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## FOCUS ON
## FUTURE PRODUCTION

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CSIR
Touching lives through innovation

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# A LASER-LIKE FOCUS ON **FUTURE PRODUCTION**

The production of goods and services is changing, and the pace of this change continues to speed up. Rapid technological changes are one of the major contributors to this change – production is now being shaped by advances in robotics, materials science, additive manufacturing, the internet of things and artificial intelligence. The Covid-19 pandemic added another dimension to this change, disrupting supply chains, rivalling technological advances as a major generator of uncertainty and forcing countries to focus on local production networks. Further, the ever-growing demand for sustainable production processes requires a focus on sustainable sourcing and close-to-market production.

At the CSIR, we adopted a laser-sharp focus on improving the competitiveness of high-impact industries to support our country's re-industrialisation. Our future production research, development and innovation (RDI) activities focus on chemicals, manufacturing and mining. In chemicals, we develop and apply disruptive and innovative chemical conversion technologies to help create a dynamic African chemical industry with modern, digitalised production processes. In manufacturing, we focus on strengthening the middle tiers of the manufacturing value chain (fabrication and assembly) and developing capabilities to assist high-value industries. In mining, our work focuses on supporting modernisation and fourth industrial revolution technology adoption within the local mining industry. These activities are all underpinned by digital transformation to exploit digital technologies for improved efficiencies and decision making.

In this edition of *ScienceScope*, centre stage goes to some of our recent RDI activities in chemicals, mining and manufacturing. Read about the establishment of an industrial biocatalysis hub that will put microorganisms at the heart of processes to produce chemical products (page 8); how learning factories are becoming an intervention to prepare the workforce of the future (page 16); and how we will work with a large mining house on the use of additive manufacturing technology to support its operations (page 25).

I hope that these articles will prompt you to get in touch with us to find out how we can work together to improve the competitiveness of production in South Africa. For comprehensive details on our work in these sectors, visit **www.csir.co.za.**

**Dr Thulani Dlamini**
**CSIR Chief Executive Officer**

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## Our Work



**ON THE COVER**
Specialists at the CSIR Photonics Centre performed refurbishment of turbine rotors for a power generation agency, using laser welding. Repairing parts in this way, using metal deposition, is time and cost effective as affected components can be addressed without completely dismantling the entire turbine. In addition, parts that could still be serviceable after repairs are not just scrapped and replaced.




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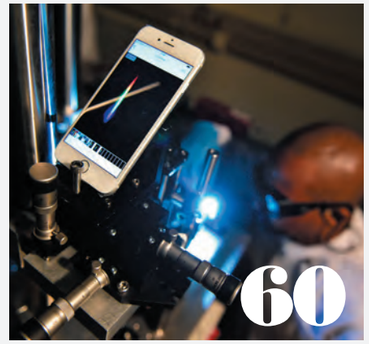
## Our People



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## Our Infrastructure



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## Our Partners



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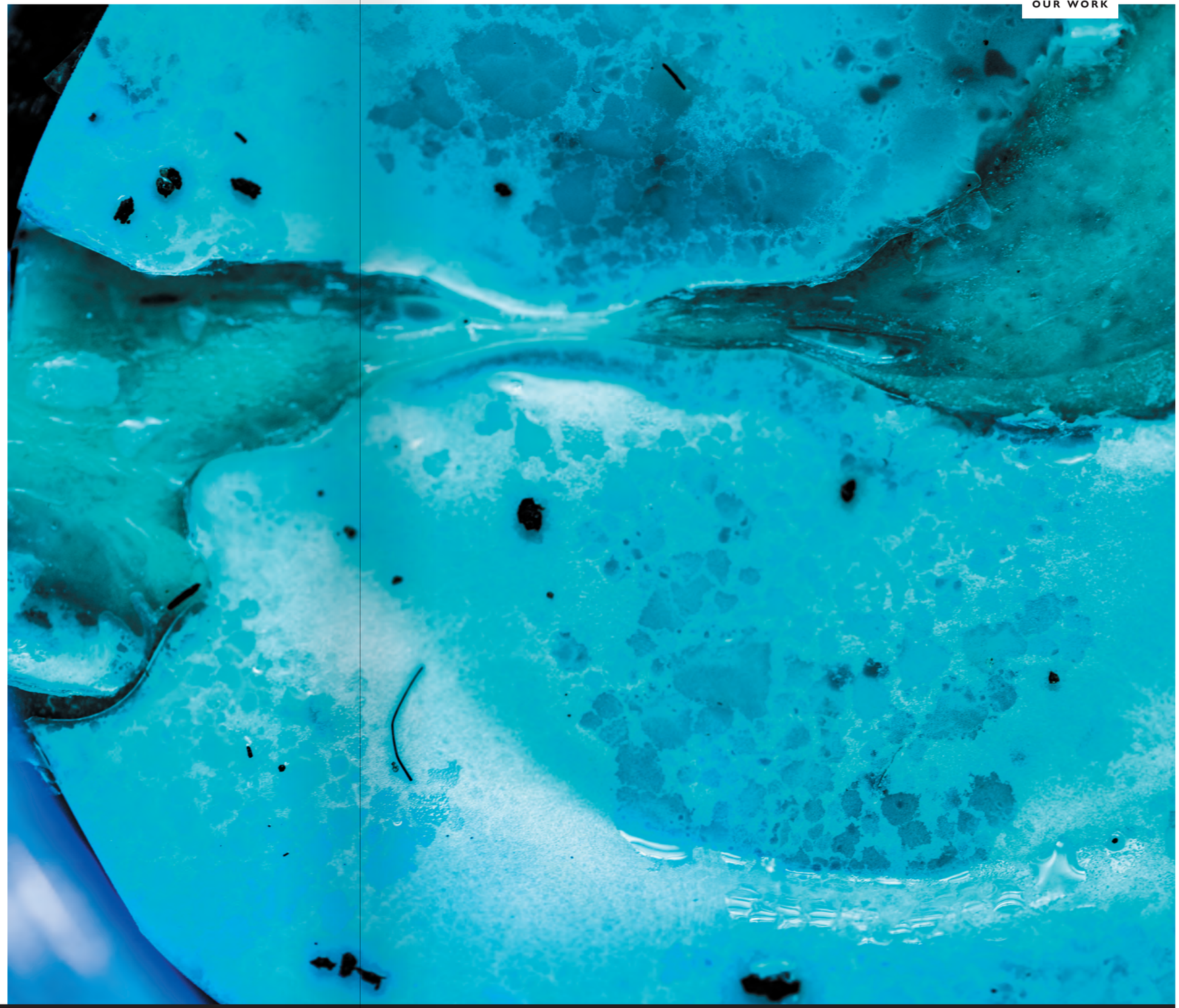
## Opinion

# Our WORK

A close-up shot of a CSIR-developed biodegradable mulch film that is starting to biodegrade during laboratory tests. While conventional plastics are widely used in farming practices, a research team has developed a more environmentally friendly solution. Read more about it on page 12.



OUR WORK

Front from left: Moloko Mathiba-Mdikane (CSIR) and Deidre Davids (APBio). Back from left: Dr Lucia Steenkamp (CSIR) and, from APBio, Stephanus Marais, Lungile Mguni and Tawanda Chakanya.

# FIRST COMPANIES BENEFIT FROM SA'S NEW **INDUSTRIAL BIOCATALYSIS HUB**

South Africa's Industrial Biocatalysis Hub, established in 2021, is operational at the CSIR, with three companies already benefitting from the support provided in technology and product development. The hub was commissioned by the Department of Science and Innovation, together with the Technology Innovation Agency.

Biocatalysis entails the use of enzymes and microorganisms in manufacturing processes to produce chemical products. The technology was identified by the Department of Science and Innovation (DSI) as a key enabling technology that supports the development of a sustainable industrial bioeconomy sector in South Africa.

The Industrial Biocatalysis Hub provides technical product and process development support to enterprises in the biomanufacturing sector that use biocatalysis technologies, with the aim of creating and expanding biocatalysis capacity and promoting uptake in industry.

Already benefitting from this value offering is protein engineering biotech company, Applied Protein Biotechnologies (APBio), one of the enterprises that were selected to form part of the programme following an expression of interest that was issued by the hub. The company has developed a potent natural insect repellent and insecticide and now has its sights set on manufacturing the product at commercial scale.



OUR WORK | *FUTURE PRODUCTION: CHEMICALS*

"Using a blend of natural citrus oils, a cocktail of enzymes from natural sources and a classical approach to biocatalysis, we produced Noot-A-Bug. However, for our process to be useful at industrial scale, our enzyme production process needs to be transferred to an appropriate bioreactor. Therefore, we approached the Industrial Biocatalysis Hub at the CSIR to assist with the optimisation and scale-up of the enzyme cocktail and the optimisation of the downstream purification and scale-up of the biocatalytic reactions that convert the citrus oil blend into Noot-A-Bug. So far, the CSIR team has been fantastic. We look forward to positive outcomes," says Chief Executive Officer and Co-founder of APBio, Stephanus Marais.

The CSIR has extensive experience in research and development in biocatalysis and a proven track record of transferring technology demonstrators and technology packages for implementation by industry. Over the years, the organisation has developed products such as industrial biologics, biopharmaceuticals, bioveterinary compounds, flavours and fragrances and food additives, and extracted natural compounds from plants, which can be used in the formulation of dietary supplements, nutraceuticals, food and feed products and cosmetics.

As part of expanding its capabilities and extending its footprint, the hub works closely with universities, which are referred to as Industrial Biocatalysis Hub nodes. Rhodes University's Department of Biochemistry and Microbiology, specifically the laboratory of Prof. Brett Pletschke, has been identified as one of the nodes that will take on research and development in biocatalysis and contribute to developing the capacity of the hub, including training and developing human capital. The node will also play a role in collaborating with industry partners in commercialising research and development projects.

"Our primary focus lies in the beneficiation of kelp. We explore ways in which we can convert kelp (*Ecklonia* and *Laminaria* spp) material into a diverse range of bioproducts for the cosmetic, feed and food, biomedical and materials industry. This capability, coupled with our well-equipped facilities, experts and strong links with various collaborators and laboratories – both locally and internationally – will enhance our ability to support enterprises to produce high-value bioproducts," says Prof. Brett Pletschke, Director of Pletschke Enzyme Science Programme – Bioproducts Laboratory at Rhodes University.

"The CSIR and the nodes of the hub intend to work together to create a platform that drives collaborative projects with enterprises aimed at localising and developing technologies in biocatalysis for implementation on a commercial scale. Enterprises that require this type of support can look forward to calls for expressions of interest over the next few years," says Dr Lucia Steenkamp, CSIR principal researcher and Director of the hub.


APBio's formulated products with insect repellent properties.

The final product, following the biocatalysis reaction.

Moloko Mathiba-Mdikane, a postdoctoral fellow based at the Industrial Biocatalysis Hub, demonstrating the scaling-up process in the sealed fermenter.

Since its formation in 2021, the hub has supported three enterprises and put in place nodes at five universities, namely Rhodes University, the University of Fort Hare, the University of the Free State, the University of the Western Cape and the University of the Witwatersrand. Additionally, four interns and one postdoctoral student have been recruited to support the three-year programme.

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Biodegradable pellets developed through a CSIR polymer formulation.

A sample of material developed by CSIR researchers that is compression-moulded and can be used in biodegradable products.

# NANOMATERIALS EXPERTS HELP OPTIMISE **BIODEGRADABLE PLASTICS FOR AGRICULTURAL USE**

Local biotech company LignOrganic drew on the CSIR's expertise in nanomaterials and its well-equipped Nanomaterials Industrial Development Facility for the development of new biopolymer solutions. The solutions enable the company to produce biodegradable pellets for products such as tree-planting containers and other agricultural applications.

LignOrganic, formerly known as Eco Invader Solutions, is known for using waste plant material to make water-soluble bioplastics. The company approached the CSIR to assist with the optimisation of its biodegradable polymer formulation. Funded by the Department of Science and Innovation Industry Innovation Partnership, the research team responded to the call by jointly improving the formulation and developing its processing parameters.

Thanks to the research team led by Dr Jayita Sinha Ray, supported by Nanomaterials Industrial Development Facility (NIDF) manager

**OUR WORK** | *FUTURE PRODUCTION: CHEMICALS*

A sample of the polymer-based material injection moulded for tensile testing.

Dr Mike Masukume and research group leader Dr Manfred Scriba, the biomanufacturing company now has a new workable biodegradable plastics formulation, well-established processing parameters (an important part of process management) and quality controls, as well as a substantial understanding of what type of applications to target.

"During the manufacturing trials of the formulations and the characterisation process, we used our knowledge in biodegradable polymers and special additives to develop a material that can be compression-moulded into usable biodegradable products. This helped the company formulate a marketable product. It, once more, highlights the importance of facilities such as the NIDF," says Scriba.

Following the signing of a licence agreement, the CSIR has transferred the technology data pack to LignOrganic to allow the company to commence with its commercialisation activities.

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A lab demonstration of thermoplastic starch production.

Biofragmentation process of a test biodegradable film.

CSIR-formulated biodegradable plastic pellets.



**OUR WORK** | *FUTURE PRODUCTION: CHEMICALS*

# SA AND NIGERIAN RESEARCHERS COLLABORATE TO MOVE FROM **CONVENTIONAL PLASTIC TO BIODEGRADABLE MULCH FILM**

**Researchers in South Africa and Nigeria hope to develop high-performance biodegradable mulch film to replace conventional plastic mulches used in agriculture.**

The CSIR, in collaboration with Elizade University in Nigeria, has secured a contract from the United Kingdom's Foreign, Commonwealth and Development Office to develop biodegradable mulch films with customised performance in various climatic conditions in Sub-Saharan Africa.

"Conventional plastic mulches are increasingly being used in agriculture and horticulture to increase crop yield, enhance early maturity, retain water, modify the soil micro-climate, control weed, decrease the use of pesticides and prevent soil erosion. However, these plastic mulch films are not biodegradable and have to be removed at the end of the crop lifecycle at a cost to the farmer. Due to contamination and for economic reasons, the used mulches are not recycled, and end up being burnt, stock-piled or landfilled, thus exacerbating the plastic pollution problem. Over time, the mulches on farms break down to microplastics, which are washed off or accumulate in the soil, leading to ecological problems," says Dr Vincent Ojijo, CSIR research group leader for advanced polymer composites.

Using its advanced polymer composites capability and technology base, the CSIR responded to the challenge to develop biodegradable mulch films. As a solution, the CSIR researchers proposed the development of bespoke fully biodegradable mulch films that synchronise the climate-specific rates of film biodegradation to crop lifecycle through unique modifications of bioplastics with locally sourced or beneficiated natural polymers, such as starch, cellulose and lignin.

"To start off, a business case for biodegradable mulch film was developed, following stakeholder engagements in South Africa and Nigeria and a market analysis to determine user requirements," says Ojijo.

Biodegradable plastic dry-blends.

The project has since secured support from manufacturers in South Africa who have indicated their willingness to do industrial trials for the biodegradable mulch films. According to Ojijo, the next phase of the project will be the actual development of the biodegradable mulch films. Upon meeting the stage gate requirements, the final phase of pilot scaling, industrial trials and field trials of the mulch films to validate manufacturability and evaluate technical and agronomical performances will commence in mid-2023," he says.

## ABOUT BIODEGRADABLE MULCH FILMS

Bespoke biodegradable mulch films offer similar mulching benefits as conventional plastic mulches. However, they are fully biodegradable into carbon dioxide, water and biomass, with the latter enriching the soil. Because they are biodegradable, the mulch films are ploughed back into the soil at the end-of-life of crop, saving on the time and cost for removal.

