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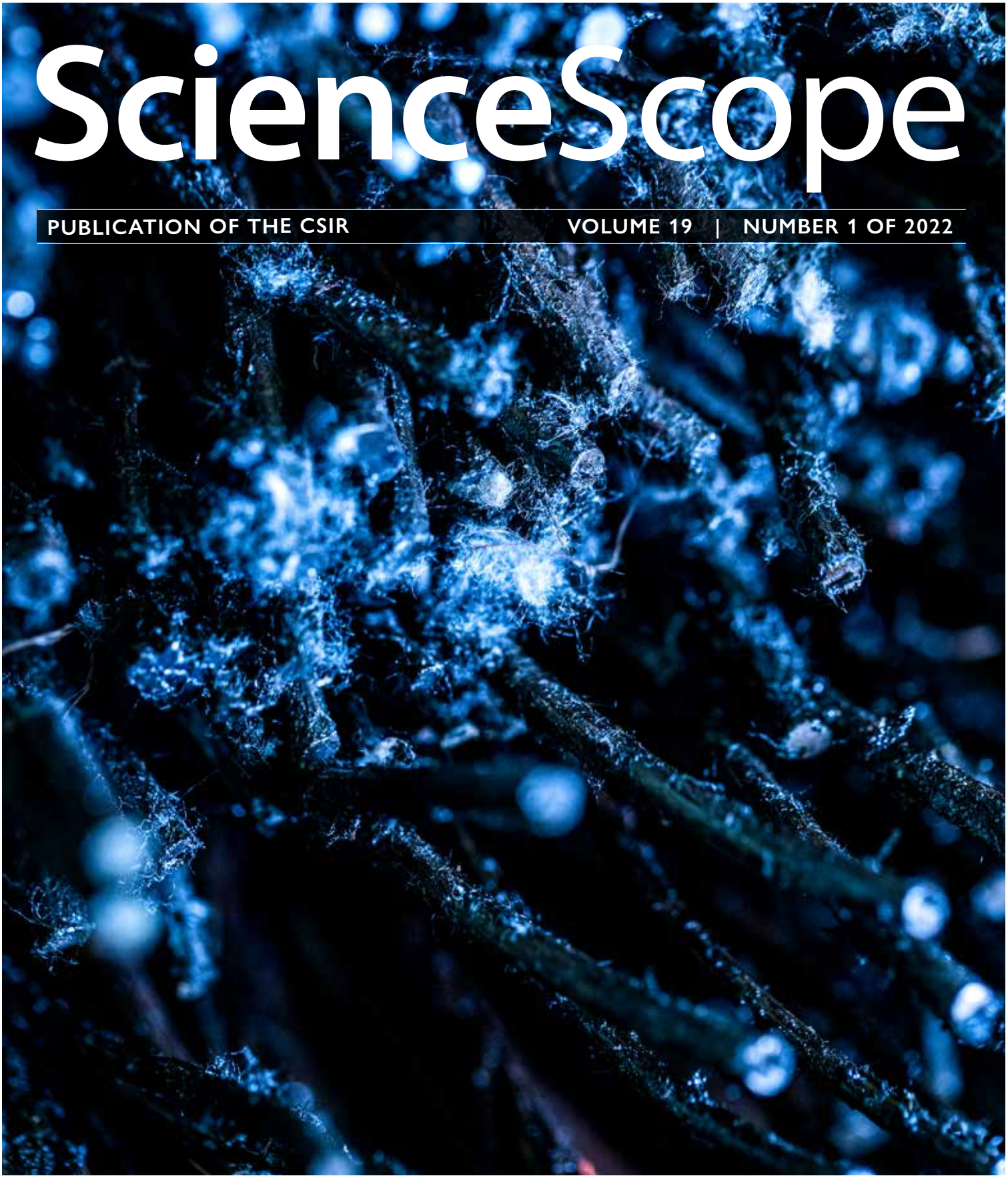

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Touching lives through innovation

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FORWARD, TO COMPETITIVE INDUSTRIES AND A CAPABLE STATE

The success of a research, development and innovation organisation such as the CSIR depends on the quality and calibre of its employees and their ability to innovate and find solutions. We need strong science, engineering and technology (SET) leadership to implement our strategy. In this edition, we take pride in introducing you to five CSIR experts who have been **promoted to chief researcher** level, the highest rung on our research career ladder (page 8). They are experts in their respective fields: radar, protein biochemistry, laser materials processing, remote sensing and precision agriculture, and blast impact and trauma biomechanics. Their skills are as diverse as our multidisciplinary skills base, which continues to be a distinguishing factor when tackling complex challenges.

