ESKOM - UJ CARINBE RESEARCH

BULLETIN

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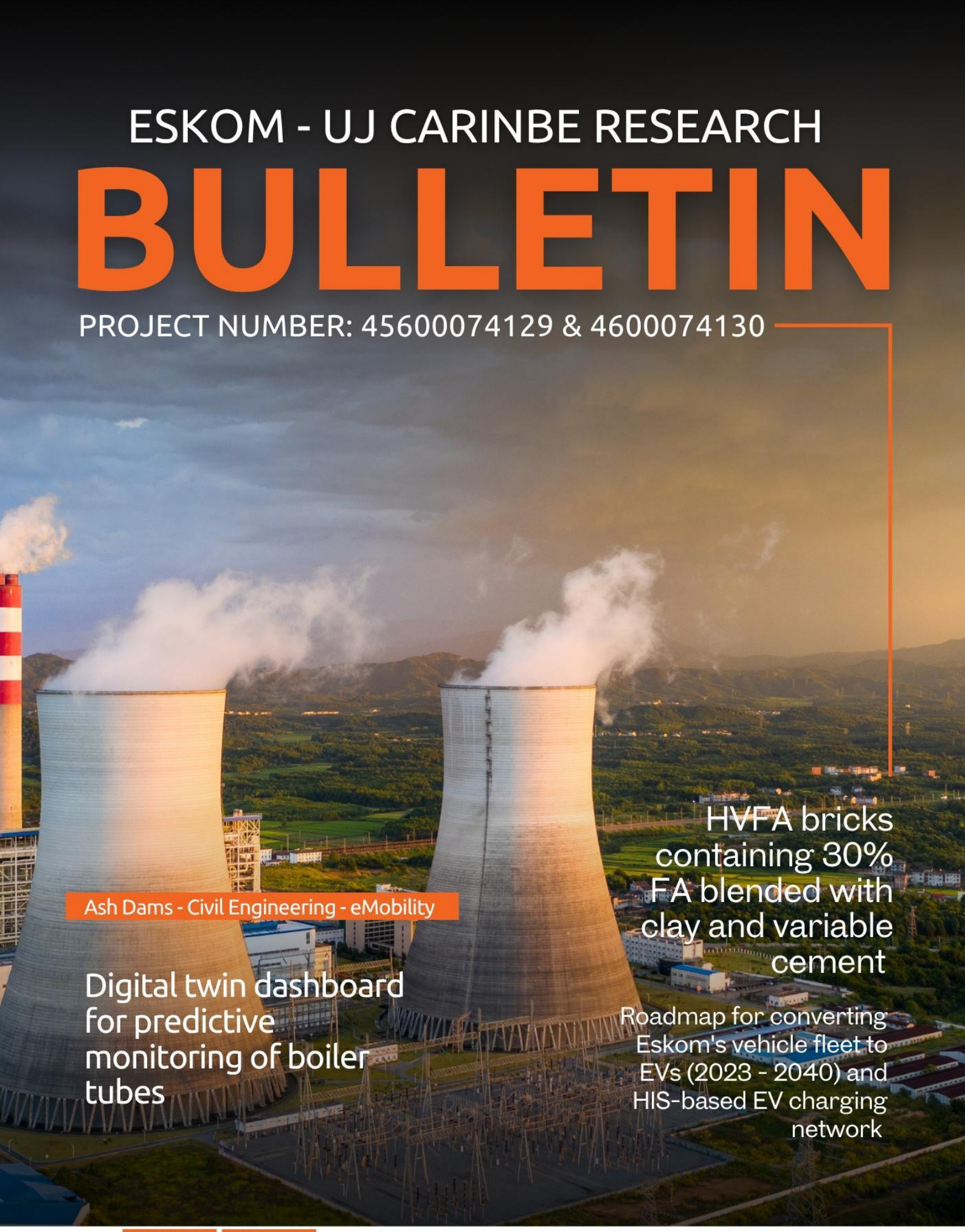

Ash Dams - Civil Engineering - eMobility

Digital twin dashboard for predictive monitoring of boiler tubes

HVFA bricks containing 30% FA blended with clay and variable cement

Roadmap for converting Eskom's vehicle fleet to EVs (2023 - 2040) and HIS-based EV charging network

20 YEARS 2005 2025 UNIVERSITY OF JOHANNESBURG

CARINBE

Eskom

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In a step forward towards sustainable construction, researchers at the University of Johannesburg's Centre of Applied Research and Innovation in the Built Environment (CARINBE) have successfully developed chemical and waste-material activators capable of transforming fly ash and bottom ash into valuable construction resources. This innovative research, spearheaded by the CARINBE team, addresses critical environmental concerns associated with ash disposal from coal-fired power stations.