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**The work resulted in the publication of four peer-reviewed journal articles as part of a doctoral study undertaken by Dr Uraisha Ramlucken, who graduated from the University of Pretoria in 2020.**

At work in the CSIR's bioprocessing pilot plant are (back, from left) Cebeni Langa and Dr Ghaneshreee Moonsamy and (front, from left), Sizwe Tyhali and Kefilwe Mmoiemang.



OUR WORK | *FUTURE PRODUCTION: CHEMICALS*

# **NEW PROBIOTIC FOR ANIMAL FEED** SECURES ADDITIONAL FUNDING FOR UPSCALING PRODUCTION PROCESSES

**The CSIR has secured additional funding to scale up production processes of a new probiotic product for use in animal feed following sound performance during research and development and preliminary animal trials.**

The CSIR has secured additional funding from the South African Micro-Finance Apex Fund after developing new local products that include a multi-strain, multimodal broiler probiotic containing four indigenous organisms. The products were well-received by end-users in the animal feed and animal production industries.

The CSIR's principal investigator on the project, Dr Ghaneshree Moonsamy, says the market for advanced probiotic technology has grown significantly in recent years, with commercial farmers using it as an alternative to antibiotic growth promoters.

"The benefits of a multi-strain, multimodal broiler probiotic are that it enhances feed quality, growth performance and palatability and protects animals from various environmental stresses. Additionally, a multi-strain probiotic improves the gut health of animals by stabilising the intestinal microflora," says Moonsamy.

The researchers relied on their bioprocess engineering skills and capability to develop a technology demonstrator with a technology readiness level of six.

In research, development and industrial efficacy trials, the product demonstrated superior performance. The final product development stage was conducted in collaboration with industrial partners OptimusBio, Afgri and Kemin.

Broiler feed augmented with the CSIR-developed probiotic.

The current Apex funding will allow the technical team to use its expertise in bioprocess development to scale up the production technology of each of the organisms to manufacturing scale, derive new product formulations using innovative encapsulation methodologies and further upgrade the current manufacturing facility by implementing new control sensors and software to allow remote off-site monitoring and control. It is envisaged that these systems will lower production cost, and at the same time, improve production efficiencies and streamline process development.

The goal for this year is to develop a techno-economically feasible process within minimum final product deviations for registering the product in terms of the legislation required for the use of biological agents in the country," says Dr Santosh Ramchuran, CSIR research group leader for bioprocess development.

It is expected that, upon completion of the project, the technology would have matured to a technology readiness level of nine and will, therefore, be ready to be transferred to a suitable technology licensee.

"With the CSIR's strategic intention of localising transformative technologies and accelerating their diffusion, this project highlights the organisation's ability to pull together its research and development capabilities to produce bio-based technologies, which contribute to the growth of South Africa's bioeconomy," Moonsamy adds.

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# FUTURE WORK REQUIRES FUTURE SKILLS: **THE CSIR LEARNING FACTORY**

The Franka Panda collaborative robot.

**D**igital interventions across multiple sectors need to include a sound understanding of the associated transformation that must occur in the workforce supporting those interventions. In addition, the rate at which technology is being introduced across different industries requires a skills pipeline that is flexible and agile to ensure effective adoption of those technologies. Limited awareness and financial means, particularly in the case of small, medium and micro enterprises, as well as low literacy levels, low-level skill sets, job displacements and peaking unemployment rates in the country are considered potential barriers to implementing digital transformation.



OUR WORK | *CSIR FUTURE PRODUCTION: MANUFACTURING*

The CSIR Learning Factory is a collaborative platform that has been established to support skills development and innovation to leverage the opportunities brought about by the fourth industrial revolution (4IR). To date, the platform has led to the formulation of introductory modules to create awareness on the fourth industrial revolution in South Africa, as well as practical stations, application cells and experience centres to support practical competency development in a modular and customisable manner.

Globally, disruptive, transformative, digital technologies have changed the way society and industry operate, engage, produce, protect and organise themselves. There is a sense that the uptake in Africa has not been as rapid when compared to first-world nations. South Africa, in particular, is experiencing a high youth unemployment rate, which was prevalent even prior to the effects of the Covid-19 pandemic. Improper skills have been identified as one of the main reasons for this challenge. Fourth industrial revolution interventions in South Africa must account for retaining the functionality of the workforce as much as possible to avoid the impacts of multiple job displacements, especially in an environment in which the majority of the workforce is classified as being in elementary occupations and considered illiterate. A key focus of 4IR interventions must then, in addition to providing opportunities for skilled workers, address enabling low-skilled workers to conduct skilled work. The teaching of 4IR-associated technologies for future applications, as well as using 4IR technologies to assist in teaching the workforce for existing occupations, will unlock many opportunities.

The CSIR Learning Factory was established to support South African industries in acquiring the skills needed to maximise the benefits of the 4IR. The aim of the Learning Factory is to provide an environment that facilitates skills development and innovation applied to the research, design, implementation and operation of 4IR technologies.

"The core objectives of the Learning Factory are to serve as a demonstrator of 4IR technologies, build and leverage human capital, and support research and innovation across the multiple stakeholders in industry, academia and government. Entrepreneurship is also a focus area of the Learning Factory," says Dr Ajith Gopal, Executive Manager for CSIR Future Production: Manufacturing.

"This is in line with the CSIR's strategy of driving innovation and skills renewal, localisation of technologies and re-industrialisation across sectors," he adds.

The aim is to unlock the potential of 4IR technologies and demonstrate the impact they have on competitiveness. "We selected specific focal points that correlate with specific industries or sectors," he explains. "Automotive industries or medical equipment manufacturers know the challenges they face and where technology adoption – and the associated skills – can improve efficiency and, ultimately, competitiveness in their environments."

With this industry-led focus in mind, the Learning Factory prioritises skills areas such as human-computer interfacing and computer-based learning, augmented reality, 3D printing at different sizes and in various materials, the internet of things and smart applications, as well as robotics – be that industrial, open source and in-house developed, autonomous or cobots.

## AT THE LEARNING FACTORY

The pilot – first physical site of the Learning Factory – was established in March 2021 on the CSIR Pretoria campus through a partnership between the CSIR and the Sector Education and Training Authority for Manufacturing, Engineering and Related Services (referred to as merSETA).

The target is to establish 18 more learning factories at South African technical and vocational education and training (TVET) institutes around the country. Currently, a pilot learning factory is being implemented in the Eastern Cape, with the EastCape Midlands TVET College.

The CSIR Learning Factory includes demonstrations of various technologies such as robotics, the internet of things, cybersecurity, simulation and additive manufacturing. It also covers theoretical training, which introduces candidates to generic 4IR applications from a South African perspective, as well as infrastructure for applications development – such as a modular and flexible configurable manufacturing cell, assembly station using collaborative robots, a smart home and energy optimisation cell; research labs to support design, incubation and prototyping; and experience centres that support experiential learning by exposing students to working environments in which 4IR technologies have been employed.

## TRAINING OPPORTUNITIES

The first online training course was launched in early 2022. The training was free of charge and, according to Gopal, "We were flooded with entries for our pilot course. From the responses we got, we found that the attendees realised that the 4IR could drive their prosperity, but they didn't know why or how specifically. After completing the course, they now have a much clearer picture of the potential benefits of 4IR interventions in their work environments."

Interested parties are invited to visit **www.4irsa.co.za** for more information.

*(continued overleaf »)*

## TRAINING COVERS:

- Artificial intelligence
- Augmented reality
- Robotics
- Additive manufacturing
- The internet of things
- Big data analytics
- Cloud computing and edge processing
- System integration
- Digital twinning
- Simulation
- Cybersecurity

The course curriculum is presented in different modules to cover topics such as the 4IR and Industry 4.0, technologies of Industry 4.0, application areas, as well as challenges and opportunities in the South African context.

## THE SMART FACTORY CONCEPT

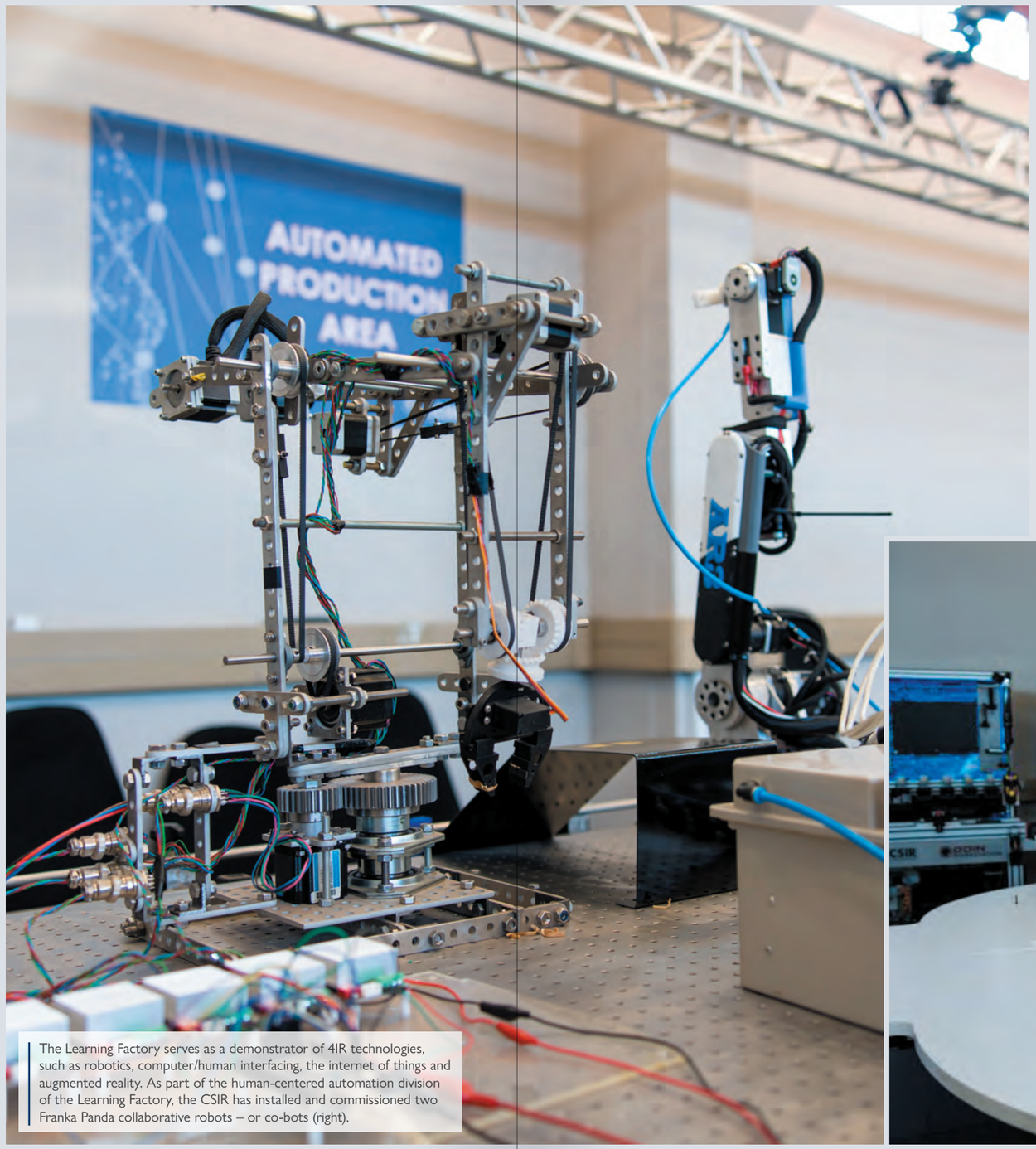
A smart factory is currently taking shape at the CSIR Learning Factory to provide a manufacturing platform to support the CSIR and stakeholders through 4IR readiness benchmarking, new product development, process innovation and research and development, as well as education.

Equipment and infrastructure (yet to be installed) will be available to support product prototyping and development, localisation of technologies to support local value chains, open sharing of best practices across multiple industries through CSIR/industrial partnerships, plant optimisation, training and technology adoption.

The platform will be linked to labs and facilities across the CSIR to support research, design, testing and production. It is expected to be operational by November 2023.

## COLLABORATIVE ROBOTICS

As part of the human-centered automation division of the Learning Factory, the CSIR has installed and commissioned two Franka Panda collaborative robots – or cobots. A cobot is able to learn tasks to work in proximity or directly with human operators, allowing for the undertaking of collaborative tasks. This is different from autonomous robots that undertake limited, repetitive tasks, away from humans, and remain static. The aim is further development of expertise in the use of cobots in both physical and virtual commissioning. These robots can play a key role in piloting production activities in a safe, adaptable manner – prior to actual implementation at manufacturing plants.




The Learning Factory serves as a demonstrator of 4IR technologies, such as robotics, computer/human interfacing, the internet of things and augmented reality. As part of the human-centered automation division of the Learning Factory, the CSIR has installed and commissioned two Franka Panda collaborative robots – or co-bots (right).





Operators at the CSIR have been building expertise on the use of the cobots and investigated different use cases, such as pick and place tasks, product testing, palletising and basic assembly tasks.

A partial assembly of a CSIR-developed ventilator – the *CSIR L.I.F.E* (Lung Inspiratory Flow Enabler) continuous positive airway pressure system – was identified as a test pilot and jigs and fixtures are currently being manufactured, with programming scheduled for later in 2022.

The cobots will enable CSIR Learning Factory users to get an introduction into robotic arms with a safe and intuitive interface. The cobots will enable fast proof-of-concept demonstrations of use cases within the envisaged smart factory. This will enable small, medium and micro enterprises to de-risk task automation by testing the proof of concept in the smart factory before implementing it in their production lines.

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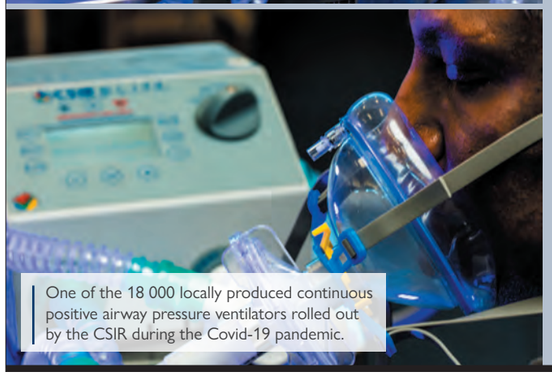

One of the 18 000 locally produced continuous positive airway pressure ventilators rolled out by the CSIR during the Covid-19 pandemic.

# DIGITAL MANUFACTURING SAVES TIME, MONEY AND LIVES

The world has gone through rapid transformation, created, in part, by the impact of Covid-19 and the sudden and radical dependance on digital technologies. Parallel to this, has been the ongoing exponential rise of the fourth industrial revolution, ushering in an era of new technologies, processes and ways of doing business.

## THE CASE OF THE FIRST WHOLLY LOCALLY PRODUCED VENTILATOR

The CSIR Centre for Robotics and Future Production was able to leverage the surge in digital transformation and the accompanying accelerated time to market in the production of ventilators, at a time when South Africa was experiencing severe challenges in coping with Covid-19.

Under the project name, *CSIR L.I.F.E.* (Lung Inspiratory Flow Enabler), the CSIR solution operates as a continuous positive airway pressure device that uses an innovative design to provide a mild level of oxygenated air pressure to keep the airways open and, thus, assist with breathing. The units are non-invasive (applied to the face and not inserted into the airway) and fulfilled a need for a breathing apparatus that is ready to use, easily applied – even outside of hospitals if needs be – for patients who are at an early stage of respiratory difficulty caused by the coronavirus. It is not for use for non-Covid-19-related oxygenation.

Development started in early 2020 when the first cases of Covid-19 hit South Africa and the state of disaster was declared. The project formed part of government's National Ventilator Project under the auspices of the Department of Trade, Industry and Competition, supported by the Solidarity Fund.