We also share how our multidisciplinary teams are contributing to building **competitive industries** – developing technologies to make the most of food waste, while supporting budding entrepreneurs (page 22); developing novel packaging solutions to prolong food shelf life to benefit the food and beverages sector (page 21); and assisting a local tech start-up to create an additive manufacturing machine for printing metal parts (page 27).

We also share a few examples of how we contribute to the development of a **capable state** – assisting the South African National Defence Force by evaluating the performance of its military vehicles on deployment along the South Africa-Mozambique border (page 44); and through the development of a novel smartphone-based system for point-of-care diagnostics, with significant potential for a future in which the illnesses of patients in remote areas can be rapidly diagnosed using a cell phone (page 52). We have also completed two projects of national interest, documenting activities and vulnerabilities along our extensive coastline. The assessments will be used to advise government on how to manage the potential risks and rewards of our coastal areas (page 32).

I hope that you will be inspired to find out more about the work of the CSIR and how we can collaborate with you.

Dr Thulani Dlamini
CSIR Chief Executive Officer

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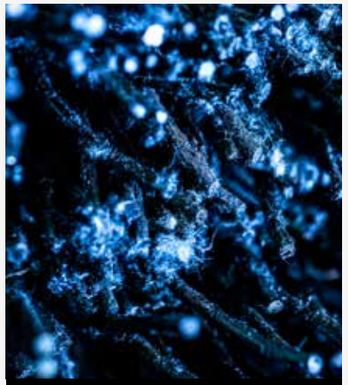
Our People



ON THE COVER
Close-up of cut mining ropes. The CSIR operates an internationally recognised steel wire rope testing facility that tests rope specimens to determine the breaking strength and general condition of mining ropes to help ensure the safety of South African miners. See page 18.

Our Work

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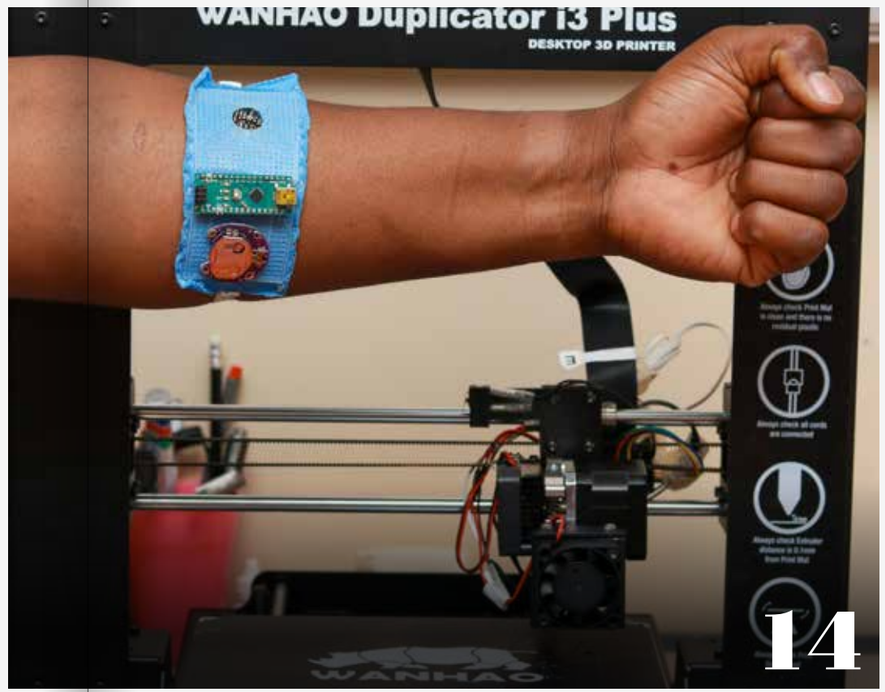
Our Infrastructure



