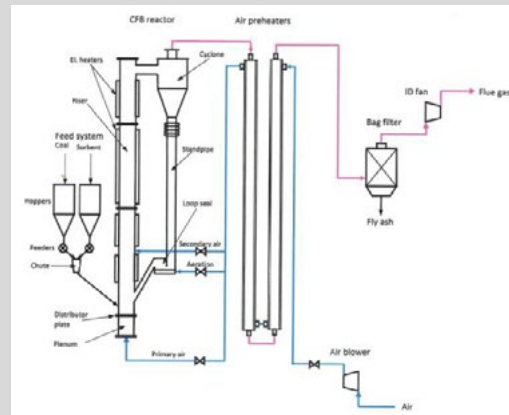
Engineering

FEED and detailed engineering activities

Long-term (4+ years)

- Target completion by mid 2029

Procurement, Construction and Commissioning



Demonstration

- Characterise and assess the performance of low-grade coals, biomass and wastes,
- Test GHG and other emissions reduction (SO₂, NO_x and N₂O)
- Costing, techno economics and business case confirmation
- Technology package for deployment





KEY FINDING

1 OF 3

CFB is proven internationally but unproven at scale on SA coal blends.

PRELIMINARY INDICATIVE CONFIRMED

WHY THIS MATTERS:

The overall process is understood and technical specifications are known.



SUPPORTING EVIDENCE

International commercial references exist above 100 MWe. Performance on SA high-ash, variable-quality coals and on coal discards has not been demonstrated at representative scale. This is the evidence gap this project is designed to close.





KEY FINDING

2 OF 3

- *A 500 kWth test unit is the minimum credible scale for validation.*
- *Basic design and costing completed*

[] PRELIMINARY [] INDICATIVE [x] CONFIRMED

WHY THIS MATTERS:

Below this scale, CFB fluid dynamics and combustion behaviour do not translate meaningfully to commercial deployment.



SUPPORTING EVIDENCE

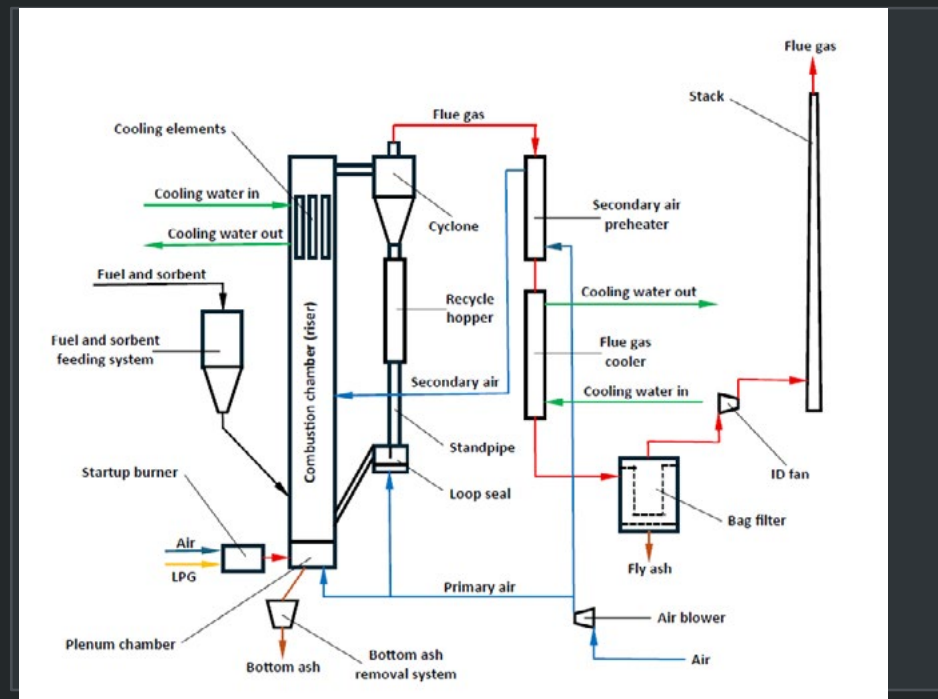


Figure 1: Simplified Schematic Diagram of the 500 kWth CFB Combustion Test Facility





SUPPORTING EVIDENCE



Figure 2: Eskom Rosherville Campus

KEY FINDING

3 OF 3

Eskom Rosherville is the recommended host site.