Within four months, in collaboration with multiple partners, the extended team was able to design, develop, test, license and produce 2 000 ventilators, using an advanced product lifecycle management (PLM) approach. A month later, production capacity was up to 8 000 units.

One of the enablers for such a rapid response was that documentation could be provided in digital formats, enabling a rigorous, documented product lifecycle methodology that would ensure scalable manufacturing, as well as compliance and licensing under the South African Health Products Regulatory Authority and guidelines of the World Health Organization. PLM software was used to facilitate rapid production scaling. The suite included components for systems engineering processes, computer-aided design tools, manufacturing execution tools, as well as quality management solutions that would ensure compliance with health product regulations for certification. Using a digital product lifecycle design methodology also ensured that the product could be manufactured in a large, scalable virtual factory environment by combining multiple factories with different capabilities to produce large volumes.

## WORKING IN A VIRTUAL FACTORY

An obvious prerequisite for the design and manufacturing approach was that the capability had to be scalable to respond to the high numbers of ventilators needed. Furthermore, working amid lockdown regulations made contracting and procurement procedures more challenging, while, at the same time, it was clear from rising Covid-19 numbers that time was of the essence. Many design, testing and manufacturing processes, which would normally run sequentially, had to run in parallel.

Riaan Coetzee, research group leader for future production systems and project manager explains: "Initially, we thought a major obstacle would be obtaining components, since travel restrictions impacted the global supply chain – which was why we had health product import shortages to begin with."

"However, it created the opportunity to work with local partners of different sizes across the country and, eventually, localise the manufacturing of a large percentage of the required parts. This is an important outcome for the manufacturing sector. The CSIR places great emphasis on partnerships, localising technology, reindustrialising our economy and, ultimately, becoming more competitive," he adds.

Digital lifecycle management addressed the time challenges presented by the many processes, and linkages between processes to understand the influencing factors and the reality of multiple planning iterations. All planning, mapping and even simulation and testing were done digitally before developing the physical product. Cost savings were possible because the digital methodology obviated the need to set up a plant first, and all production optimisation could be done virtually – many activities ran concurrently. Digital lifecycle management also enabled the team to identify which other entities to bring on board to speed up design, manufacturing and the regulatory approval process – resulting in a virtual factory.


In the end, only two factory visits were necessary, and more than 1 000 teleconferences during the 60 to 80-hour work weeks served to emphasise the benefit – and enabling ability – of digital transformation.

Coetzee says: "The project demonstrates the value of a digital product approach for South Africa. Adoption of fourth industrial revolution technologies has not been as rapid locally as it has been in other countries. Digital is the way to go."

Other benefits of the digital approach include that it is scalable, depending on the size of project, and that it can be easily replicated.

By design, this approach is inclusive, allowing multiple design, production and quality software solutions to feed into one true digital backbone. Workflows, standards and guided execution make it easy to undertake practical, on-the-job training.

Coetzee adds: "The Covid-19 restrictions emphasised the benefit of digital manufacturing in that collaboration is possible without co-location. In this digital environment, all skills are immediately accessible, regardless of where they are physically based."

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Multispectral imaging technology makes it possible to detect UV emissions caused by an electrical discharge that may result in a failure on high-voltage transmission powerlines.


The QUVIR camera system is the latest offering in the CSIR-patented range of powerline inspection products.

The QUVIR has a full colour LCD display.

# WORLD-FIRST TECHNOLOGY FOR **DETECTING CORONA DISCHARGE ON HIGH-VOLTAGE POWERLINES**

## CSIR AND UVIRCO SIGN LICENCE AGREEMENT FOR NEXT-GENERATION CORONA-DETECTING CAMERA

The CSIR and UViRCO have entered into a licensing agreement on the CSIR's corona-detecting camera system. The quantifiable ultraviolet, infrared (QUVIR) camera system is the latest offering from the CSIR's patented range of powerline inspection products and a world first because of a unique, radiometric ultraviolet (UV) quantification feature.

The camera is a compact device that can detect and visualise UV emissions caused by an electrical discharge, which is a sign of corona. The camera indicates locations of damage, fouling or bad installations that may result in a failure on high-voltage transmission powerlines. Since corona is not visible to the naked eye in daylight, the cameras make use of multispectral imaging technologies and can operate in full daylight or darkness.

The latest QUVIR camera performs imaging in three wavebands, namely, visible, UV C and infrared. Moreover, it does not only detect the corona emissions, but also radiometrically determines the intensity of the UV C radiated at the source, which is a world first in such detection systems, and the temperature of the discharge location. The UV image of the discharge is overlaid on either a visible or infrared background image so that the operator can accurately locate the source of the discharge, look for visible damage and perform proper diagnostics and appropriately repair the problem. If the UV co-locates with a hotspot, then an arcing condition is detected.





The UV intensity measurement now allows researchers to investigate the correlation between UV intensity and the rate of damage under ambient weather conditions. This means that users can determine the time to failure for a given discharge location.

QUVIR is the ninth product in the corona camera – or CoroCAM® – family. The first camera systems were developed by the CSIR nearly 30 years ago in response to a request from energy supplier, Eskom. The request was for a safe and reliable technology solution to detect electricity discharges on high-voltage powerlines, which were causing significant energy wastage, financial losses and threathening electricity outages. Development of the early camera systems was jointly funded by Eskom and the CSIR, however, the more recent QUVIR system is co-funded by South Africa's Technology Innovation Agency.

UViRCO was established by the CSIR in 2008 as a spin-out venture to market and manufacture the CoroCAM® brand of corona cameras. The CSIR has since then sold its shares in UViRCO to Menston Holdings, a black economic empowerment company. In conjunction with its distributor network, UViRCO has captured significant market share and sold cameras internationally to utility companies in over 50 countries. The CSIR continues to act as a research and development partner for UViRCO.

The CoroCAM® products are known in the global market for their high-end performance, reliability and good support.

## MORE ABOUT THE CAMERA

The cameras are ergonomically designed and easy for operators to handle. Since high-voltage installations are typically high-towering structures, which makes it difficult to spot problems from the ground, the cameras can also be used in aerial applications on helicopters or unmanned vehicles to perform diagnostic inspections. UV quantification, can, however, only be performed during static inspections. Aside from powerlines, the cameras are also used for routine inspections of power substations and distribution networks.

QUVIR has a full colour LCD display, a viewfinder, a user interface menu, a hot-button interface to provide the operator with quick access to regularly used functions, and a rotatable comfort grip. The camera can be remotely controlled and, thus, is suited for fixed installations and use on unmanned aerial vehicles.

Images and videos can be recorded on a secure digital card and transmitted via a commercial downlink to a ground station.

CoroCAM® products are manufactured, assembled, tested, qualified and maintained in South Africa and the company has contributed to job opportunities.


The QUVIR camera is the ninth product in a range of cameras developed to detect electricity discharges on high-voltage powerlines.

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# FASTER PARTS REFURBISHMENT OR REPLACEMENT: **THE CASE FOR LASER-BASED MANUFACTURING**

Laser-based manufacturing and 3D printing technologies have found their way into many sectors of the economy and have seen significant refinement and advances in recent years. Parts and components of different sizes can now be produced from plastic ceramics or metals such as titanium.

The use of laser-based technology for worn parts to be refurbished instead of replaced has caught on in South African industries as its advantages became increasingly obvious. Repairing the component at a fraction of the cost of a new component saves a substantial amount of money, not only in replacement cost, but often in reduced production loss if the replacement component has a long lead time – as is the case with many parts that have to be imported to South Africa. In essence, the useful lifespan of production equipment is extended.

Laser-based manufacturing technologies allow industries in the power-generation, mining and chemical processing sectors to improve the efficiency or reliability of equipment at a lower comparative cost. It has several advantages, such as that the energy consumption is lower than for traditional manufacturing procedures, the wastage of materials is less and the environmental impact is reduced.

***"Laser-based manufacturing presents a circular economy opportunity to improve operational efficiency through improved maintenance and parts management practices."***

*Dr Lerato Tshabalala, CSIR Photonics Centre*

"The technology has a lower carbon footprint because so much happens digitally in a controlled environment. In addition to this, it brings operational benefits such as faster throughput and better process control," says Dr Lerato Tshabalala, research group leader for laser-enabled manufacturing at the CSIR Photonics Centre.

"Because it is digital, the process could potentially be fully automated, providing consistent quality and productivity. All these aspects are in line with the benefits and opportunities brought about by the fourth industrial revolution and future production techniques," she adds.

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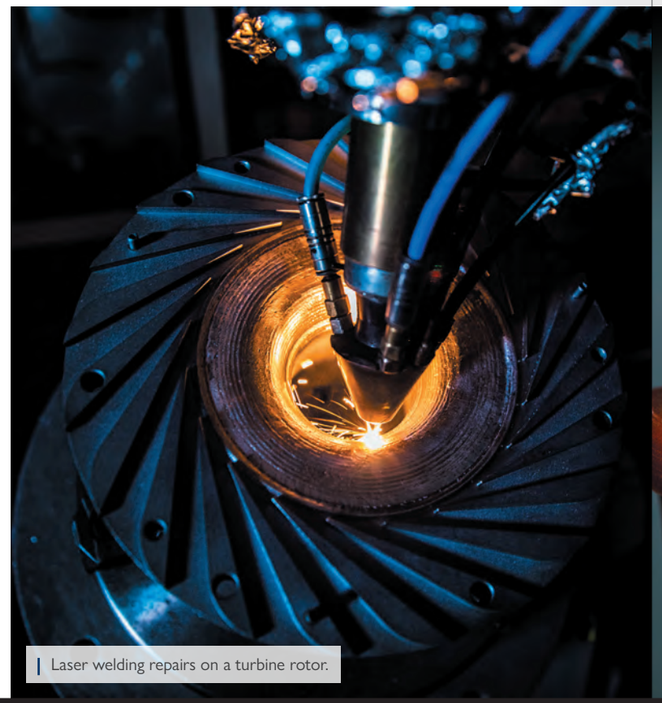

Laser welding repairs on a turbine rotor.





# ON-SITE MINING PART REPLACEMENT USING **3D PRINTING**

The CSIR entered into a collaborative research agreement with a large mining house on the implementation of additive manufacturing technology to support its operations. The project provides the client with on-demand fabrication of spare parts for mining and processing equipment using 3D printing – at the mining site, where it is needed.

The time-saving benefits of drawing on additive manufacturing to fabricate parts on demand are obvious. "It means shorter downtimes and lower logistical costs since the digital process and refurbishment do not take as long as waiting on imported replacement parts to arrive in the country and reach the mine," says Dr Lerato Tshabalala, research group leader for laser-enabled manufacturing at the CSIR Photonics Centre.

The project includes an analysis of the inventory of spare parts, such as impellers for pumps, shaft sleeves, gasket bonnet valves and mining rock drill bits, exploring the impact of adopting a digitally distributed supply chain and then digitising, locally producing and testing these parts at mines in South Africa.

## HOW IT WORKS

In short, parts are characterised based on complexity, ease of production and cost to select the optimum manufacturing process. The quality control and validation procedure forms part of the process to validate the processed part as set out by product specifications. Destructive and non-destructive testing can be performed using accredited laboratories. The potential for refurbishment, as well as on-demand manufacturing, is determined on a case-by-case basis with the end-users. If the part cannot be refurbished, its suitability for replacement through 3D-printing is assessed and a manufacturing technology is identified. Most parts would need to go through reverse engineering to get their computer-aided design models, which is used in the 3D-printing process.

Another objective shared by the CSIR and its partners on this research project is positively impacting the surrounding host communities at these mines – not only through the creation of new jobs in on-site part manufacturing, but also through other economic activities focused on improving the wellbeing and living conditions of the mining host communities. The intention is for a percentage of what the mine spends on spare parts to go the communities around them, rather than foreign suppliers.

The CSIR's laser-enabled manufacturing group at the CSIR Photonics Centre has a specialised and diverse portfolio of capabilities, such as laser welding, laser hardening, shock peening, metal additive manufacturing and a mobile laser refurbishment system for onsite processing applications.

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Rebuilding of a turbine blade tenon.

Photonics-based technologies are found in several sectors, including health, automotive manufacturing, solar energy, power generation, mining and ICT. This has contributed to the need for building skills in this field.

# DRIVING AFRICA'S PHOTONICS **KNOWLEDGE BASE**

## SUPPORTING RESEARCH INTO THE SCIENCE OF LIGHT ON THE CONTINENT

The African Laser Centre was established in 2003 as a virtual network with membership open to all research institutes on the continent, serving as a platform for building skills through research collaboration, training and knowledge sharing in photonics-related fields. Today, almost 20 years later, the joint research continues to add value in fields that are facing challenges around the world, such as health, energy and manufacturing.

Collaborative research undertaken as part of the African Laser Centre (ALC) is aligned with the socioeconomic objectives of African nations. In the 2020/21 reporting year, research projects included investigations into laser-based health interventions in areas such as cancer detection, diabetes and HIV, as well as novel processing techniques for the automotive and energy sectors. Many high-quality scientific publications are produced every year in the form of peer-reviewed journal articles or conference papers based on the research output.

The ALC is funded by the Department of Science and Innovation and operates within the CSIR Photonics Centre. It is a flagship programme under the African Union New Partnership for Africa's Development. Besides the node at the CSIR in South Africa, other research institutes participating in the programme, include those from countries such as Algeria, Botswana, Egypt, Ghana, Kenya, Mauritius, Nigeria Senegal, Sudan, Tanzania, Tunisia, Uganda and Zimbabwe.

Hardus Greyling, Manager: National Programmes at the CSIR Photonics Centre, outlines the broad objectives of the ALC: "The intention is to promote research and training in lasers, optics and photonics. This is a rapidly growing field of technology with significant scope for innovation and the invention of new products and services in fields as diverse as health, aerospace, information and communications technology and many more. Ultimately, photonics plays a significant role in modern technologies that can improve industries, and, subsequently, benefit Africa's people."

Given the isolation of many researchers in Africa, the ALC is able to help facilitate collaboration by maintaining a database of laser researchers in the region. Beyond linking African laser institutions, the ALC also connects researchers with international counterparts.

"As with many technical fields, photonics is also battling a brain drain that we need to reverse," Greyling says. "This is where the support via the ALC can make a difference – through financial or technical resources."

In the 2021/22 financial year, 64 students were supported through the various ALC programmes, of which 43 were South Africans. Seventeen scholarships at South African universities were approved, of which eight were continuation applications, made up of 11 at PhD level and six at Master's level.

The group yielded 34 journal articles and 14 conference papers and undertook 14 collaborative photonics research projects across the continent in countries such as Algeria, Botswana, Egypt, Kenya, Nigeria, Sudan and Tanzania. Stringent peer review of new project proposals, as well as an assessment of progress on funded projects, is undertaken by a panel of scientists from different parts of the world.

### SPECIFIC ALC PROGRAMMES

- The ALC Research Collaboration Programme, which invests in supporting interactions between South African and African research partners;
- The ALC Education and Training Programme, which focuses on the development, organisation and presentation of summer/winter schools, seminars and small conferences on lasers, optical technologies and spectroscopy;
- The ALC Knowledge Exchange Programme, which supports the mobility of PhD and Master's degree students on short-term exchange visits between South African and African research institutions, thus supporting the development of new capabilities and competencies across the continent; and
- The ALC Scholarship Programme, which provides bursaries at Master's and PhD level for non-South African students studying at South African higher education institutions.

Delegates attending the African Laser Centre LRC Biophotonics in Cancer Symposium, at the University of Johannesburg in 2019.