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Opinion

Our PEOPLE

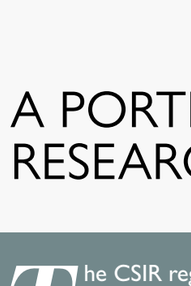
Teaming up interns with experts is a useful way of transferring knowledge and contributing to a pipeline of young, talented researchers and engineers.

Amidst the high unemployment rate of young people in South Africa, the CSIR has given 55 young people a much-needed head start that will help position them favourably in the job market.

On pages 12 and 13, two of these interns, Thembelihle Mdakane and Ally Maluleke, and their supervisors, Prisha Mandree and Dr Ghaneshree Moonsamy, are featured. Pictured are Thembelihle Mdakane (left) and Dr Ghaneshree Moonsamy.

A PORTFOLIO OF BEST-IN-CLASS RESEARCHERS

The CSIR regards a solid base of principal and chief researchers as an important indicator of the organisation's capacity to fulfil its mandate and retain its status as a distinguished research organisation on the continent. Attaining the highest rung on the organisation's research career ladder, that of chief researcher, requires local and international recognition, a sustained track record and significant outputs in a specialised research field, with proven impact on society and within the research community. At the end of 2021, the organisation welcomed five new chief researchers who are helping the organisation touch lives through innovation in a variety of domains.



LEADER IN BLAST PROTECTION RESEARCH

Dr David Reinecke started his career in aviation prior to joining the CSIR. Some of his noteworthy achievements during that time included assembling the first Rolls Royce E4B gearbox manufactured in South Africa, the industrialisation of the Rooivalk Attack Helicopter transmission system, and successfully bidding for international manufacturing contracts on the Trent 500 engine programme.

Reinecke joined the CSIR in 2004 and has successfully grown the CSIR's protection research capability, an essential capability in the context of defence and security, through the attraction of leading scientists, the acquisition and implementation of core infrastructure and equipment, the training of young researchers, as well as the development of vital blast test infrastructure at the CSIR Detonics Ballistics and Explosive Laboratory.

Recognising a gap in local protection research, Reinecke has established a CSIR trauma biomechanics research capability. With support from his management team and young researchers, Reinecke was successful in attracting and increasing external funding to grow capabilities and research in this field.

Reinecke has developed nine technology demonstrators in the fields of blast impact, structural response, trauma biomechanics and military mobility fields; contributed to two British Standards and an international military modelling and simulation standardisation recommendation; and co-authored several international reports that are used to update international survivability test standards.

EXPERT IN PRECISION AGRICULTURE

Professor Moses Cho joined the CSIR in 2007 and has grown through the ranks, from senior researcher to principal researcher, and now chief researcher. Cho and his team, in collaboration with their German counterparts, have developed a bush information system for mapping bush encroachment and woody biomass in southern Africa by combining several remote sensing technologies, such as hyperspectral, synthetic aperture radar and lidar sensing. This work has enhanced South Africa's ability to respond to the impact of environmental change.

Rated as an established researcher by the National Research Foundation, Cho is an associate editor for two international journals, the president of the African chapter of the International Association of Landscape Ecology and the technical committee convenor for algorithm development and application for the African Association of Remote Sensing of the Environment. He has published over 100 journal and peer-reviewed conference papers.

RENOWNED PROTEIN BIOCHEMIST

Dr Tsepo Tsekoa has earned recognition for his expert knowledge of recombinant production and the characterisation of biologics, including vaccine antigens, enzymes and antibodies. His work focuses on the development of cost-effective production processes for biologics, prioritising partnerships with industry and other collaborators to expedite South African self-sufficiency and expand access to expensive biopharmaceuticals for low to middle-income countries.