[] PRELIMINARY [] INDICATIVE [x] CONFIRMED

WHY THIS MATTERS:

Sitting at an Eskom operational footprint unlocks grid access, coal handling and utilities, shortens permitting pathways and aligns the evidence directly to Eskom’s fleet strategy needs.





RESULTS & DATA
Example of international plant



Fuel Flexibility

Fuel flexibility confirmed

Emissions Control

Emission control capabilities confirmed

Combustion Efficiency

High combustion efficiency



Figure 3: Samcheok Green Power Plant, South Korea.

Key Take-away

Guaranteed emissions:

SO₂: 50 ppm

NO_x: 50 ppm

PM: 20 mg/m³n

CO₂: 800 g/kWh

Source: Amec Foster Wheeler

CFB boilers: 4×550 MW_e

Fuel: high-moisture Indonesian coal and biomass





WHAT THIS MEANS FOR FUTURE TECHNOLOGIES



Practical takeaways — what should your organisation do with these results?

1

Clean Coal Technology

The technology allows for clean coal combustion with reduced emissions of SO₂/NO_x/PM/CO₂ that falls within newer and more stringent environmentally accepted standards.

2

Energy Transition

Clean coal technologies will provide baseload power in the transition period to the low carbon economy.
The use of coal discards and biomass for energy generation will support a circular economy.

3

Industrial Application

There is an opportunity to repower old Eskom coal-fired plants with a cleaner ultra supercritical CFB technology and extend their operational life.

Opportunity for local industry to use their low grade coal and discards – optimized reserve utilization and possible mine life extension

4

Capacity Building

Training of local engineers, scientists and operators to build a skills base for future commercial deployment.





CONCLUSIONS & RECOMMENDATIONS



Figure 4: Łagisza 460 MW SC CFB power plant, Będzin, Poland

Source: Amec Foster Wheeler



CONCLUSIONS

- C1** • CFB Technology for coal combustion has already been commercialized in many jurisdictions with excellent fuel flexibility and emission control capabilities.
 - C2** • Localisation attempts in neighbouring countries hit operational challenges — SA needs a local pilot plant to derisk the technology.
 - C3** • The current project will enable us to meet the IRP 2025's 2030 deadline.
 - The project will also support Eskom's JET strategy
-
- R1** • Support for the next phases is the most direct way for industry to shape the 2030 demonstration — and the policy direction that follows.





*“The Next Frontier of
Coal Innovation”*



**Presenting -
Emissions Scope 1 & 2**

Juan du Plessis

Climate Change Advisor | Promethium Carbon

Juan du Plessis is a mechanical engineer with a Bachelor's degree in Mechanical Engineering and a Master's in Additive Manufacturing from North-West University. He currently serves as a Climate Change Advisor at Promethium Carbon, where he assists organisations with developing climate change mitigation strategies, conducting GHG inventories, and ensuring compliance with carbon regulations. He specialises in carbon footprint calculation using ISO 14064 standards and the GHG Protocol, lifecycle assessments, and energy efficiency. He has worked across mining, finance, floriculture, and manufacturing sectors. His presentation addresses how coal operations should understand, measure, and report their Scope 1 and 2 emissions in the current South African regulatory environment, as carbon tax and reporting requirements continue to tighten.





COALTECH COLLOQUIUM 2026

FUTURE TECHNOLOGIES

RESEARCH FOCUS AREA

THEME

*The Next Frontier of Coal
Innovation*



Advancing the Future of Sustainable
Coal

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ENHANCING SCOPE 1 AND 2 EMISSIONS MANAGEMENT IN THE SOUTH AFRICAN COAL MINING INDUSTRY