Fly ash and bottom ash, traditionally viewed as industrial waste, pose significant environmental challenges due to potential groundwater contamination and dust pollution. The newly developed chemical activators utilise optimised combinations of sodium hydroxide, sodium silicate, and sodium sulphate. Additionally, waste-derived phosphogypsum activators were developed, creating robust, cementitious materials that not only recycle waste products but significantly enhance the performance of construction materials.

ASH ACTIVATORS

PAVES THE WAY FOR SUSTAINABLE CONSTRUCTION MATERIALS

Task team Lead: Mr j. Matsimbe & Dr P. Mubiayi

Chemical Activators: Optimised formulations of NaOH, Na_2SiO_3, Na_2SO_4 achieving compressive strengths up to 5.2 MPa in 14 days .

Waste-Derived Activators: Phosphogypsum-based activators yielded unconfined compressive strengths of 0.66 MPa after heat curing, with enhanced heavy metal immobilisation

The chemical activators demonstrated considerable effectiveness in laboratory tests, with fly ash-based mixtures achieving compressive strengths up to 5.2 MPa within 14 days—remarkably superior to non-activated counterparts. This highlights their substantial potential for applications in roads, bricks, pavers, and mortars.

Moreover, the phosphogypsum-based activators effectively converted fly ash into composites suitable for soil stabilisation and lightly trafficked road pavements, achieving unconfined compressive strengths of up to 0.66 MPa after heat curing. Crucially, these composites demonstrated enhanced immobilisation of harmful heavy metals, greatly mitigating environmental risks.

These activators represent a critical step forward in the eco-friendly reuse of coal combustion by-products, potentially reducing the ecological footprint of construction activities while simultaneously cutting disposal costs.

The next phase of this pioneering work will focus on the application and large-scale testing of these activated materials in actual construction scenarios, setting a new benchmark for sustainable infrastructure projects. This development aligns perfectly with global environmental sustainability goals, marking a transformative shift towards more resilient and eco-conscious building practices.

Next Steps: Scale-up trials in real-world paving and mortar applications; long-term durability monitoring.

Ash Bricks

Task team Lead: Prof. F. Okonta & Mr T. Haundi

A Sustainable Future for consruction

In another task commissioned by Eskom to the University of Johannesburg, researchers have successfully developed innovative high-volume fly-ash (HVFA) bricks, representing a significant step towards developing low cost sustainable infrastructure materials. The project, undertaken in CARINBE at UJ seeks to address critical environmental concerns related to the disposal of fly ash (FA) and bottom ash (BA), by turning these industrial by-products into valuable construction materials.

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Fly ash, a by-product of coal combustion in power plants, has long posed environmental challenges due to its storage and disposal. Recognising the potential to repurpose this waste, the research team focused on creating construction materials that utilise a substantial proportion of ash, significantly reducing waste and promoting environmental sustainability.

These innovative HVFA bricks incorporate 30% fly ash combined with clay, enhanced by cement contents varying from 2% to 8%. The bricks undergo a low-energy, low-temperature drying process at 40 degrees Celsius over seven days, dramatically cutting down the carbon footprint compared to conventional kiln-fired bricks. Moreover, initial testing demonstrates promising mechanical strength and durability, positioning these bricks as a viable alternative for conventional building materials

The introduction of HVFA bricks offers substantial economic benefits, reducing the costs associated with waste management and disposal while simultaneously lowering production costs in the construction sector. Stakeholders have lauded the initiative as a critical step towards more sustainable construction practices.