### RECENT ALC-FUNDED PHOTONICS-BASED RESEARCH

Some of the most recent studies included health-focused research, such as investigating anti-cancer, anti-inflammatory and anti-diabetic properties of African plants using photonics-based principles; the inactivation of bacteria using short-pulse lasers; point-of-care biosensors for HIV detection; and studying the effects of Cannabidiol derivates in photodynamic cancer treatment.

In other sectors, studies included the re-manufacturing of new automotive components from end-of-life components via hybrid selective laser melting/high-speed machining; evaluations of photovoltaic solar cells; the synthesis and development of phosphors to potentially improve efficiency for solar cells; and the development of wear and oxidation/corrosion-resistant coatings for the power generation and mining sectors via a laser induction hybrid cladding process.

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Dr Thulani Dlamini, CSIR Chief Executive Officer

# COLLABORATIVE APPROACH NECESSARY TO **MAKE THE SA MINING INDUSTRY GLOBALLY COMPETITIVE AGAIN**

**Much like mining is the cornerstone of the South African economy, harnessing research, development and innovation to deliver value, is one of the cornerstones of competitive industries.**

South Africa holds more than 80% of the world's platinum reserves but extraction is inhibited by challenges that include increasing depths to safely access mineral deposits, low efficiency and productivity with a high cost of production, ageing infrastructure and skills shortages.

Concerns about mineral resource scarcity are widespread and, at the same time, many countries, such as Australia, Canada and China are investing significantly in strengthening their mining-related research, development and innovation (RDI) capabilities. This makes cost and differentiation competitiveness a challenge for South Africa.

## ACCESSING RESERVES AT DEEPER, MORE DANGEROUS DEPTHS

We must admit that holding 80% of the world's platinum reserves is of little value if the country cannot benefit from the extraction and beneficiation thereof. Changing the way we mine means equipping ourselves with information about the host rock that would enable efficient and accurate decision-making.

We understand that the provision of detailed orebody knowledge ahead of mining is crucial to mitigate falls of ground and ensure optimal extraction. Hence, at the CSIR, our team of geophysicists has been optimising a suite of geophysical technologies and techniques for optimised and safer extraction of minerals.





The journey towards zero harm has been a multiyear effort and we applaud mining operations that regularly report zero fatalities. Through the CSIR fire and explosion research and testing facility at Kloppersbos, we continue to provide mines with safety training. In keeping with the drive for digitalisation, we are enhancing the facility through the inclusion of virtual reality-based immersive training modules for emergency preparedness, including the correct use of self-contained self-rescuers.

## UPSKILLING MINE EMPLOYEES

Technological innovation is at the core of our business. In fact, we have set up a learning factory, a one-of-a-kind facility developed in partnership with the Manufacturing, Engineering and Related Services Sector Education and Training Authority to provide an environment that facilitates skills development and innovation to leverage opportunities stemming from the fourth industrial revolution (4IR).

Through this facility, we have made a commitment that technologies developed will not exclude those who may not be technologically savvy. This commitment is also reflected in our engagements with organised labour. Last year, through the Mandela Mining Precinct (MMP), we signed a memorandum of understanding with organised labour to ensure that all relevant stakeholders can participate in the modernisation research agenda (also see page 38).

As a key player in the National System of Innovation, we realise that the provision of an environment that facilitates skills development and innovation for the operation of 4IR technologies is a necessity. Through the MMP, we have partnered with industry to establish an underground testing facility at Royal Bafokeng Platinum's Maseve Mine. Indeed, this facility will afford academia, science councils and industry greater collaboration opportunities in the areas of mechanisation and modernisation.

## ENSURING LEGACY MINES ARE NOT LEFT BEHIND IN THE DIGITALISATION OF MINING

4IR technologies to improve safety, productivity and efficiencies have become an important value driver for the mining industry. In fact, research by Accenture showed that digital technologies can assist mining houses to unlock approximately R153 billion in value by 2026. The ability to predict future events related to productivity, safety and financial sustainability will become a key enabler to the mining industry in the future. Predicting the future involves asking the important "what if" questions. Digital twin technologies provide a means to simulate "what if" scenarios to support and inform future decision-making processes. The CSIR's product lifecycle management capability will make this possible.

## ENVIRONMENT, SOCIAL AND GOVERNANCE: CIRCULAR ECONOMY AND MINING UNDER INCREASING ELECTRICITY COSTS

The 2019 Integrated Resource Plan points to the increasing cost of electricity in real terms up to 2050, as the ageing coal fleet is replaced with new generation capacity. For the mining industry, our climate models point to good solar sources in the gold and platinum mining regions of South Africa, thus providing alternative energy generation options, including both battery electric and green hydrogen fuel cell implementations. The mining sector is considered a resource-intensive industry from an energy consumption perspective. As shown in our recent report on the circular economy in mining, the CSIR believes that mining presents many opportunities for the introduction of circular economy thinking by designing out waste, keeping products and materials in use for longer, and regenerating natural systems. This will significantly improve the competitiveness and sustainability of the sector.

## THE NEED TO INNOVATE

The Minerals Council South Africa (Mining Council) is of the view that a key opportunity for the South African mining industry is to find carefully prioritised niche themes where the RDI ecosystem can generate short-term revenue streams that enable partners to re-build an ecosystem for the longer term. Significant investments are required to achieve modernisation goals set by the mining industry and to deliver on the sustainable return on investment for all stakeholders. We have partnered with the Minerals Council and other mining stakeholders in the development of the CSIR Mining Roadmap to revitalise mining extraction RDI.

It will require all stakeholders in mining RDI, including the Minerals Council, mining companies, mining equipment suppliers, government and research institutions to have a shared goal and integrated plan for the revitalisation of South Africa's mining industry to become globally competitive in niche areas.

***Author: Dr Thulani Dlamini, CSIR Chief Executive Officer***

*Dr Thulani Dlamini is the Chief Executive Officer of the CSIR. He joined the CSIR in 2005 as the head of the National Laser Centre and, in 2008, he was appointed in the position of Group Executive: Research and Development, a position he held until 2011 when he left the CSIR to join Sasol. At Sasol, he was the Executive Manager: Research and Development and later became Vice-President for Strategic Research and Technology. Dlamini holds a PhD in chemistry from the University of the Witwatersrand and a Master's in Business Leadership from the University of South Africa.*

# REDUCING THE COLLISION OF **TRACKLESS MOBILE MACHINES IN MINES**

The collision avoidance system can generate heap maps, which indicate areas that are vulnerable to collisions.

CSIR researcher Mvikeli Mpofu demonstrates the trackless mobile machine collision avoidance software used to predict the performance of traffic management systems, helping mines to prevent vehicle collision.

**The CSIR seeks to offer industry futuristic solutions that resolve potential risks in mining operations. As part of this drive, the organisation has developed a trackless mobile machine collision avoidance system digital twin to predict the performance of traffic management systems.**

The digitilisation of mining operations has become an area of significant focus for the mining industry in South Africa, as well as on the international stage. Increasingly, mining companies around the globe are improving the efficiency of mining operations through the progressive implementation of fourth industrial revolution technologies. Various digital innovations continue to be explored and investigated in the quest to improve operational efficiency, safety and compliance in the sector. Among these technological nuances, the mining industry is adopting automation in mining as an emerging specialty.

Automation in mining focuses on the development of technologies to digitalise mining operations for the enhancement of daily operations. However, trackless mobile machines (TMM) have contributed 10% to the fatalities reported in the industry in the past year. In keeping with industry standards derived from immersive consultation and continuous collaboration with industry, the CSIR has developed a TMM collision avoidance system digital twin, which can be utilised to predict the performance of traffic management systems in terms of vehicle interactions that directly link to safety and risk management.

The project demonstrated that the TMM collision avoidance system digital twin can be used by the mining sector to model the effectiveness of vehicle interaction controls, identify high-risk accident areas in the mine and evaluate the effectiveness of the risk mitigation controls. This will enable timely and evidence-based decision-making, including the formulation and implementation of appropriate controls to prevent TMM accidents. The primary value add of the TMM collision avoidance digital twin is shifting the process of risk evaluation from a subjective framework to an objective one.

The CSIR-developed TMM digital twin technology aims to offer a close-to-real time and continuous safety risk management solution, focusing on assessing and improving the effectiveness of vehicle interaction controls. This technology has the capability to proactively identify high-risk areas and activities per shift, including assessing and quantifying the various risks within the traffic management system. The CSIR is also focusing on future modules, which will be centred on the decarbonisation of TMM fleets and estimation of vehicle fuel usage, given certain usage models.

The TMM collision avoidance system digital twin has the ability to generate heat maps, giving an indication of areas that are more prone to TMM collisions. The process will support mining companies in making informed decisions on continuous safety improvement initiatives. These initiatives can include review of the effectiveness of vehicle interaction controls, review of the traffic management plan and required training and behaviour change interventions.

The CSIR is continuously working on predictive solutions that will resolve potential risks in mining operations. These include the simulation of multiple vehicle interaction events and the identification of potential gaps within the traffic management plan. This is achieved through employing a systematic methodology that involves applying predictive analysis, setting up a configuration and presenting possible scenarios. The TMM digital twin simulation platform will, in the long run, significantly reduce vehicle collisions, ensuring smoother operations and safer environments within mines.

## INDUSTRY COLLABORATION FOR ADVANCEMENT

**Drawing on its organisational values, the CSIR adopted industry collaboration as its strategic direction in advancing industry solutions. This has been achieved by working closer with industry to develop solutions that are relevant to the market and bring effective solutions to industry challenges. The TMM collision avoidance digital twin was developed in consultation with various stakeholders. They have added crucial inputs to the development of the software with the aim of supporting the mining industry's digitalisation journey.**

## ABOUT DIGITAL TWINS

A digital twin is a virtual representation of a physical product or process, used to understand and predict the physical counterpart's performance characteristics. Digital twins are used throughout the product lifecycle to simulate, predict and optimise the product and production system before investing in physical prototypes and assets. By incorporating multi-physics simulation, data analytics and machine learning capabilities, digital twins are able to demonstrate the impact of design changes, usage scenarios, environmental conditions and other endless variables – eliminating the need for physical prototypes, reducing development time and improving the quality of the finalised product or process.

***Source: Siemens***

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The deeper the mine, the higher the temperature. In intermediate to deep-level mines (typically gold and platinum) hot environments expose miners to heat disorders that impact on health and performance.

Meet the scientist: Vuyo Tsotsotso leads the CSIR's heat tolerance testing activity. He has five years' experience in deep-level gold mining production, ventilation, occupational hygiene and mine health and safety, as well as two and a half years' research and development experience at the CSIR. Aside from a BSc Honours in mining engineering from the University of the Witwatersrand, he also holds an advanced certificate in mine environmental control (issued by the Minerals Council South Africa) and a blasting certificate for hard rock metalliferous mines (issued by the Department of Mineral Resources and Energy).





# SUPPORTING WORKER SAFETY **IN SA'S HOT MINES**

The CSIR assists mining clients to establish and maintain heat tolerance screening facilities at mines in the interest of a safe workforce and to comply with a mandatory code of practice for occupational health issued by the Department of Mineral Resources and Energy.

The South African mining sector employs a significant number of workers. According to figures released by the Minerals Council South Africa in 2021, this number is well over 450 000 people – predominantly in gold and platinum mines. Many of these mines are intermediate to deep-level mines and classified as 'hot environments' that can cause heat stress and disorders such as heat stroke, heat exhaustion and heat syncope. Such conditions affect worker health and job performance and increase the incidence of accidents.

The primary objective of heat tolerance screening is to identify gross or inherent heat intolerance. This occurs in individuals with an unacceptable risk of developing excessively high body temperatures during work in hot environments.

The CSIR trains heat tolerance screening supervisors through theoretical study, as well as practical experience in a climatic chamber. It also ensures that effective heat tolerance screening facilities are established on site.

Vuyo Tsotsotso is a mining engineer at the CSIR and leads the organisation's activities in this domain. "When we refer to a hot mine, we mean the underground environment. The official measure is the so-called dry bulb temperature of higher than 37°C, and a wet bulb temperature above 27.4°C," he explains. "These temperatures generally occur in intermediate to deep-level mines and this means most gold and platinum mines."

Heat stress occurs when our body is unable to cool itself enough to maintain a healthy temperature. Tsotsotso explains, "Normally, the body cools itself by means such as sweating, but sometimes sweating is not enough and the body's temperature keeps rising. This can be caused by the virgin rock temperatures in underground mines, low air flow rates and high humidity," he adds.

Heat stress also occurs during surface activities at places such as construction sites or inside facilities such as furnaces, smelters and kilns. Measuring heat stress entails environmental measurements of air temperature, air flow rate, the level of radiant heat exchange (where applicable) and evaluation of the rate of a person's metabolic heat production while performing work activities.

Heat tolerance screening forms part of the assessment of fitness to work in hot environments. This includes an assessment of physical activity designed and timed to raise body temperature and maintain an external work rate of approximately 80 W. This is done using a bench-stepping regimen at a fixed step rate of 24 steps per minute and a fixed stepping height of 30.5 cm, for 30 minutes. The assessment of relative heat tolerance is based on oral temperature, which is recorded at the end of the 30-minute bench-stepping exercise. At this point, a candidate in the heat tolerance screening test is deemed heat tolerant and permitted to work in hot environments when the recorded oral temperature is below or equal to 37.6°C and is deemed heat intolerant if the recorded oral temperature is higher than 37.6°C.

The CSIR issues a heat certificate of competence to tolerance screening supervisors who pass the theoretical test and successfully conduct the required procedure in an appropriately equipped heat tolerance screening centre. Unsuccessful candidates are provided with areas of improvement required to attain accreditation in terms of occupational health legislation.

Tsotsotso notes, "Over time, research has shown trends in the types of people who are more susceptible to heat stress, based on factors such as age, weight, general health and gender." Workers can develop heat stress acclimatisation over time to improve tolerance levels.

The CSIR assists mines with heat stress management programmes that cover several interventions, including engineering and design of work areas, administrative controls and personal protective equipment.

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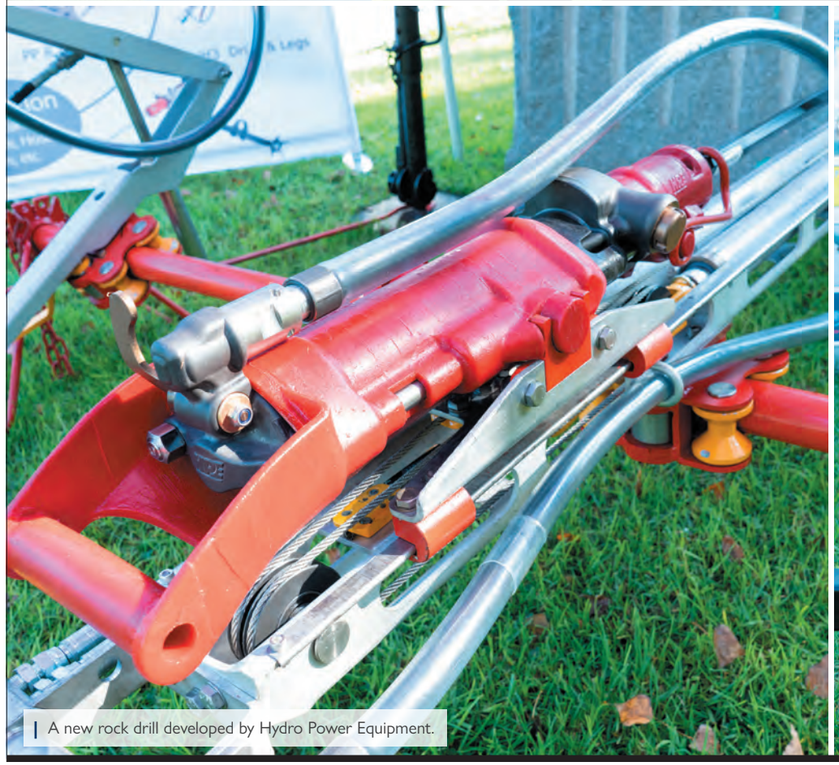
From left, Ulrich Kienle, Hydro Power Equipment Director; Fatheela Brovko, CSIR Impact Area Manager: Mining and Mineral Resources; Martin Pretorius, Mandela Mining Precinct Research Programme Manager; and Julian Wills, Novatek Director.