Juan Du Plessis

Promethium Carbon

Project Number: F2025-X | Presented: May 2026

COMPLETED





CONTEXT & RESEARCH PROBLEM

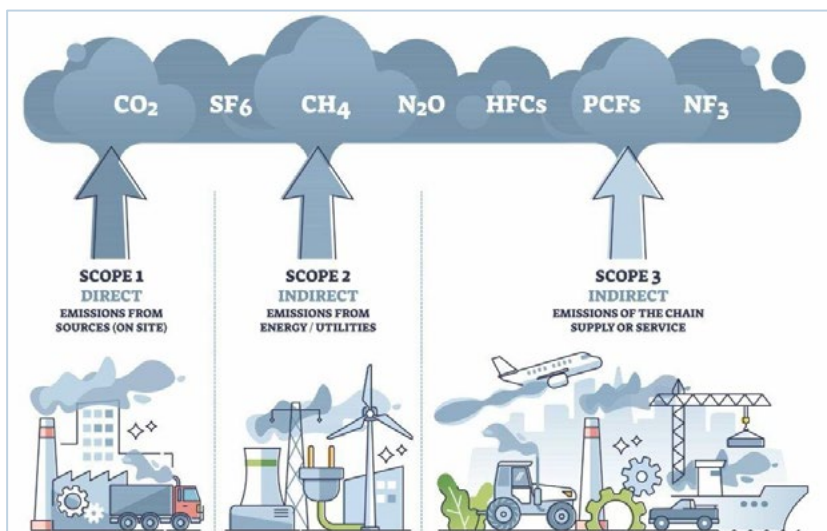


Figure 1: Greenhouse Gas Emissions from General Company Operations¹

¹Peterdy, K. Miller, N. Carbon Accounting. Corporate Finance Institute. 2022.

Why does this matter?

- South Africa's coal mining sector is facing increasing pressure to manage GHG emissions while maintaining its role in energy security and economic activity.
- The research addresses a sector-wide knowledge gap: Scope 1 and 2 emissions are significant, but reporting consistency, verification, emissions management, and quantified mitigation planning remain uneven.
- Emissions management directly affects carbon tax exposure, carbon budgeting, access to finance, and stakeholder credibility.
- This research helps the sector to measures to improve emissions management and to identify and prioritise high-impact mitigation actions.

Total Scope 1 & 2 Emissions:
6 733 ktCO₂e

Main Emission Drivers:
Diesel combustion, fugitive methane,
and purchased electricity





RESEARCH OBJECTIVES

*What did this project
set out to achieve?*

FUTURE TECHNOLOGIES
RESEARCH FOCUS AREA

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01

Investigate current practices of emissions management in the South African coal mining sector

02

Document current best practices for emissions management

03

Evaluate the South African coal mining sector's emissions management progress against best practices