In the past seven years, Tsekoa has led the development of eight technology demonstrators at technology readiness levels six to eight; five of these technologies have been transferred to industry, and four are currently being used in commercial settings. His work led to the establishment of a small, medium and micro enterprise that employs 13 people. Tsekoa's involvement in the national response to the Covid-19 pandemic has resulted in the licensure of a Covid-19 diagnostic technology by the South African Health Products Regulatory Authority.

AN EXPERT WHO HELPED PUT TARGET RECOGNITION AND IMAGING ON THE RADAR

Willie Nel has been working in the field of radar since 1999, with a focus on radar system design, radar-based target recognition, imaging radar and radar signal processing.

He has published more than 30 research papers on radar target recognition and imaging and is the primary engineer behind several CSIR radar technology demonstrators. These range from the digital backend for South Africa's first airborne synthetic aperture radar; the high-range resolution modes for Fynmeet, the system used to characterise the radar cross section of the naval frigates acquired in the early 2000s; and the MECORT radar research facility used to create radar target recognition, inverse synthetic aperture radar and anti-multipath technology for the radar industry; to a multi-static radar network that demonstrated the ability to detect small drones over a 5x5 km area with Swiss counterparts.

Nel is the chief engineer for the CSIR's synthetic aperture radar group, with a focus on the development of airborne, unmanned aerial vehicle and spaceborne synthetic-aperture radar systems. Since 2015, he has been presenting tutorials and guest lectures on radar-based target recognition in countries such as Australia, China, India, the United Arab Emirates, the United Kingdom and the United States of America.

A LASER-FOCUSED SCIENTIST

Professor Sisa Pityana is revered for his contribution to human capital development in the field of laser technology in South Africa and Africa. He has supervised 20 PhD students and six Master's students in his quest to groom the next generation of researchers.

His area of expertise is laser materials processing, looking into titanium, aluminum and other materials, such as metal matrices and functional graded structures, in addition to metal alloys necessary in the aerospace, energy and biomedical sectors. His current focus, among others, involves research, development and commercialisation of titanium aluminide alloys. Pityana has been instrumental in developing research programmes and facilities at the CSIR Photonics Centre. These facilities include, among others, a world-class laser shock peening laboratory and 3D laser printing facilities for both research and commercial purposes.

CSIR CHIEF RESEARCHERS

- Prof. Adele Botha
- Dr Bonex Mwakikunga
- Dr Bruce Sithole
- Dr David Reinecke
- Dr Fisseha Mekuria
- Dr Jeremy Gibberd
- Dr Keith Ferguson
- Dr Letlibe (Jackie) Phahlamohlaka
- Prof Marlien Herselman
- Dr Moses Cho
- Dr Pedro Monteiro
- Dr Sisa Pityana
- Prof. Suprakas Sinha Ray
- Dr Tsepo Tsekoa
- Dr Willie Nel

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A JOURNEY OF GETTING COMFORTABLE WITH **UNLEARNING, RE-LEARNING AND BEING WRONG**

Dr Lehlogonolo Ledwaba returns home with a PhD from the City University of Hong Kong

*H*er PhD studies could hardly get any more relevant and now Dr Lehlogonolo Ledwaba is ploughing back her newly acquired knowledge on the use of distributed ledger technologies for distributing, buying and selling renewable energy in a community context.

Dr Lehlogonolo Ledwaba first joined the CSIR as a bursar in 2013 before joining the CSIR workforce in 2018, by which time she had completed her MSc through a CSIR Master's Studentship. She secured a scholarship to pursue her PhD studies at the City University of Hong Kong's Department of Computer Science in the same year.

"Honestly, this is the strangest story of extraordinary luck," she says chuckling. "Initially, I wasn't even going to do a PhD; I was going to settle for an MSc, but my research group leader, John Isaac, convinced me to do it while I still had the advantage of youth on my side. And that's how my PhD journey started," she says.

"I believe in a future for South Africa where technology – and access to technology – is not a privilege for the few – but one of the main tools that empowers individuals and communities."