A new rock drill developed by Hydro Power Equipment.


A new rock drill developed by Novatek.

# MANDELA MINING PRECINCT SHOWCASES **BETTER ROCK DRILLS FOR SA MINES**

The Mandela Mining Precinct showcased two lighter, significantly faster, quieter and more energy-efficient rock drills to stakeholders at its premises in Johannesburg as part of a drive to locally develop technologies that contribute to safe, efficient mining. The drills were manufactured by two local original equipment manufacturers, Hydro Power Equipment and Novatek, as part of an industry innovation challenge, the Isidingo Drill Design Challenge.

Two new locally developed rock drills underwent several weeks of underground tests at Impala Platinum in Rustenburg, successfully demonstrating that they could be used in the harsh underground environment of South African mines. Drilling is a primary function of mining, but existing technology has presented mines in South Africa with challenges, including fatigue experienced by drill operators because of the time required to assemble and disassemble a heavy rock drill. Moreover, traditional drills used in gold and platinum mines are extremely loud and place operators very close to the rock face being drilled. This presents various occupational health and safety risks.

Hydro Power Equipment and Novatek each independently designed, prototyped and tested a rock drill that satisfies the production and occupational health and safety requirements of gold and platinum group metal mines. The challenge has brought South Africa a step closer to improving efficiencies and safety in mining, while creating new opportunities for local original equipment manufacturers (OEMs) to operate within the mining value chain.

The Mandela Mining Precinct (MMP) is a public-private partnership between the Department of Science and Innovation (DSI) and the Minerals Council South Africa. Managed by the CSIR, the initiative is aimed at revitalising mining research, development and innovation in South Africa to ensure the sustainability of the industry.

Beeuwen Gerryts, DSI Chief Director: Technology Localisation, Beneficiation and Advanced Manufacturing, says the basic premise of open innovation, as cited in the Department's White Paper on Science, Technology and Innovation, is to make the innovation accessible to all active players so that the knowledge or outputs can circulate more freely.

"Through the MMP's first open innovation challenge, we are proud to present the mining industry with two innovative rock drills that have demonstrated faster, more efficient and, importantly, safer drilling," he says, encouraging the mining industry to continue to support local OEMs.

"The Isidingo Drill Design Challenge was launched to promote a culture of innovation among local manufacturers," says Sietse van der Woude, Minerals Council South Africa Senior Executive: Modernisation and Safety. "What we have seen during the underground tests demonstrates the understanding by our OEMs that innovation is a key guiding principle for achieving a modernised mining industry."

"The MMP has a mandate to modernise the mining industry through directed research, development and innovation," says MMP Director, Johan Le Roux, adding that bringing new technologies to the market is an important cornerstone of the MMP's strategy.

"Our strategy allows us to take a 360-degree approach to our research, not only considering human-centric design principles, but also through the Successful Application of Technologies Centred Around People, or SATCAP, research programme, promoting people-centric modernisation by including mine employees in the design and development of equipment," he says.

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*South Africa is the world's top platinum-mining country and a major producer of palladium. It holds the largest-known reserves of platinum-group metals globally.*

# REKINDLING MINING-RELATED RESEARCH IN PURSUIT OF THE MODERNISATION OF SA MINES

To rekindle mining-related research and development in South Africa, several new research centres are being established at South African universities.

MMP strategic advisor Dick Kruger.

The establishment of several mining research centres at universities is facilitated by the Mandela Mining Precinct (MMP), under the South African Mining Extraction Research, Development and Innovation strategy, which focuses on the modernisation pathway for mining to 2030.

"As mining-related research in South Africa has declined, the number of competent researchers in mining-related areas has also decreased, diminishing the capacity for this type of critical research at a time when the country needs to modernise its mines to make them safer, more sustainable, globally competitive, and improve their longevity," says MMP strategic advisor Dick Kruger.

The research centres have been established at the University of Pretoria, for research on mechanised mining systems; the University of the Witwatersrand for research on real-time information management systems and strategic applications of technology centred around people; and the University of Johannesburg for the longevity of current mining operations. The process of establishing a research centre for advanced orebody knowledge is under way.

The research centres are funded by the Department of Science and Innovation through the MMP. Each centre comprises a full-time research leader, administrative staff and several financially supported postgraduate students. Each centre must support at least one postgraduate student from a formerly disadvantaged higher education institution who is studying in a mining-related field.

"The research centres conduct fundamental research to create new knowledge about mining technology, data systems and processes associated with the sector, and have a people-centric focus on the impact of modernisation on jobs and skills; environmental, social and governance issues; and stakeholder inclusivity," says Kruger.

The outputs from the research centres will inform the applied research at the MMP, the results of which are felt on mine sites, in communities and throughout the mining value chain. These results will, in turn, inform the next iteration of the strategic focus for fundamental research.

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OUR WORK | *CSIR FUTURE PRODUCTION: MINING*

Back from left: Mpho Lithlakanyane, Department of Mineral Resources and Energy; Franz Stehring, Divisional Manager Mineral Resources, United Association of South Africa; Gabriel Nkosi, National Health and Safety Coordinator, Association of Mineworkers and Construction Union; Dr Thulani Dlamini, Chief Executive Officer, CSIR; Mike Fafuli, Research and Policy Development Officer, National Union of Mineworkers; Johan Le Roux, Director, Mandela Mining Precinct; and Gideon du Plessis, General Secretary, Solidarity. Front from left: Roger Baxter, Chief Executive Officer, Minerals Council South Africa; Nolitha Fakude, President, Minerals Council South Africa; Melanie Roy, Economic Research and Policy Institute Research Manager, The National Union of Metalworkers of South Africa; and Dr Phil Mjwara, Director-General of the Department of Science and Innovation.

# GROUND-BREAKING PARTNERSHIP TO **INCLUDE MINEWORKERS IN RESEARCH AND DEVELOPMENT**

The Mandela Mining Precinct, the largest public-private partnership of its kind, signed a ground-breaking agreement with five unions representing the majority of 450 000 mineworkers to ensure that all direct stakeholders can participate at a strategic and policy level in research and development planning for a modernised mining industry.

The Mandela Mining Precinct (MMP)-Organised Labour Consultative Forum was formally established in October 2021 with the signing of a terms of reference at the CSIR. The founding of the forum is a milestone, one that ensures that all industry stakeholders have a say in mine modernisation.

A public-private partnership between the Department of Science and Innovation and the Minerals Council South Africa to establish the MMP was launched in 2018. Hosted jointly by the Minerals Council South Africa and the CSIR, the MMP seeks to revitalise mining research, development and innovation in South Africa to ensure the long-term sustainability of the industry.

The trade unions that signed the agreement are the Association of Mineworkers and Construction Union, the National Union of Mineworkers, the National Union of Metalworkers of South Africa, Solidarity and the United Association of South Africa.

The Precinct regards organised labour's participation and input in the programmes to modernise mining to make it safe and sustainable as critical to the success of this work.

As a model for greater collaboration in an innovation ecosystem, the Precinct has already brought together industry players – from private sector companies to original equipment manufacturers, as well as academics and academic institutions – to find implementable, game-changing solutions to some of the industry's toughest challenges.

The inclusion of organised labour has been long anticipated and was initiated through the South African Mining, Extraction, Research, Development, and Innovation Successful Applications of Technology Centred Around People research programme.

The new forum will engage regularly with the Precinct's management on current research, deliverables and future projects.

Mike Fafuli, Research and Policy Development Officer at the National Union of Mineworkers.

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# MANDELA MINING PRECINCT DEMONSTRATES **NEWLY DEVELOPED SMART DIAMOND DRILL RIG**

A laboratory setup that mimics a diamond drill rig, referred to as the smart diamond drill, designed and built by the University of Pretoria, was recently demonstrated by the Mandela Mining Precinct. Diamond drilling is used in the mining industry to probe the contents of known ore deposits and potential sites.

One of the challenges that negatively affects drill performance, in terms of drilling rate, hole accuracy and drill bit wear, is the poor understanding between the interaction of the diamond drill and the rock being drilled into. The development of a smart diamond drill seeks to circumvent that challenge.

"The concept revolves around the idea that a diamond drill operator makes use of sensory inputs such as vibration, noise and visual feedback during drilling to adjust the operational parameters and afford optimal performance of the machine," says Mandela Mining Precinct Programme Manager, Michelle Pienaar.

"To capture these sensory inputs, a series of sensors on the drill rig were installed to continuously record the data while the drill is being operated. The intention is that, by using artificial intelligence algorithms, such as artificial neural networks on the recorded data, a closed-loop control system will then be devised. The idea is that it will result in the drill rig being able to monitor and adjust its operational parameters in real time to emulate a highly skilled drill operator," she says.

The smart drill concept offers short-term value by facilitating a better understanding between the interaction of the drill bit to that of the rock, and offers longer term value related to autonomous rock drills by capacitating optimal drill performance.

Above: Dr Abrie Oberholster of the University of Pretoria and research lead on the project showcases the smart drill rig and how it works during a demonstration hosted by the Mandela Mining Precinct at the University of Pretoria. Right: The drill rig with sensors attached to the rig.

Numerous tests were carried out on different types of rock samples to test the rate of penetration. The results indicate that, by using artificial neural network technology, one could classify the rock type and hardness with high accuracy.



OUR WORK | *CSIR FUTURE PRODUCTION: MINING*

# A SUITE OF GUIDELINES FOR **MECHANISED MINING SYSTEMS**

The Mandela Mining Precinct has developed a suite of guidelines as part of its research programme for mechanised mining systems.

The programme aims to provide sustainable mechanised drill, blast and mechanical rock breaking solutions to advance to systems that will help facilitate achieving zero harm, while maintaining and defending desired production rates at minimised costs in the gold and platinum group metals mining industries.

Aspects covered are energy utilisation, ventilation engineering, pillar design, mechanised equipment, shaft infrastructure and access development, stakeholder inclusion in equipment design and development, and engagement of workers in the development of equipment by original equipment manufacturers.

"We created the guidelines to provide a framework to support mining companies, equipment manufacturers and workers. This will enhance the inclusion of all mining industry stakeholders in equipment design and development processes," says Martin Pretorius, Mandela Mining Precinct Programme Manager.

The guidelines can be accessed at ***https://mandelaminingprecinct.org.za/guidelines/***

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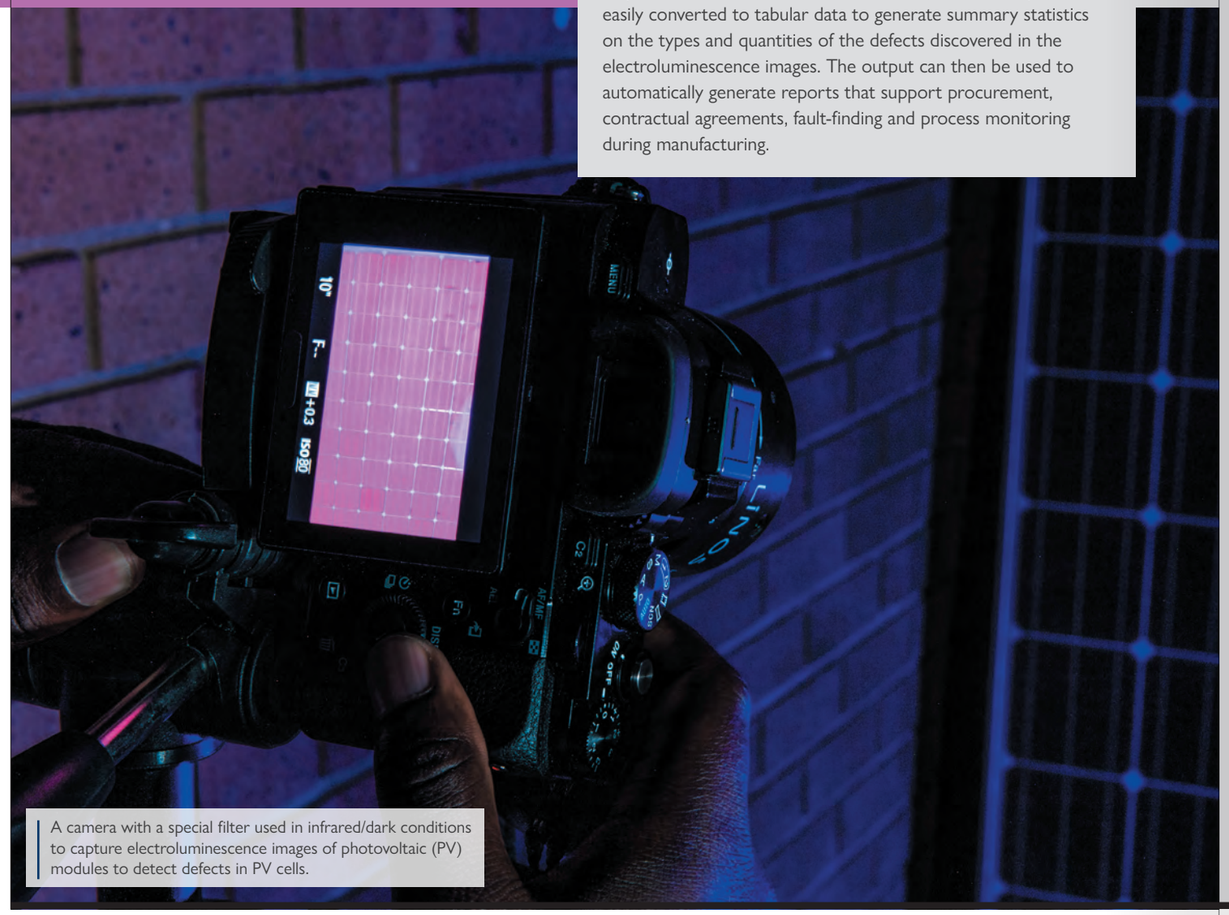
# ARTIFICIAL INTELLIGENCE EMPLOYED TO DETECT DEFECTS IN **ELECTROLUMINESCENCE IMAGES OF SOLAR PHOTOVOLTAIC MODULES**

The CSIR is drawing on its expertise in solar photovoltaics and artificial intelligence to develop a solution to detect defects in electroluminescence images of photovoltaic modules, similar to x-ray images of the human skeleton.

Electroluminescence images reveal defects in solar cells that are invisible to the naked eye. Such images of solar cells are cropped from an electroluminescence image of a photovoltaic (PV) module and artificial intelligence produces a pixel-level classification of the features and defects in the image, based on the results from training on human-labelled ground truth images.

Artificial intelligence can handle thousands of electro-luminescence images of full-sized modules to produce defect maps for a whole batch of PV modules. The colour maps are easily converted to tabular data to generate summary statistics on the types and quantities of the defects discovered in the electroluminescence images. The output can then be used to automatically generate reports that support procurement, contractual agreements, fault-finding and process monitoring during manufacturing.