04

Identify opportunities and recommend further emissions management enhancements

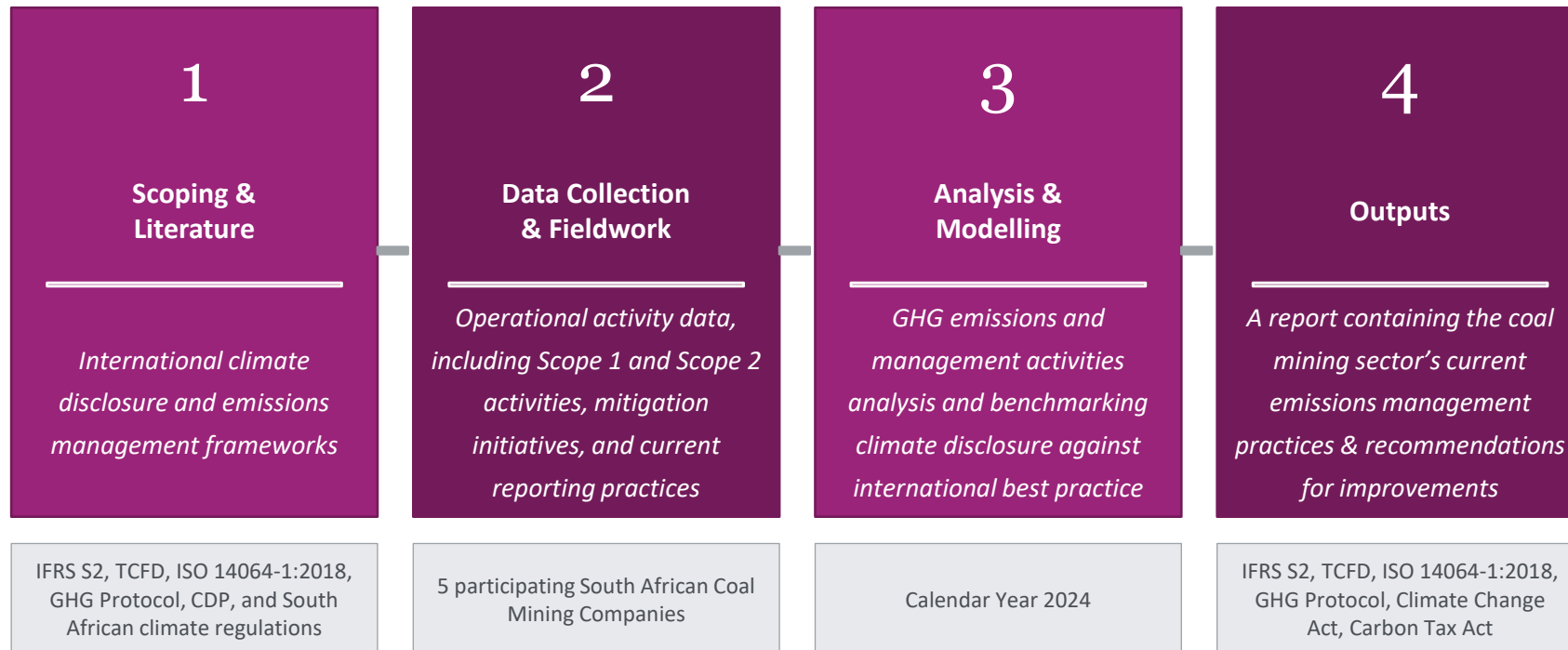




RESEARCH APPROACH & METHODOLOGY



This research combined sector benchmarking, GHG inventory analysis, and climate disclosure assessment to evaluate how South African coal mining companies currently manage Scope 1 and 2 emissions





RESULTS & DATA

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Total Scope 1

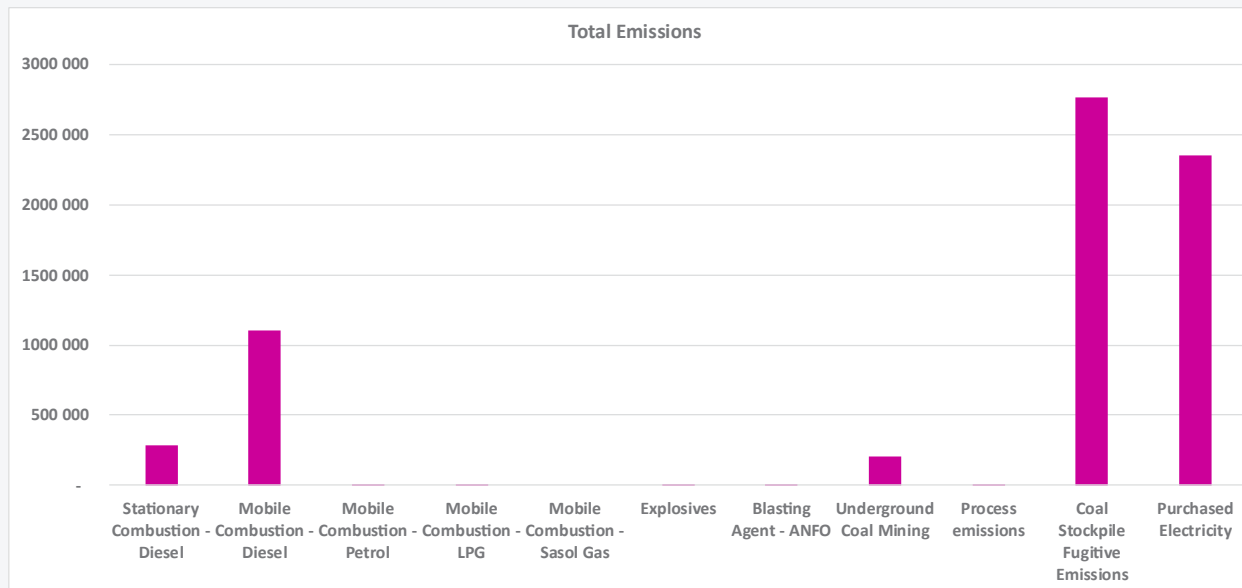
4.38 million tCO₂e

Total Scope 2

2.35 million tCO₂e

Fugitive Methane

2.76 million tCO₂e



Key Take-away

- Operational emissions are concentrated at fugitive methane, diesel combustion, and purchased electricity.
- Companies are already implementing energy-efficiency and renewable electricity initiatives, but methane remains one of the largest and least-addressed operational emissions sources.





KEY FINDING

1 OF 3

The sector’s operational emissions are concentrated in a few main sources, diesel use, methane leaks, and electricity consumption.