Future project phases include the integration of red soil to further optimise the brick-making process, alongside ongoing assessments of mechanical performance and durability. Eskom’s continued support underscores the project's alignment with broader industry goals of sustainability and innovation in infrastructure development.

This breakthrough exemplifies a forward-thinking approach to industrial waste management and sustainable development, marking a promising pathway toward eco-friendly infrastructure solutions.

On Digitalisation

Predictive analytics– An interactive dashboard for Duvha coal ash dam

Task team Lead: Prof. I. Musonda & Dr R. Alowo

Transforming Ash Dam Risk Management

In an effort to advance environmental safety and infrastructure integrity, the University of Johannesburg, through the Centre for Applied Research and Innovation in the Built Environment (CARINBE), has unveiled a cutting-edge dashboard designed to enhance ash dam monitoring. Developed using sophisticated Interferometric Synthetic Aperture Radar (InSAR) technology, this new digital platform promises to revolutionise the management and safety oversight of Ash Dam Facilities (ADFs).

The dashboard is a product of extensive research and development aimed at addressing critical environmental and safety challenges associated with coal-fired power plants, particularly around ash dam integrity. Spearheaded by Prof. Innocent Musonda, Dr Rebecca Alowo and a dedicated team of researchers, including Mr Funeka Grootboom from Eskom, the platform utilises satellite data to detect millimetre-scale ground deformations, enabling precise monitoring of structural integrity, seepage, and moisture content levels at ash dam sites.

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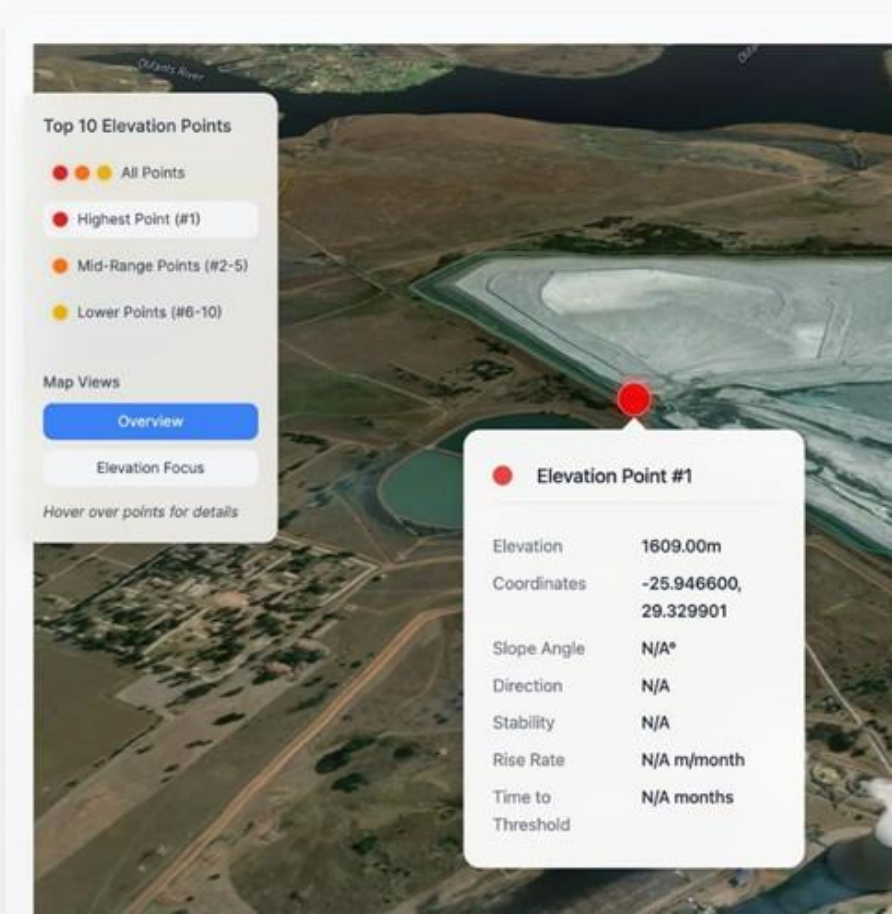
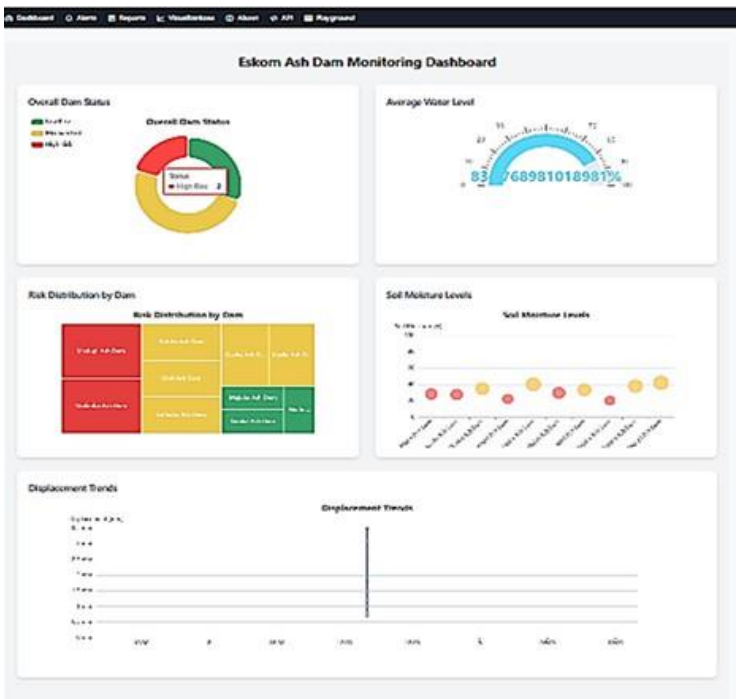
Highlighting its operational advantages, the dashboard offers real-time data visualisation and automated alerts, significantly enhancing the capacity for proactive risk management. Its introduction is a timely response to previous infrastructure failures, such as the catastrophic Jagersfontein tailings dam collapse in 2022, underscoring the urgent need for improved monitoring solutions.