"We have an opportunity to become market leaders for technologies that are made specifically to perform well and be implemented in developing economies – where a lot of the infrastructure that existing solutions assume to be in place, may not necessarily be there," she says.

A CASE FOR RENEWABLE ENERGY

Ledwaba, a CSIR senior technologist, completed her PhD at the City University of Hong Kong in a three-year programme, which she started in September 2018. She spent the majority of the time in Hong Kong, but had to complete the remainder of the degree remotely from South Africa when national borders closed as a result of the Covid-19 pandemic. Her research focused on the use of distributed ledger technologies as a means of establishing a local marketplace in which households equipped with a renewable energy generation source and a smart meter, can buy and sell energy alongside their neighbours and local communities.

"These local networks are called microgrids and my work also investigated what additional challenges and requirements would need consideration once we deployed these microgrid networks into rural communities that are geographically distributed and decentralised from the national energy grid," she says. Distributed ledger technologies form the backbone of cryptocurrencies such as Bitcoin and Ethereum. Ledwaba hopes that her research will help change the energy landscape in South Africa and update the current grid from a mono-directional to a bi-directional, peer-to-peer distribution scheme.

"South Africa needs to move towards renewable energy, especially with the great potential we have for renewables, and since the national grid currently cannot handle the load," she says.

"So, by developing the smart, transactive microgrid, we hope to have end users take control of their own energy needs, aid their communities to maintain a stable supply, reduce carbon emission and the country's reliance on coal, and help to get rid of load shedding once and for all," she says.

LEARNING IS A LIFELONG PROCESS

As with any journey, Ledwaba's PhD journey had both highlights and lowlights, the lowest moment being losing both her father and grandmother within three months of each other at the same time she was preparing to submit and defend her PhD.

"Reaching that finish line was difficult. Too many things happened at the same time. To have been able to successfully defend and pass my degree, despite everything, is definitely my proudest moment!"

Ledwaba has learned a lot of lessons through her research career and PhD journey, and is a better person for it. She encourages fellow researchers joining the science, technology, engineering, and mathematics field to be inquisitive and never stop learning. "Get comfortable with being wrong, with changing your mind later, with established processes and knowledge bases changing, and with having to relearn and unlearn," she says.

"Science is about progress and sometimes that progress is rapid and means that you must go back and change something that is already established. New knowledge is always coming out and you can end up being wrong, very wrong, many times in your career," she adds.

Nevertheless, Ledwaba encourages those still pursuing their studies to 'ride it out', as science and research is a rewarding journey of innovation and impacting people's lives positively. "I wholeheartedly believe that South Africa's future lies within technology and leveraging the fourth industrial revolution to change people's lives for the better," she concludes.

FUN FACTS ABOUT DR LEHLOGONOLO LEDWABA

- Eldest of two daughters
- Raised by a computer scientist father
- Wanted to be a molecular biologist
- Favourite childhood author: Enid Blyton
- Avid reader and relatively decent dancer
- Born without fingerprints

CSIR senior engineer Prisha Mandree (right) shows YES intern Ally Maluleke how to operate the vacuum filtration rig in the bio-based laboratory.

PARTNERING TO BUILD A SOLID PIPELINE OF **FUTURE SCIENTISTS AND ENGINEERS**

The CSIR has shown that strength in partnerships not only applies to jointly developing or localising technologies, but also to building a strong pipeline of young professionals in science, engineering and technology. A partnership between Youth Employment Services and the CSIR is a testament to how national challenges like the unemployment of young people can be mitigated through meaningful training programmes that enhance their skills.

CSIR senior engineer Prisha Mandree has first-hand experience of the importance of investing in young professionals as supervisor of an intern of Youth Employment Services (YES) placed at the CSIR.

"The youth are finding it increasingly difficult to find employment due to a lack of work experience, and this is exacerbated by the many challenges currently facing South Africa. The relationship between YES and the CSIR gives young people a chance to get practical training in the fields of science and engineering, which contributes to them being more marketable," says Mandree.