CONFIRMED

WHY THIS MATTERS:

Current mitigation efforts are mostly focused on energy efficiency measures, while methane leakage is one of the biggest Scope 1 contributors.

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SUPPORTING EVIDENCE

Scope	Activity	Emissions [ktCO ₂ e]
1	Stationary Combustion	288
	Mobile Combustion	1 103
	Explosives	18
	Process Emissions	208
	Fugitive Emissions – Coal Mining and Stockpiles	2 763
Total Scope 1 Emissions		4 381
2	Purchased Electricity	2 353
Total Scope 2 Emissions		2 353
Total Scope 1 & 2 Emissions		6 733

Table 1: Participating coal mining companies’ Scope 1 & 2 Emissions Summary for CY24





SUPPORTING EVIDENCE

Scope	Activity	Emissions [ktCO ₂ e]
Category 3: Fuel- & Energy-related Activities		
3	Well-To-Tank Emissions of Fuels Purchased	301
	Transmission & Distribution Losses	319
Total Category 3 Emissions		620
Category 11: Use-of-Sold Products		
3	Stationary Combustion of Coal ¹	384 654
Total Category 11 Emissions		384 654
Total Scope 3 Emissions		385 274

Table 2: Participating coal mining companies' Scope 3 Emissions Summary for CY24

KEY FINDING

2 OF 3

Research shows that value-chain emissions, mainly from the use of sold coal, are orders of magnitude larger than operational emissions.

CONFIRMED

WHY THIS MATTERS:

Even if mines reduce their operational emissions, most of the climate risk sits outside their boundary.





KEY FINDING

3 OF 3

The gap analysis and benchmarking indicate that maturity and completeness are uneven across participating companies, limiting comparability and highlighting the need for further mitigation efforts exploration.

CONFIRMED

WHY THIS MATTERS:

Highlight a practical transition pathway that balances emissions reduction, regulatory readiness, operational efficiency, and long-term sector competitiveness

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SUPPORTING EVIDENCE

Short Term (1-5 Years)

- Standardise MRV
- Strengthen Governance and Climate Disclosure
- Expand Energy Efficiency and Renewable Power Procurement
- Deploy Digital Twins and AI-Driven Optimisation

Medium Term (5-10 Years)

- Scale Methane Utilisation and Begin CCUS Readiness Planning
- Integrate Renewables and Begin Fleet Electrification
- Expand Nature-Based Rehabilitation and Carbon Sequestration Projects
- Support Workforce Transition and Regional Development

Long Term (10+ Years)

- Deploy CCUS and Carbon Mineralisation at Scale
- Develop Coal-By-Product Circular Economy Industries
- Advance Full Fleet Electrification and Autonomous Operations
- Pursue Product Use Reassignment and Value-Chain Diversification
- Establish a National Low-Carbon Mining Innovation Hub

Figure 2: Sector Decarbonisation Implementation Roadmap





WHAT THIS MEANS FOR FUTURE TECHNOLOGIES



Practical takeaways — what should your organisation do with these results?

1

Clean Coal Technology

Prioritise methane measurement and abatement as a core clean-coal technology pathway. Opportunities include methane capture, flaring, and utilisation for energy generation.

2

Energy Transition

Accelerate alternative electricity procurement, energy-efficiency projects, and phased fleet electrification to reduce dependence on carbon-intensive grid electricity and diesel consumption.

3

Industrial Application

Investigate alternative coal value chains such as coal-to-chemicals, advanced carbon materials, and coal by-product beneficiation.

4

Capacity Building

Strengthen sector-wide MRV systems, climate disclosure capability, and technical skills in emissions management, scenario analysis, and decarbonisation planning.





CONCLUSIONS & RECOMMENDATIONS

*The key outputs from
this research and
what to do next.*

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CONCLUSIONS

- C1** South African coal sector's operational emissions are primarily driven by fugitive methane, diesel combustion, and purchased electricity.
- C2** Many coal companies are implementing energy-efficiency and renewable electricity initiatives.
- C3** Methane management, Scope 3 reporting, and standardised climate disclosure practices are areas of improvement across the sector.

RECOMMENDATIONS FOR INDUSTRY

- R1** Adopt a phased implementation roadmap that combines short-term operational improvements with longer-term investments.
- R2** Expand understanding of the value-chain emissions and explore decarbonisation opportunities.