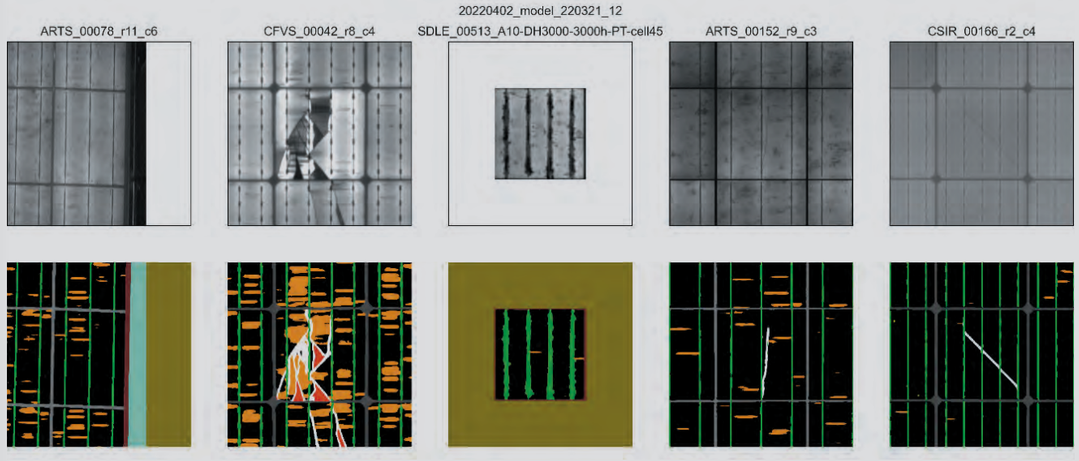


A camera with a special filter used in infrared/dark conditions to capture electroluminescence images of photovoltaic (PV) modules to detect defects in PV cells.





**Examples of electroluminescence images and the pixel-level predictions generated by artificial intelligence**




Samples of electroluminescence images taken of mono-crystalline and multi-crystalline silicon solar cells with intrinsic features like cell spacing, ribbon interconnects and grain boundaries (top row) and extrinsic defects detected by artificial intelligence – cracks (white), inactive areas (red), gridline defects (orange) and corrosion (dark green).

CSIR principal researcher Lawrence Pratt says stakeholders throughout the PV value chain lack the tools to analyse the millions of images taken every day on PV modules across the globe. He says that this has led the organisation to develop a cloud-based tool using artificial intelligence to enable the analysis and quantification of defects visible in electroluminescence images of PV modules.

Pratt developed the idea over years of professional work in the fields of applied statistics and solar PV module testing in the United States of America and South Africa. He formalised the idea in a proposal with Dr Richard Klein, his PhD supervisor at the University of the Witwatersrand's School of Computer Science and Applied Mathematics. A multidisciplinary CSIR team brought the technology demonstration to technology readiness level six in 2021/22 and published the first of three planned journal articles in *Renewable Energy*.

The team plans to pilot the cloud-based solution with potential clients who wish to analyse their own electroluminescence images using artificial intelligence for computer vision. Plans also include a pilot in South African factories that assemble PV modules and use electroluminescence images to classify modules into quality bins and monitor for processing issues.

"The information contained in the visual electroluminescence images is transformed into structured data that can be easily summarised by conventional analytical methods. The summary data complement the information contained in the electrical performance data already available to stakeholders to provide a better understanding of the quality of PV modules installed at any given PV plant," Pratt says.

***In 2015, the CSIR launched its Energy Centre to research and develop solutions for the many challenges facing the national electricity grid. In 2019, the organisation started implementing a new strategy to accelerate the introduction of fourth industrial revolution (4IR) solutions to support industrial development in the country. The new strategy included a focus on achieving smarter resource usage and sustainable economic growth. Sustainable economic growth requires the expansion of electricity generation from renewable resources, such as wind and solar, as contributors to the national grid. The technology demonstrator developed for defect detection in solar PV modules evolved from the CSIR strategy to focus on both renewable energy and 4IR solutions.***

## ENQUIRIES:

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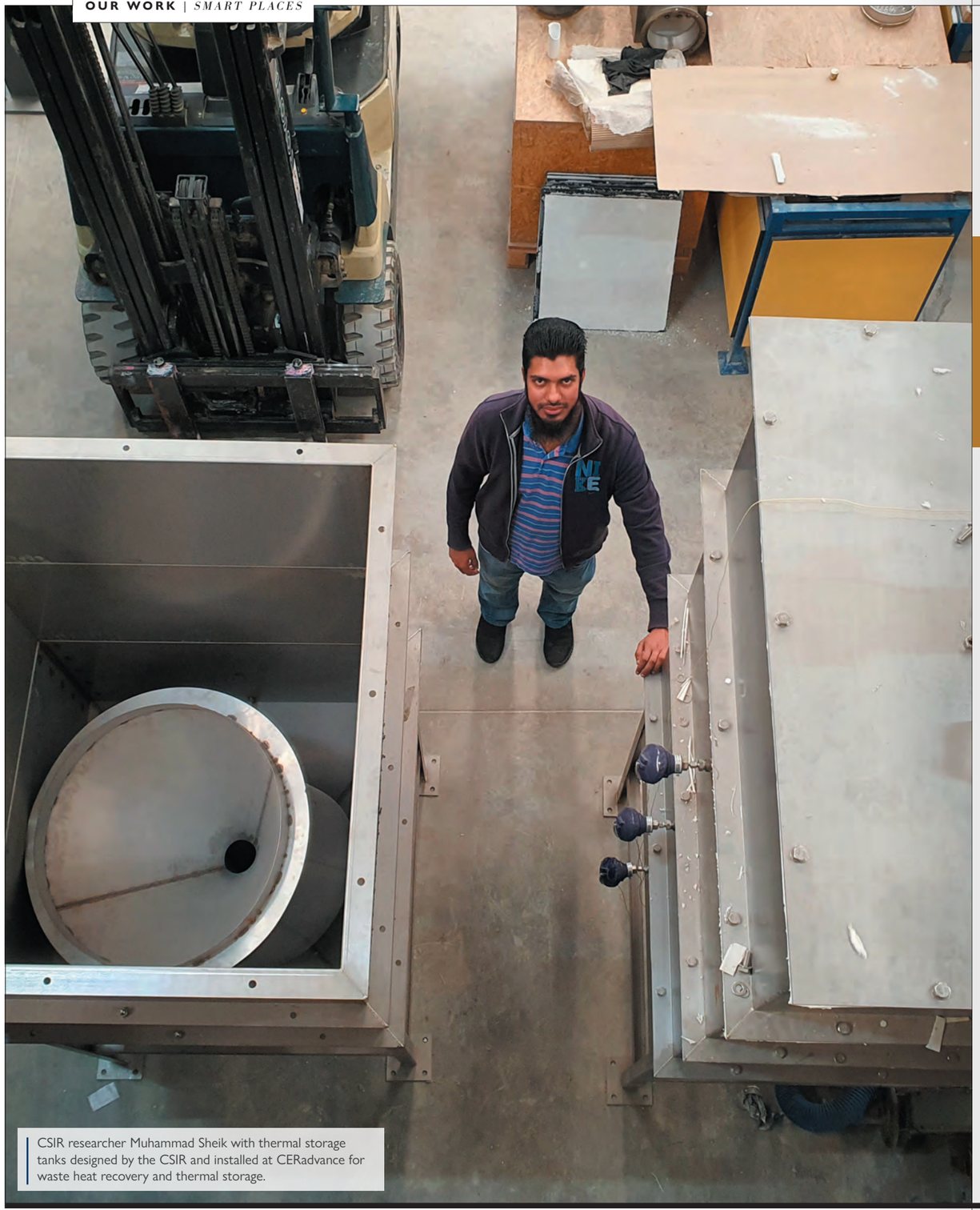

CSIR researcher Muhammad Sheik with thermal storage tanks designed by the CSIR and installed at CERadvance for waste heat recovery and thermal storage.



OUR WORK | *SMART PLACES*

# PILOTING NOVEL THERMAL WASTE HEAT **RECOVERY TECHNOLOGY IN A LOCAL INDUSTRIAL PLANT**

As part of a drive to develop novel thermal components and design thermal systems, the CSIR has undertaken a pilot project at a local ceramic company, CERadvance, to look into the recovery of waste heat, as well as the storage and reuse of energy in the manufacturing process.

Historically, the South African industry was developed in a context of low coal and electricity prices, which resulted in inefficient and carbon-intensive industrial systems. Today, rising energy-generation costs, coupled with pressure to reduce greenhouse gas emissions, are negatively affecting the competitiveness of industry. The CSIR's group for thermal systems is establishing capabilities in thermal process design and optimisation, as well as targeted technology development into waste heat recovery and thermal energy storage solutions.

Waste heat recovery technology has potential to improve industrial energy efficiency, yet it is not widely used by industry, especially when batch-wise processes are considered. Thermal energy storage can play an important role in shifting the supply of waste heat to match demand. The CSIR is developing technologies for cases where off-the-shelf solutions are not widely available, with a focus on thermal energy storage technologies.

Developing novel technical solutions for specific industry problems will lead to novel thermal components and system design. In the pilot project, the CSIR looked into the ceramics company's recovery of waste heat, as well as the storage and reuse of energy in its manufacturing process. The company operates a series of high-temperature electric kilns for the sintering of ceramics at temperatures exceeding 1 000 °C.

Once a firing cycle is complete, convection cooling is utilised to reduce the temperature of the kiln contents. This generates an exhaust air stream with a temperature that is initially above 800 °C, which steadily decreases over time until the contents of the kiln have been cooled to ambient temperature.

During the production process, a slip that is cast using plaster moulds is produced. These moulds absorb water from the slip in the casting process and must, therefore, be dried to continue the production process. Currently, the company utilises several inefficient electric ovens for the drying of the moulds at temperatures of approximately 60 °C. In this context, a thermo-chemical heat storage system was developed. The system includes two packed bed heat storage reactors (containing Zeolite 13X) that are directly connected to a series of high-temperature ceramic kilns. Hot air is extracted from the kiln chimneys and diverted through the packed bed reactors for storage. The packed bed reactors are connected to a drying chamber to use the stored heat to dry the casting moulds. The CSIR and CERadvance designed and developed a novel sliding gate-type ceramic valve to switch between the charging and discharging of the two storage vessels. This allows one reactor to charge, while the other is available to discharge the heat to a drying chamber.

The capturing of waste heat from the ceramic kiln chimneys drastically reduces the need for electrical drying. This not only reduces costs, but also greenhouse gas emissions. Zeolite can store heat much longer with minimal losses compared to conventional sensible heat storage systems. This is useful in batch-wise manufacturing processes. The system has the added benefit of not only providing hot air, but also very dry air. Hot air, coupled with low humidity in the drying chamber, significantly increases the drying rate of the moulds.

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# CSIR SUPPORTS EMERGING INNOVATIVE **INDUSTRIES WITH ENVIRONMENTAL MANAGEMENT SERVICES**

Several exciting industries are becoming prominent in the South African landscape, from telescopes that aim to improve our understanding of the universe, to innovative energy technologies. The CSIR is supporting the planning and sustainable development of these industries through data collation and impact assessment.

## ENVIRONMENTAL AUTHORISATION – FIBRE OPTIC CONNECTION FOR THE SQUARE KILOMETRE ARRAY RADIO TELESCOPE

The planned Square Kilometre Array (SKA) radio telescope in the Northern Cape is a Strategic Integrated Project prioritised in South Africa's National Development Plan and forms part of a global mega-science project. Approximately €700 million (R12 billion) worth of contracts will be awarded to companies and service providers in the SKA member countries for the construction of the radio telescope. The SKA aims to improve our understanding of how stars formed and evolved after the Big Bang, the nature of gravity, and possibly even life on other planets.

A high-speed fibre optic internet connection is required to transfer the big data collected by the SKA radio telescope to a data processing facility in Cape Town. The SKA fibre optic cable development, being lead by the CSIR-hosted South African National Research Network (SANReN), required environmental authorisation from the National Department of Forestry, Fisheries and the Environment.

"We supported SANReN by conducting an environmental impact assessment in line with the requirements set out in the National Environmental Management Act 1998 (Act 107 of 1998). The fibre optic cable was granted environmental authorisation in January 2022 and construction is expected to start towards the end of the year," says Luanita Snyman-Van der Walt, CSIR senior environmental impact assessment practitioner.

## SPATIAL DATA INVENTORY – SOUTH AFRICAN OFFSHORE WIND ENERGY INDUSTRY

Offshore wind is becoming an increasingly affordable and technically viable option for emerging markets' energy mix. South Africa has been experiencing an energy crisis for the past few years, with persistent loadshedding that began in 2008. Studies have shown that offshore wind energy can help the country's limited electricity generating capacity, while simultaneously reducing carbon emissions. Initial analyses indicate that South Africa has tremendous potential to establish an offshore wind industry given its extensive coastline and offshore wind resources, resulting in an estimated technical potential of 59 GW fixed platform and 289 GW floating platform offshore wind energy production.

The World Bank has launched a global offshore wind development programme to support emerging markets in developing roadmaps that aim to proactively consider offshore areas suitable for wind energy development; explore potential social, economic, and environmental costs and benefits; identify and engage with key stakeholders; and determine the applicable legislative framework for offshore wind development.

"As an initial step to developing a roadmap for the South African offshore wind industry, the World Bank tasked the CSIR with collating a comprehensive inventory of available spatial data of relevance to developing an offshore wind industry in South Africa and to identify data gaps. The data inventory will serve as a point of departure for subsequent marine spatial planning, as well as the identification of potential offshore wind pilot sites and development zones," says Snyman-Van der Walt.

## SYSTEMS MODELLING FOR IMPACT ASSESSMENT – GREEN HYDROGEN ECONOMY

Reductionist, silo-based frameworks for impact assessment are limited in considering human-nature complexity and uncertainty. While impact assessment approaches, like environmental impact assessment and strategic environmental assessments, are good at identifying individual elements of complex social-ecological




systems, such as biodiversity, jobs, air quality and infrastructure, they often fall short in exploring the inter-relationships and feedbacks between critical system elements.

"Frequently, the dynamics of these relationships are more important than the individual elements themselves. A limited and partial understanding of the socio-ecological system dynamics may result in piecemeal impact assessment that can mislead the decisions they aim to inform," says Snyman-Van der Walt.

She says that the CSIR has commenced with research on how systems thinking can improve the theory and practice of impact assessment. "The organisation is applying this research through developing and prototyping a systems modelling approach for impact assessment as part of a strategic analysis for South Africa's emerging hydrogen economy. Green hydrogen (hydrogen produced using renewable energy and sustainable water sources) stands to contribute greatly to achieving global and local decarbonisation ambitions. South Africa's renewable energy resources, land availability, platinum group metal resources and port infrastructure position it as a competitor in the global hydrogen economy, initially producing green hydrogen for exports to countries like Germany and Japan, and for use in local chemical industries," she says.

South Africa's hydrogen economy journey started in 2007 when Cabinet approved the national hydrogen and fuel cells research, development and innovation strategy (HySA Strategy). The HySA Strategy is currently implemented by the Department of Science and Innovation through the 15-year Hydrogen South Africa programme. Ultimately, hydrogen can be integrated into the South African local economy, with application in the logistics and mobility industries, especially. However, the hydrogen economy, including all its different components, stakeholders and applications, is a complex and far-reaching industry.

"A systems modelling approach to understanding and assessing the potential environmental, social and economic impacts associated with the green hydrogen lifecycle holistically, as well as how to best manage and mitigate these impacts, will greatly contribute to the sustainable development of a hydrogen economy in South Africa," she says.

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# CONTINUED INVESTMENT IN LOW-COST **WASTEWATER TREAMENT SOLUTIONS**

## MICROALGAE HOLD THE KEY TO REMOVING UNWANTED NUTRIENTS FROM DOMESTIC WASTEWATER

**The CSIR has developed an algae-based wastewater treatment (phycoremediation) technology to assist local municipalities to extend the lifetime of existing wastewater treatment pond systems and improve domestic wastewater effluent quality.**

South Africa faces a lack of access to clean water, due to insufficient water supply, inadequate infrastructure maintenance and investment, recurring droughts driven by climatic variation, inequities in access to water and sanitation, as well as deteriorating water quality.