The technology provides comprehensive coverage and high-resolution data, surpassing traditional manual monitoring methods. With its capability to analysed historical displacement trends, soil moisture fluctuations, and stability predictions, the platform allows for early identification and remediation of potential hazards, ultimately protecting lives, properties, and ecosystems.

This development signifies a significant shift towards adopting innovative solutions in industrial asset management. The dashboard's predictive analytics and detailed reporting functions enable stakeholders, from technical operators to corporate decision-makers, to access critical data efficiently, fostering informed and timely decision-making.
This dashboard represents more than a technological leap—it is a crucial step forward in sustainable industrial practices, aligning operational safety with environmental stewardship, and setting new standards for infrastructure monitoring across the industry.

Further on Digitalisation

Digital Twins for effective asset management

Task team Lead: Prof. D. Madyira & Mr T. Bingudza

Monitoring Boilers at Medupi power station

In a major stride towards enhancing operational reliability and reducing power outages, Eskom, in collaboration with the Centre for Applied Research and Innovation in the Built Environment (CARINBE) at the University of Johannesburg, embarked on developing a state-of-the-art digital twin dashboard designed specifically to monitor and manage coal-fired boilers. This task was led by Prof. D. Madyira and coordinated by Mr C. Bathandwa and Mr F. Grootboom from the Eskom side.