The partnership, which started in 2020, resulted in 55 experiential learning opportunities for YES youth placed at the CSIR. Of the 55, 14 young people were placed with small and medium-sized enterprises (SMEs) that have, at some stage, been supported by the CSIR's industry-facing centres, such as the Biomanufacturing Industrial Development Centre (BIDC), the Biorefinery Industry Development Facility, the Photonics Prototyping Facility and the Nanomaterials Industrial Development Facility, with process and product development. Two young professionals were placed with the CSIR's bioprocessing research group and two with the biorefinery research group in KwaZulu-Natal.

"We placed the selected candidates with SMEs because of the increasing need to assist these enterprises with additional manpower to grow their companies and increase revenue. In turn, interns stand to gain a wealth of experience from working alongside entrepreneurs," says BIDC Programme Manager, Lara Kotze-Jacobs.

Upon surveying the SMEs, 12 indicated that they would be able to host interns and provide them with vocational learning opportunities. These companies include Bluegold Holdings, Setsong, Kutleng, OptimusBio and Aditiv Solutions.

Two interns who are particularly enjoying their internship experience are Thembelihle Mdakane and Ally Maluleke, who have been placed at the CSIR's bioprocessing research group and have described their experience so far as enriching and valuable.

"My experience as a CSIR intern has been nothing short of amazing. I have gained experience in biosciences and the process of producing bio-based materials, which is very valuable for the career path I want to follow. The CSIR workforce has been friendly and welcoming, and it has been easy for me to learn and adjust quickly because the environment is conducive to rapid learning. The opportunity that the YES programme and the CSIR have provided me with, has served as a great career foundation for me, and I will forever be grateful," says Mdakane.

Sharing these sentiments is Alley Maluleke from, Ga-Molapo in Limpopo. "I get to work with instruments in the lab on a regular basis, which means that I now have experience in operating many of the sophisticated equipment in the lab. I have thoroughly enjoyed working with a supportive and diverse team; I feel that by the time I complete my internship, I will be fully equipped with all the skills I need to build my career."

CSIR senior researcher Dr Ghaneshree Moonsamy, who also supervises interns, says it has been an enriching experience to contribute to the skills development, training and workplace exposure of the interns.

"Most young graduates are willing to learn and develop themselves; they merely seek an opportunity to further their skills and gain work experience. It is indeed a privilege to positively impact their personal development," says Moonsamy.

The YES programme interns at the CSIR come from Gauteng, KwaZulu-Natal and Limpopo. Before being placed, each of them went through a rigorous interview and selection process. During the 12-month internship period, they are equipped with suitable skills for industry uptake and receive a monthly stipend from the CSIR.

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Victor Agbakoba showcases the final look of his 3D-printable bionanocomposite filament for a wearable e-textile device, which has the ability to measure one's heart rate.

RECOGNITION FOR HIS E-TEXTILE DEVICE **SPURS ON PHD STUDENT VICTOR AGBAKOBA**

CSIR PhD student Victor Agbakoba's research on a custom-made 3D-printable bionanocomposite filament for a wearable e-textile device received an honourable mention at the 2021 Natural Fibrenamics Awards. The award ceremony was held online at the fifth International Conference of Natural Fibres in Portugal.

Victor Agbakoba's 3D-printable bionanocomposite filament was prepared by melt-mixing poly (lactic acid) biopolymer and cellulose nanocrystals. The cellulose nanocrystals were extracted from sawdust at the CSIR's Biorefinery and Industry Development Facility.

Agbakoba explains that the applicability of poly (lactic acid) and cellulose nanocrystals bionanocomposite is limited due to issues like inadequate dispersion and poor flexibility. To tackle the issue of dispersion, Agbakoba used green solvents to re-disperse the freeze-dried cellulose nanocrystals prior to melt-mixing them with the biopolymer. Furthermore, Agbakoba added optimised ratios of non-toxic bio-based additives to improve the miscibility and flexibility of the final bionanocomposite filament.