According to South Africa's 2019 Water and Sanitation Master Plan, 56% of the country's 1 150 municipal wastewater treatment works (and approximately 44% of the 962 water treatment works) are in a poor or critical condition, while 11% of this infrastructure are dysfunctional. This implies that South Africa's water resources are negatively impacted and polluted by wastewater that is not properly treated. This has far-reaching health and economic impacts on downstream users, such as farmers abstracting water for irrigation of export crops.

South Africa is a water-scarce country and wastewater treated to standard allows water entities to maximise the amount of water to be reused, rather than for it to go to waste.

Water funding is set to rise in South Africa from R27.4 billion in 2021/22 to R47.4 billion in 2024/2025, with bulk water infrastructure developments as the key target.

The United Nations Sustainable Development Goals set 2030 as the target for countries to substantially increase water recycling and safe reuse and, for South Africa to reach these targets, the country may have to opt to allocate funds to water entities and municipalities to improve their wastewater treatment processes and maintenance, as well as build new treatment plants.

In response, CSIR scientists have applied the basics of phycoremediation for the biological transformation of excess contaminants, including nutrients such as inorganic and organic carbon, phosphorus, nitrogen, sulfates and heavy metals. In 2015, the CSIR developed a specific consortium of microalgae that removed excess nutrients (nitrates and phosphates) from domestic wastewater.

"Microalgae use sunlight to convert inorganic nutrients present in wastewater to organic matter and produce biomass, which can then be removed from the water to produce fertiliser, for example," says CSIR senior researcher Maronel Steyn.

Implementation cost for the technology is low, as the technology can be applied to existing waste stabilisation pond systems, only requiring installation of three to five bioreactors (tanks).

The technology is a potential solution to assist local municipalities to extend the lifetime of existing wastewater treatment pond systems and improve the domestic wastewater effluent quality. This provides a solution to prevent eutrophication of the surface water sources (rivers) and impacting quality of water, such as use of water for irrigation or export crop production.

Government is investing in water treatment plants that are now overburdened or unable to treat residential wastewater due to population increase and urban migration. These areas can save or prepare their budgets by utilising low-cost technology to upgrade their plants and reduce environmental pollution.

Advantages of the CSIR's technology include that the ponds are gravity fed; therefore, they do not require any electricity. It was also designed with existing human resource and skill shortages in mind, especially for rural municipalities with limited budgets. Phycoremediation is also increasingly viewed as a solution for closing the nutrient or phosphorous cycle as part of the green economy in that the algae biomass can be used for beneficial products such as biofertilisers or animal feed containing high levels of nutrients.

"In developing this solution, the aim was to build a self-sustaining system that is independent of electricity or expensive chemicals and that can be effectively operated within the current financial and capacity constraints of countries within the Southern African Development Community by making use of existing infrastructure, such as waste stabilisation pond systems. With the circular economy, it is an advantage to have a solution that not only helps solve the eutrophication problem, but also closes the loop by recycling nutrients from a waste source," says Steyn.

The CSIR Water Research Centre is also pursuing research, development and innovation in smart water use in the agricultural sector; and acid mine drainage technology for efficient and viable treatment of mine wastewater qualities.


## ENQUIRIES:

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**2014**

**CSIR/DSI/WRC**
*Start of the CSIR project funded by the Department of Science and Innovation and the Water Research Commission to develop the algae-based wastewater treatment technology*

**2015**

**RATIONALE**
*Fertiliser use in agriculture and poorly treated wastewater effluent identified as main reason for eutrophication of surface waters in SA*

**2016**

**IMPLEMENTATION**
*Successful implementation of the technology at the first pilot site: Motetema Wastewater Treatment Works*

**ALGAE RACEWAY**
*Upscaling of algae growth through an algal raceway at CSIR, Pretoria*

**2017**

**PARLIAMENTARY GRANT FUNDING AND AFRICAN DEVELOPMENT BANK**
*Start of the Parliamentary Grant and African Development Bank project at second pilot site: Brandwacht Wastewater Treatment Works*

**2018**

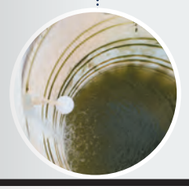
**SADC**
*Conclusion of African Development Bank project and feasibility studies for phycoremediation technology in SADC (Malawi and Botswana)*


**2019**

**CLIMATE ADAPTATION**
*New African Development Bank contract awarded to further extend technology into SADC countries; test for climate adaptation*

**PARLIAMENTARY GRANT PROJECT**
*Parliamentary Grant funded pilot study at Brandwacht Wastewater Treatment Works successfully concluded*

**2019**



**2020**

**COVID-19**
*A global pandemic caused by SARS-CoV-2 causes the world to lock down. This halts most research activity and field assessments*

**ALGAE BENEFICIATION**
*Algae biomass collected and dried and tested for beneficiation – biofertiliser, animal feed, biofuel*

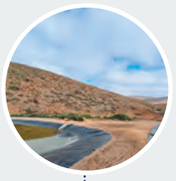
**2021**

**MALAWI IMPLEMENTATION**
*Phycoremediation technology implemented at University of Malawi Wastewater Treatment Works*

**SADC FEASIBILITY**
*Feasibility studies concluded in Namibia, Mozambique and Mauritius*

**2022**

**BITTERFONTEIN WASTEWATER TREATMENT WORKS**
*In a third pilot study, the technology is implemented under West Coast climatic conditions*



**2022**

# Our PEOPLE

The CSIR is known for attracting top talent in the field of science, engineering and technology. Dr Advaita Singh, a researcher with expertise in the genetic engineering of plant systems and producing low-cost proteins of pharmaceutical interest, is one of them. Singh completed his MSc and PhD in biotechnology through the CSIR studentship programme. His PhD research focused on the plant-produced anti-HIV CAP256-VRC26 antibodies.

The local manufacturing of protein-based vaccines in Africa is limited. Pharmaceutical prices increase along with global inflation and, as a result, over half of the global population are unable to afford critical medication, limiting access to essential medicines that are an essential part of a functional healthcare system.

The CSIR's plant-based production platform can be used to produce novel biopharmaceuticals or for the localised production of cost-effective biopharmaceuticals for veterinary and human applications.

# CSIR SCIENTIST RANKED **AMONG SA'S TOP MATERIALS SCIENTISTS**

**More than 30 000 scientific publications have cited Professor Suprakas Sinha Ray's nanotech inventions and discoveries over the last 15 years.**

Ray is a chief researcher and manager at the CSIR's Centre for Nanostructures and Advanced Materials at the Department of Science and Innovation-CSIR Nanotechnology Innovation Centre. He leads one of the CSIR's most productive research groups, working on new materials for smart packaging, energy, sensors, carbon dioxide conversion, water purification, drug delivery, cosmetics, manufacturing and even wound healing.

According to figures collected by prominent website, *research.com*, in December 2021, Ray's 615 research articles had been cited 34 509 times by scientists from over 180 different countries. This is a measure of his output and performance as a scholar, and the website ranks him as South Africa's number two researcher in materials science.

"My name is ranked, yes, but it is really a team achievement as a research centre, as the CSIR and as a country," he says.

"For our group, this kind of recognition means we are making an impact in the science community. It means we are doing something relevant for the world, and that really boosts our motivation. It also means that funders can see how well our researchers are doing."

He says that the ranking reflects the hard work of the centre's junior and senior experts in fields as diverse as modelling, chemistry, biochemistry, engineering and physics.

"We have the most diverse team, which we have built from the bottom up," he says. "For example, we can draw on computer modelling and medical knowledge when it comes to wound healing materials, because we can predict how a material might interact with human skin, and we can predict side effects like swelling or secondary infection."

He says his multidisciplinary team is also making an incredible impact on sustainable agriculture and environmentally friendly chemicals, first by developing new 'green' materials, and then by transferring those technologies to industry.

"We are serving seven different industries right now," says Ray. For instance, the team is working with Sappi on biomass conversion, which means finding value-added uses for the plant waste created during their paper-making process. The team is also working with Engen on processing optimisation for environmentally benign polymers, and has provided medical nanotechnologies to 3Sixty Health.

"We have been setting up our centre for the last decade, and now we are moving fast. In the next decade, we will do more and more."

He says that one of the most important ways to keep the team moving so fast is to develop their management skills. "You can be a good scientist but if you don't know how to manage a project you won't make an impact."

To him, being rated South Africa's second-highest materials scientist is simply a steppingstone to bigger things. "We want to be even more relevant to society and industry. We want to see, in four to five years, that we are top in the country and in Africa. We are doing something good here, so we would like to be number one in relevance and cutting-edge science."

Ray says "cutting edge" today means researching and creating sustainable materials in the most efficient way possible.

"For any new materials that we are trying to develop, we now ask ourselves what the fate of that material will be," he says. For instance, his team is working on smart packaging made from plant-based polymer nanocomposites, which can be discarded to biodegrade without harming the environment.

Ray says that they are now also using data science to streamline the research process. "Say for instance we want to develop a new plastic material, there are thousands of research papers already available on plastic materials known as polypropylene composites. Before wasting time and money testing new plastics blindly, we can first gather all this available data and use artificial intelligence (AI) to predict how new materials will work, so that we can select only the best candidates to test," he explains.

He says that this all comes neatly full circle because the very AI that he uses relies on nanotechnologies and materials developed by top scientists like him.

"The future lies in advanced manufacturing, robotics and AI. These industries need tougher, lighter, more intelligent materials that don't disturb the environment or human health."

The demand for such materials is already booming globally, and Ray and his team are now in a comfortable sprint to meet that need. "You cannot invent if you are not moving fast. If you are even a little bit slow, you will be out of the race."

OUR PEOPLE

***"My name is ranked, yes, but it is really a team achievement as a research centre, as the CSIR and as a country."***

***- Prof. Suprakas Sinha Ray***


Prof. Prof Suprakas Ray addresses the audience during the launch of the CSIR/DSI Nanomaterials Industry Development Facility (NIDF).

Prof. Ray and CSIR Chief Executive Officer Dr Thulani Dlamini (left) hosted South Africa's President Cyril Ramaphosa during a tour to the NIDF.

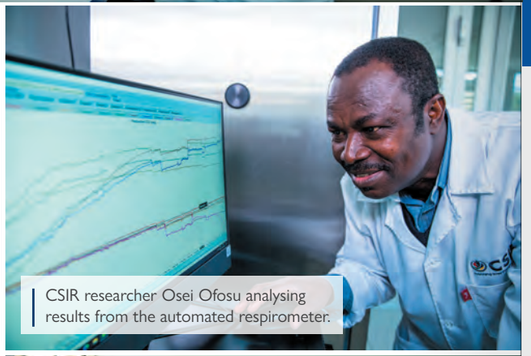
# Our INFRASTRUCTURE

Biodegradation testing in an automated respirometer in the newly established testing facility for biodegradation at the CSIR in Pretoria. The facility was funded by the United Nations Industrial Development Organization (UNIDO) to assist the local plastics industry with the verification of imported or locally produced products that are being promoted as biodegradable. Full story on page 56.

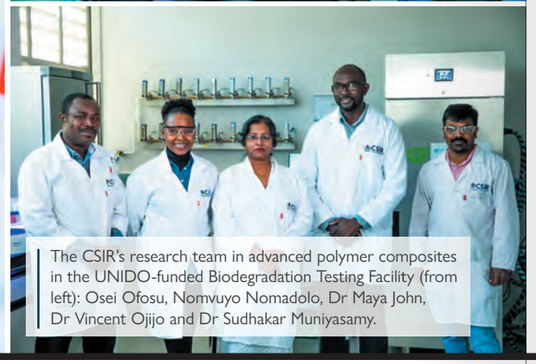


CSIR researcher Nomvuyo Nomadolo conducts an experiment using the automated titrator.


User interface to operate the automated titrator.



CSIR researcher Osei Ofosu analysing results from the automated respirometer.



The CSIR's research team in advanced polymer composites in the UNIDO-funded Biodegradation Testing Facility (from left): Osei Ofosu, Nomvuyo Nomadolo, Dr Maya John, Dr Vincent Ojijo and Dr Sudhakar Muniyasamy.





# MAJOR MILESTONE IN THE QUEST TO MOVE FROM CONVENTIONAL PLASTICS **TO ENVIRONMENTALLY SUSTAINABLE ALTERNATIVES**

## AFRICA'S FIRST ISO-ACCREDITED BIODEGRADATION TESTING FACILITY

The CSIR is becoming home to Africa's first ISO-accredited biodegradation testing facility. Funded by the United Nations Industrial Development Organization, the facility will assist the local plastics industry with the verification of imported or locally produced products that are being promoted as biodegradable in various markets.

Over the years, there has been a gradual increase in eco-conscious consumers, stringent environmental legislation and global initiatives, resulting in a demand for eco-friendly products. It has culminated in a global trend that is moving away from petroleum-derived products that cannot be recycled, towards greener products, which are sustainable, functional, environmentally friendly and can offer diverse end-of-life options such as biodegradability, compostability and recyclability.

Through this facility, South Africa will be capable of establishing the conditions and timeframes of the biodegradation of materials and verify biodegradable claims on products. Additionally, the United Nations Industrial Development Organization (UNIDO) project deals with developing an action plan based on tasks such as assessing the most common plastic items reported in land and marine litter surveys; identifying commercially available, environmentally sustainable alternatives for replacing conventional plastics; undertaking end-of-life analysis of alternative materials; developing prototype demonstrators using selected alternative materials; and carrying out lifecycle sustainability assessments to evaluate the environmental impact of using different materials.

CSIR principal researcher Dr Maya John says the biodegradation facility, established in collaboration with UNIDO and the Japanese government, is anchored in firm support for the transition from conventional plastics to environmentally sustainable alternatives. The facility is well-furnished with equipment such as an automated respirometer, a carbon, hydrogen, nitrogen and sulphur analyser and an automated titration system. This will build Africa's capability and enable a strengthened local bioplastics and sustainable alternative material industry. UNIDO has further provided biopolymers –polyhydroxy butanoate-co-hydroxy hexanoate (PHBH) – for developing prototype demonstrators and supported the ISO accreditation of the facility.

The commissioning of the automated respirometer enabled researchers to open the facility's doors and start with the first testing of samples for an industry partner.