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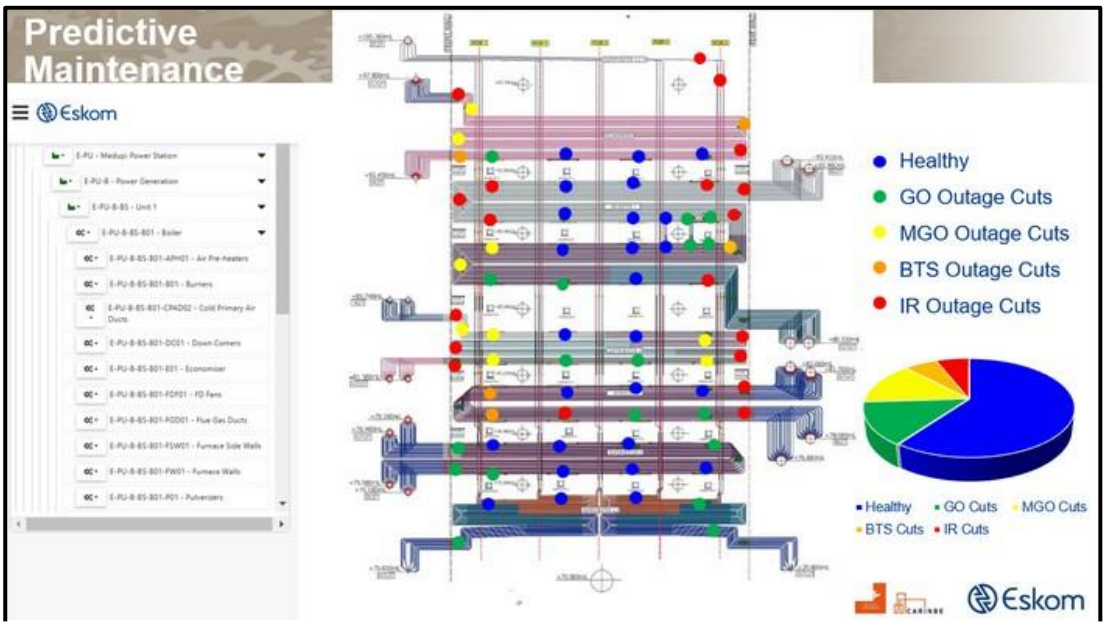

The dashboard addresses a critical challenge identified in Eskom's operations: unexpected boiler tube leaks, which are responsible for more than 37% of power outages. Traditional monitoring methods relied heavily on manual data capture in spreadsheets, a system fraught with inefficiencies and prone to errors, complicating data analysis and decision-making.

Developed by a team led by experts Innocent Rice and Tirwirei Bingudza, the innovative dashboard employs advanced predictive digital twin technology, enabling precise, real-time monitoring and predictive analytics. The dashboard integrates interactive 3-D modeling of boiler components, detailed erosion tracking, and predictive maintenance functionalities, significantly improving accuracy in forecasting boiler tube lifespan and repair needs.

One of the key advantages over traditional methods is the automatic generation of inspection and quality assurance reports, as well as predictive cutting instructions for boiler maintenance—tasks that previously took weeks of manual effort. This automation not only enhances operational efficiency but also dramatically reduces maintenance preparation time, allowing Eskom engineers and technical staff to focus more on critical analysis and decision-making.

By transitioning from reactive to predictive maintenance strategies, Eskom anticipates significant reductions in unplanned outages, directly contributing to increased power generation reliability and fewer instances of load shedding. Furthermore, the digital twin's robust data validation processes ensure improved data integrity, supporting Eskom's overarching goal of sustainable operational excellence.

The digital twin dashboard's success at Eskom's Medupi Power Station is expected to set a new industry benchmark, positioning Eskom at the forefront of digital transformation in the energy sector and offering a scalable solution to be deployed across its entire fleet

3D Printing with Eskom Coal Ash

Task team Lead: Prof. J. Mahachi & Prof I. Musonda

In a significant milestone for sustainable construction and waste valorisation, the University of Johannesburg have successfully demonstrated the viability of using coal ash from Eskom's Kusile power plant for 3D concrete printing. This pioneering project, spearheaded by Prof. Jeffrey Mahachi and Prof. Innocent Musonda, offers a promising solution to South Africa's dual challenges of managing coal ash waste and addressing the critical housing backlog.

The initial phase of research, conducted by the Centre for Applied Research and Innovation in the Built Environment (CARINBE) and the Sustainable Materials and Construction Technologies (SMaCT) Research Centre, validated the structural integrity and practical usability of coal ash in additive manufacturing. By substituting up to 40% of traditional Portland cement with coal ash, the team achieved impressive results, maintaining excellent printability, rapid setting times, and essential early-age compressive strengths exceeding 16 MPa within 24 hours.