**The Japanese government, through UNIDO, funded a project that will assist the local industry with the verification of imported or locally produced products that are being promoted as biodegradable in various markets. The new ISO-accredited biodegradation facility is part of the outputs of a CSIR-UNIDO project to develop an action plan to support the transition from conventional plastics to environmentally sustainable alternatives.**

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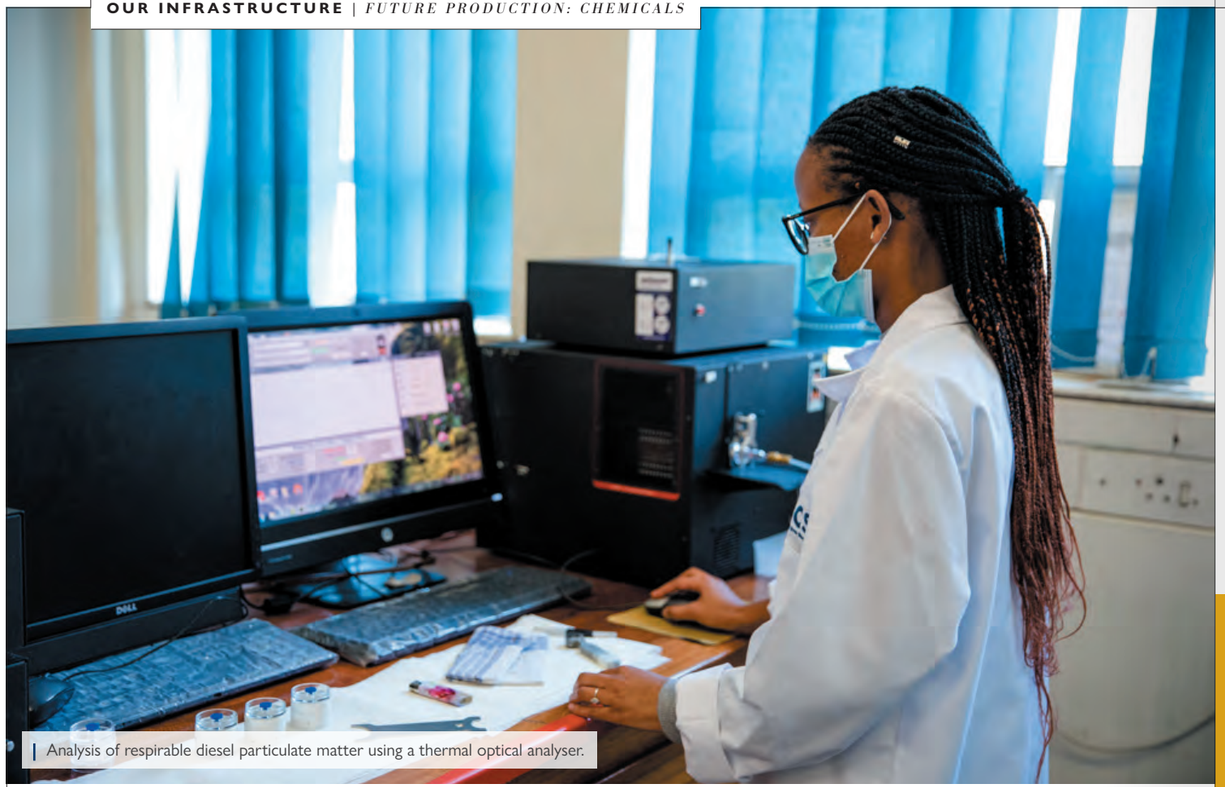

Analysis of respirable diesel particulate matter using a thermal optical analyser.

An advanced D8 X-Ray diffraction instrument used for respirable silica dust analysis conducted for mining companies.

25 mm cassettes preparation for respirable dust sampling.



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# SUPPORTING THE MINING INDUSTRY IN FOSTERING **HEALTHIER WORKING ENVIRONMENTS AND COMMUNITIES**

## THE CSIR AIR AND DUST LABORATORY

The mining industry has faced challenges in the realm of health and safety of employees and communities for decades. Globally, the industry continues to encounter immense challenges relating to various hazardous aspects of mining operations. One such hazardous factor, is air pollution. It is one of the leading risk factors that gives rise to numerous illnesses and even the death of thousands around the world. The CSIR Air and Dust Laboratory supports mines to ensure that hazardous air quality does not harm workers.

The CSIR Air and Dust Laboratory, the first laboratory to be accredited for the analysis of diesel particulate matter in Africa, is equipped with dynamic instruments to measure substances such as respirable dust, diesel particulate matter, fall-out-dust, particle size distribution and metals such as chromium in stack emissions. Drawing on its capabilities and sound track record in airborne dust analysis, the laboratory plays a crucial role in supporting the efforts of the South African government in eliminating silicosis in the mining industry. These efforts are achieved through collaborative efforts with the Mine Health and Safety Council.

Respirable silica dust, one of the most prominent contributors of air pollution in mines, is a substance commonly found around stones, rocks, sand and clay. This substance is naturally found in mining spaces due to the nature of mining operations, and the inhalation thereof has the potential to lead to silicosis, an inflammatory disease of the lungs, which increases the risk of lung cancer. Recent studies have proven that many former miners who were exposed to silica dust suffer from tuberculosis and develop cancer in the later stages of their lives.

Respirable diesel particulate matter is another prominent contributor to air pollution in underground mining, where diesel-powered mining equipment is used and where there is a high combustion of diesel fuel. The pollutant irritates the cardiovascular system, leading to tuberculosis and eventually cancer of the lungs, as classified by the Occupational Safety and Health Administration. Heavy combustion of diesel fuel leads to smog in low-lying areas and it affects the health of the communities in those areas.

In addition to supporting the Departments of Mineral Resources and Energy, the CSIR Air and Dust Laboratory also provides mining clients with analyses and related services on pollutants that are harmful to employees, surrounding communities and the natural environment. The laboratory supports mines to achieve their desired control measures of silica dust exposures. This is achieved through the analyses of sampled dust for silica content and submitting reports to the mine occupational health managers.

The CSIR Air and Dust Laboratory participates in national and international proficiency testing schemes that optimise quality control and analytical performance. All the methods and measurements are traceable to international standards and the laboratory contributes to the data compiled in these methods. The CSIR laboratory is also accredited to measure diesel particulate matter according to the international method of the National Institute of Occupational Safety and Health (NIOSH) 5040 and was the first laboratory to obtain accreditation from the South African National Accreditation System for the NIOSH 5040 method in Africa. Other services offered by the laboratory are particle and size analysis, elemental analysis (iron, chromium, copper, manganese, calcium and sodium) and Fourier Transform Infrared (for dust, liquids and filters).

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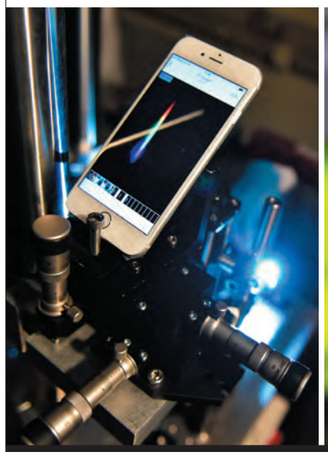
Below: In the field of health, the partners are looking into projects on plant-produced vaccines, smartphones to diagnose diseases and locally manufactured health equipment such as ventilators. Above: Collaboration may strengthen progress made to use television whitespaces to allocate unused spectrum to underserved communities. Right: Representing the partnership are CSIR Chief Executive Officer Dr Thulani Dlamini (left) and DBSA Chief Executive Officer Patrick Dlamini.








# PARTNERING FOR ACCELERATED **AND IMPACTFUL SOCIOECONOMIC DEVELOPMENT**

## THE CSIR AND THE DEVELOPMENT BANK OF SOUTHERN AFRICA

The CSIR and the Development Bank of Southern Africa (DBSA) have signed a five-year framework agreement to collaborate on projects of mutual interest. The pair has identified several opportunities for collaboration, including water, energy, infrastructure development, emerging and small-farmer support, and the DBSA's Development Labs, known as D-Labs. The partnership is expected to drive innovation aimed at achieving positive social and economic impact.

### STRENGTHENING THE NATIONAL HEALTH INDUSTRY

The partnership will look at improving healthcare through the development of innovative, safe, high-quality pharmaceuticals with an initial focus on localising gene expression technology. A second driver is to ensure that such products are made available in Africa by building pilot- and commercial-scale manufacturing facilities in Sub-Saharan Africa. The partnership will also work towards establishing South Africa's biologics production capability with the goal of commercialising a minimum of two plant-produced vaccines by 2025. Notable projects that have been identified include the CSIR's bilevel positive airway pressure ventilator and a biosensing technology that converts a smartphone into a diagnostic tool.

### DIGITAL ECONOMY TRANSFORMATION

Under this programme, the partners aim to promote digital education inclusivity in southern Africa. The CSIR's television white spaces secondary geo-location spectrum database resulted in the allocation of unused spectrum to provide broadband services to underserved communities. As a result, a pilot project has been established to create a number of small businesses that will provide digital access through digital educational content to four rural area schools in one grade.

### ENERGY INDUSTRY TRANSFORMATION

Efforts to help South Africa transform to greener energy methods will include the retrofitting of mobile and stationery diesel equipment with battery and hydrogen fuel cell drives. Such projects will look at trackless machinery and logistics vehicles in mining, airports and ports. The projects aim to develop port and airport auxiliary power units and support emerging farmers through the use of battery-powered pickup trucks and fuel cell-powered water pumps for borehole water pumping.

### MEET THE DBSA

**The DBSA plays a critical role in supporting government to leverage skills and capabilities to drive innovation in key priority sectors of the economy, such as energy, information and communication technology, water and sanitation, education and health, as well as various municipal infrastructure programmes to achieve positive social and economic impact in South Africa, the region and beyond.**

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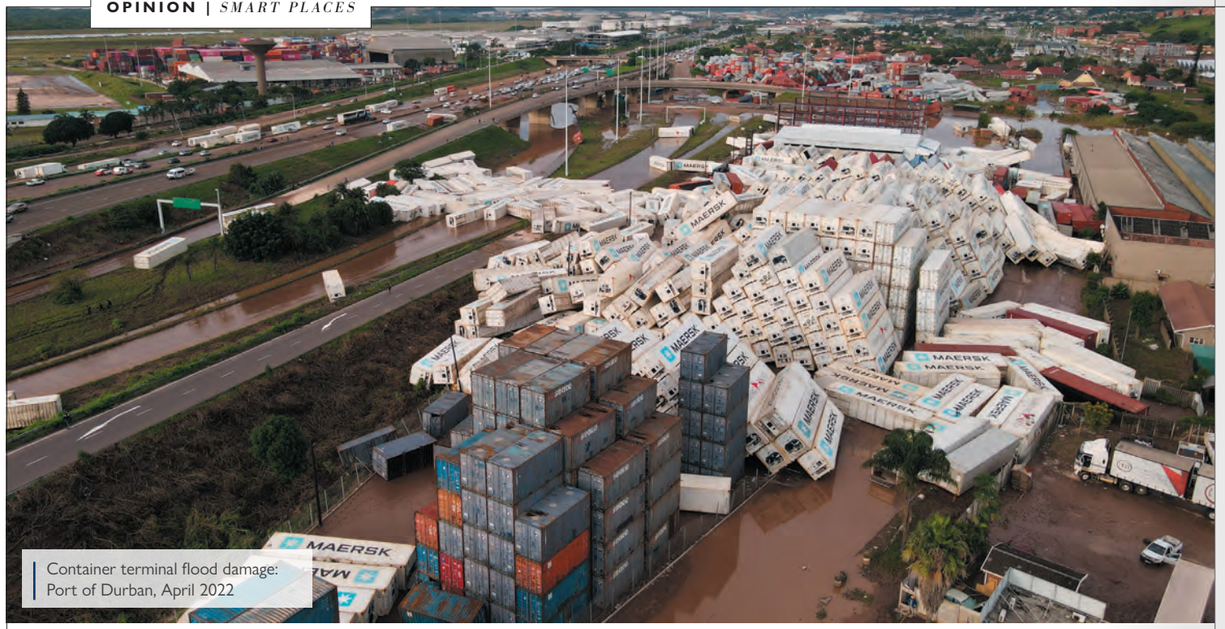


Container terminal flood damage: Port of Durban, April 2022

# PORTS NEED TO INVEST IN RESEARCH TO **RESPOND TO CLIMATE CHANGE**

**By Carl Wehlitz, CSIR senior engineer and Eugéne Mabille, CSIR research group leader for coastal engineering and ports infrastructure**

Since the earliest recordings of history, ports have been seen as the gateway to the outside world. This still holds true today, since ports still form an integral part of global trade in modern society. More than 80% of the world's trade volume is transported by sea and, therefore, ports are regarded as the main gateway to global supply chains, as well as trade-led development.

Climate threats, such as extreme storms and changing weather systems, have a significant impact on coastal zones and infrastructure. Owing to its exposed location, a port is particularly vulnerable to these threats and more so to those associated with global warming and climate change. Phenomena such as rising sea levels, increasing storm surges, extreme winds and waves, and coastal flooding count among the climatic hazards that could adversely impact port operations and cause extended down time. Given the critical role of ports, it is becoming a matter of strategic importance for ports to enhance their resilience to these threats.

It is essential that port authorities and operators start prioritising research and innovation into smart technology, sensors, data networks, artificial intelligence and modelling to help plan for changing needs resulting from climate change. Ports in Europe and Asia have already started preparing for climate change, as extreme weather events are set to increase in frequency and intensity.

Unfortunately, most African ports are lagging and will experience significant disruptions if the future effects of climate change are ignored. The majority of South Africa's port infrastructure was designed when climate change was not a reality or a consideration. Design criteria used at the time have become outdated and may not be applicable in the near future.

Sea level rise is considered to be one of the most detrimental phenomena likely to impact port infrastructure and operations. While raising the mean sea level might seem arbitrary in many instances, it is the secondary effects that are of concern. As the mean sea level rises, so do the associated extreme sea levels, allowing storms of greater magnitude to reach the ports before being dissipated. For this reason, research into the optimal upgrading of current infrastructure is becoming essential. Research into port resilience should, therefore, include re-evaluating the size and type of armour units, height of breakwaters and resilience to overtopping. In this regard, physical modelling can play an important role in testing various options before deciding on the best-suited solution.

Technology has become integral in the way we operate and interact with one another, and the use of technology in all its forms is essential if ports are going to adapt to the effects of climate change. The use of sensors and data networks can provide information to port authorities and operators, allowing them to change and adapt their daily operations as events unfold. This is one form of mitigation, but does not allow for longer term planning and protection of vital infrastructure, such as breakwaters. On the other hand, the data provided by the sensors can be used as input to modelling and build datasets that are invaluable for artificial learning and predicting future trends. By being able to predict the future changes in the frequency and intensity of extreme events, new design criteria for future coastal structures can be adapted and mitigation options for existing structures can be explored.

Research into coastal resilience should also focus on soft engineering solutions. Engineers generally think in terms of hard structures when it comes to marine protection, however, a greater appreciation of eco-friendly alternatives is starting to gain acceptance. By understanding the local environment and working with nature, engineering designs can be tailored to meet the project's business requirements, as well as the climate action goals for sustainable development.

Regrettably, when it comes to research, whether it is physical or numerical modelling, or instrumentation, port authorities and other stakeholders are prone to focus on the costs. What is often overlooked is that the cost of research to obtain a viable solution is far less in comparison to the actual costs of infrastructure construction, or the consequences of key infrastructure failures. The challenge is that, in most cases, the quantification of catastrophic failure is difficult until it occurs. The question that should be asked is: Is it not more cost effective to spend money on research to prevent this? The data and knowledge gained from research are as crucial as the final solution.

The recent events of coastal flooding in the KwaZulu-Natal province of South Africa in April 2022 should be regarded as a wakeup call to ports to start taking the necessary action. These events severely interrupted operations at the Port of Durban, which is one of the busiest ports of its kind in Africa. This highlights the fact that ports can expect climate change impacts, not only from the marine environment, but also from the terrestrial environment. The hope is that the recent floods at the Port of Durban will prompt port authorities and governments across the continent to invest in port research, development and innovation into the effects of climate change.

Ports throughout Africa need to engage with important stakeholders to determine what their perceived impacts of climate change are, so that a holistic approach can be put in place to counter these impacts in future. For instance, the types of exports could change as land temperatures rise and seasons change. A region classified as Mediterranean could become more arid as winters become warmer and drier. There would be some adaptations and mitigation that would be applicable to most ports, however, other adaptations would need to be very port-specific. Without a holistic approach, it is possible that some significant challenges might be overlooked.

The CSIR's research group for coastal engineering and port infrastructure has started to collaborate with industrial partners in South Africa and other global markets, to jointly address issues of development and innovation in the coastal engineering environment to address challenges posed by climate change. By joining forces, we hope that the tide of damage at our ports can be stemmed.

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Debris from infrastructure flood damage in Durban, KwaZulu-Natal.

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