Figure 2: Examples of 3D printed structures using coal ash-based mixes. a) 300 mm diameter hollow section printed with 40% FA mix; b) and c) are the respective plan and side views of a 500 mm diameter Eskom logo printed with 30% FA mix

This development not only promotes environmental sustainability by significantly reducing cement use and thus lowering carbon footprints but also presents a scalable solution to Eskom's environmental and logistical challenges associated with ash disposal. The 3D printing process promises faster construction times and reduced material waste, aligning perfectly with emerging technologies aimed at revolutionizing the housing sector. The next exciting phase of this innovative project involves constructing a full-scale prototype house using this groundbreaking ash-based 3D printing technology. This prototype will aim for full compliance with South African building regulations and standards, paving the way for broader adoption of this method across the nation.

This remarkable achievement represents a leap forward in sustainable, efficient, and environmentally responsible building practices. By converting industrial waste into valuable construction material, the University of Johannesburg is setting a new standard for sustainable infrastructure and economic resilience in South Africa.

Laboratory set-up of the 3D concrete printing equipment

E-Mobility for Eskom

Transitioning Eskom's extensive fleet to electric vehicles (EVs)

Task team Lead: Prof. W. Musakwa, Dr. O. Dzobo & Dr. M. Gololo

In a significant move towards sustainable transportation, Eskom, in partnership with the University of Johannesburg's Centre for Applied Research and Innovation in the Built Environment (CARINBE), embarked on comprehensive research into transitioning Eskom's extensive fleet to electric vehicles (EVs). The research led by Prof W. Musakwa, Dr O. Dzobo and Dr M. Gololo, also maps strategic locations for EV charging infrastructure across South Africa, effectively preparing the nation for a major shift in mobility.

This initiative aligns Eskom with global sustainability goals and South Africa's carbon emission reduction targets. Eskom, South Africa's primary electricity supplier, operates a diverse and ageing fleet crucial for infrastructure maintenance and expansion. However, this fleet has historically relied on internal combustion engines (ICE), incurring high fuel and maintenance costs. Recognising the imperative to modernise and streamline its operations, Eskom commissioned CARINBE to undertake detailed research to evaluate the feasibility and economic viability of converting its fleet to EVs.

Fleet data inputs

tem description	Existing ICE		Replacement EV
ke / model	MiniBus		E-MiniBus
irce	Petrol	Diesel	AC
vehicles	1	1	1
r vehicle (km per year)	90 000	90 000	90 000
ears)	15	15	15
st per vehicle (ZAR)	R 550 000	R 600 000	R 1 100 000
ce cost (ZAR/km)	R 0.20	R 0.20	R 0.14
ce cost increase (% per year)	10%	10%	10%
cost per vehicle th)	R 2 500	R 2 500	R 2 000
cost increase (% per year)	8%	8%	8%
	lit/km	lit/km	kWh/km
	0.09	0.09	0.015
battery replacement cost (% of le prize)	N/A	N/A	30%

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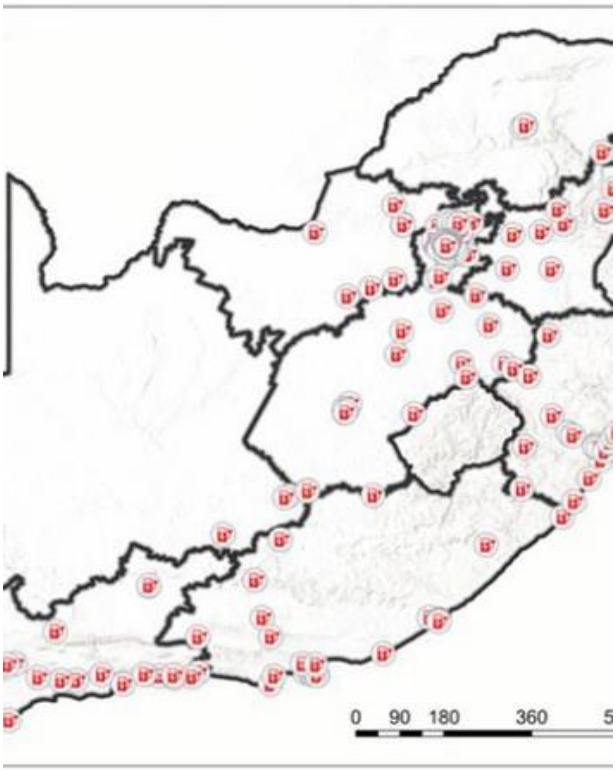
Complementing the fleet electrification, CARINBE researchers undertook a pioneering GIS-based mapping project, identifying existing and potential EV charging infrastructure sites nationwide. This detailed mapping project addresses the critical issue of charging station accessibility—a vital factor influencing EV adoption. The analysis pinpointed priority areas in urban centers such as Gauteng, KwaZulu-Natal, and the Western Cape, regions characterized by high population density, economic activity, and robust electricity infrastructure.

This research emphasizes the dual strategic approach of transitioning to EVs and developing supporting infrastructure as essential steps for South Africa's successful entry into the era of electric mobility. With its detailed data-driven insights, the research provides Eskom and other industry stakeholders with robust guidelines to navigate challenges such as grid capacity upgrades and infrastructure deployment.



Mapping of EV charging stations across South Africa.

Phase	Timeframe	ICE Vehicles to be Replaced	Recommended EV Models	Key justification	Key Strategies for Implementation
Short-Term	2023 - 2028 (Years 1-5)	- ICE Hatchbacks (Toyota Vitz, Starlet) - Diesel & Petrol Panel Vans (Toyota Quantum, VW Caddy Cargo) - Minibuses (Hiace-Ses'fikile)	- GWM Ora 03 - BYD Atto 3 - MAXUS eDeliver 3 Panel Van - ekamva EV Minibus	- These vehicles achieve break-even within 2 to 5 years at annual mileage ≥50,000 km. - Immediate cost savings in urban environments where charging infrastructure is available. - Lower maintenance and operational costs compared to ICE alternatives.	- Deploy in urban areas where charging infrastructure is available. - Prioritize high-mileage fleet vehicles (≥50,000 km annually). - Establish fast-charging hubs for panel vans and minibuses.
Medium-Term	2029 - 2034 (Years 6-11)	- Light-Duty Trucks (Hino 500 1322 4x4 F-C) - Double-Cab Bakkies (Toyota 2.7 VVTi, Isuzu X-Rider, Amarok V6)	- JAC N75 EV 4-Ton Truck - L11 Double Cab Bakkie MAXUS T90 EV	- Break-even occurs between 5 to 10 years, making them viable for mixed urban and intercity use. - Charging infrastructure must expand for full deployment. - Higher upfront cost compared to short-term EV options but lower total ownership cost.	- Expand charging infrastructure along national highways and logistics routes/corridors. - Partner with municipalities for green electricity supply and grid readiness. - Scale up EV maintenance and support services for commercial vehicles.
Long-Term	2035 - 2040 (Years 12-17)	- Heavy-Duty Dropside Trucks (IVECO Eurocargo) - Long-Distance Minibuses (Hiace-2.5D GL Bus)	- MAXUS eDeliver 3 Cab (Dropside Truck) - ekamva EV Minibus	- EV trucks and buses require stronger charging infrastructure and higher capital investment. - Best suited for regions where charging networks are well-developed.	- Develop high-capacity charging stations for long-haul operations. - Implement battery swap or megawatt fast-charging technology.

Eskom's phased fleet electrification roadmap

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Moving forward, the next steps outlined by CARINBE include establishing more comprehensive charging infrastructure, particularly high-capacity stations along major transport corridors. Further research and pilot projects are proposed to ensure that charging infrastructure and vehicle deployment occur seamlessly, minimizing disruption and optimizing operational efficiencies.

This pivotal research project positions Eskom at the forefront of the transition towards sustainable energy solutions in transportation, potentially reducing operational costs significantly, lowering emissions, and contributing positively to South Africa's climate commitments. The successful execution of this strategy could serve as a model for other corporations and government bodies facing similar challenges, reaffirming Eskom's leadership in sustainability and innovation.

Eskom's journey towards complete fleet electrification not only symbolizes a transformative shift in corporate and environmental responsibility but also marks a crucial step in South Africa's broader movement towards sustainable and resilient infrastructure.

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CENTRE FOR APPLIED RESEARCH AND INNOVATION IN THE BUILT ENVIRONMENT

ESKOM-EPEP RESEARCH UPDATE

Compiled By: Prof. Innocent Musonda

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