As a result, the bionanocomposite filament possessed excellent balance between strength and flexibility – which he says is a key requirement for the wearable e-textile device he made. Agbakoba proceeded to directly 3D print a grid pattern onto a stretchable polyester fabric; this resulted in a hybrid material where the bionanocomposites grid acts as a lightweight exoskeleton. Thereafter, a pulse-rate monitoring sensor and a programmable Wi-Fi-enabled microcontroller (Arduino nano) were stitched directly onto the fabric. The conductive pathway was established via direct stitching of the circuitry, using a 0.1 mm enamel-coated copper wire; the ends of the wires were soldered to establish the connections. For this version of the device, the pulse rate is measured, processed and transmitted in real time. The measured signal is visually transmitted by different blinking sequences of LED lights located on the surface of the microcontroller.

To receive recognition at this level, while doing my PhD, is really affirming and is an indication that I am on the right track with my studies. It also makes me feel good to see all the hard work I put in, pay off," says Agbakoba.

As a PhD student under the supervision of Dr Maya Jacob John of the CSIR's Centre for Nanostructures and Advanced Materials, and Prof. Percy Hlangothi of the Nelson Mandela University, Agbakoba was able to tap into his academic support structure for guidance on how he can best demonstrate bionanocomposite materials for 3D-printing applications by using biopolymers and adding waste biomass – an innovation that extracts value from waste to develop high-value products.

"The use of waste biomass, together with biopolymers for 3D-printed materials, is an untapped space in the country. 3D printing is a technology that has not been fully explored and there's generally a heavy reliance on imported materials for it. Therefore, my research aims to fill this gap in the market," adds Agbakoba.

Agbakoba is passionate about using his education and the skills he has acquired to respond to industry-related problems and needs.

"The knowledge that I have gained through my PhD experience, together with the Natural Fibrenamics Award, has proven to me that education needs to be a multidimensional experience. The collaboration with an academic institution like the Nelson Mandela University and the CSIR has encouraged me to keep a good balance between theoretical and practical knowledge. The combination of academic guidance and industry-based knowledge has empowered me to consider starting my own business in the future, where I would develop systems to assist small, medium-sized enterprises and contribute towards a bio-circular economy," Agbakoba says.

He notes that having access to infrastructure, funding, a network of experts and intellectual guidance from an academic institution have all contributed to creating a conducive environment for him to excel.

"I wish more research students could have the same opportunities that I have had. Even though I am based at Nelson Mandela University, I have access to the state-of-the-art processing and testing equipment at the CSIR and I can contact the experts who give me guidance when I need it. My supervisors also encourage me to participate in international workshops and this, in fact, was my fourth presentation at an international conference. Additionally, the bursary funding that I have received through the Department of Science and Innovation covers all the expenses that come with my research project. All these things play a big role in making one's PhD experience a little easier," Agbakoba concludes.

Agbakoba intends to improve the functionality of his e-textile device. Additionally, the future versions of this technology will feature integrated wireless communication capabilities, like Wi-Fi and Bluetooth, for convenient transmission of these signals to a receiver device such as a mobile app.

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INNOVATION IN BIO-BASED RURAL ROAD STABILISERS EARNS **DR VESHARA RAMDAS L'ORÉAL-UNESCO RECOGNITION**

CSIR senior researcher Dr Veshara Ramdas was one of the young talents recognised in the postdoctoral category of the L'Oréal-UNESCO International Awards for Women in Science for her work on a bio-based road stabiliser product as an alternative to soil binders such as cement, lime or bitumen for road construction in rural areas.

In recent years, South Africa's road construction industry has declined due to a lack of public spending, rising material costs and lower profit margins. Rural South Africa is feeling the brunt of this decline the most. Rural roads are made from lateritic or gravel soils due to the lack of funding and engineering input during construction, and insufficient maintenance. This means that rural roads are generally poor due to their inability to withstand harsh weather conditions like heavy rainfall and soil erosion.

Ramdas' interests in pursuing research involving the use of the bacteria *Bacillus spp* in road stabilisers came after she completed her CSIR internship, during which she mainly focused on bioprocessing. The research topic was encouraged by her CSIR co-supervisor Dr Rajesh Lalloo.

"I know that solving this problem using biobased alternatives will end up having positive benefits for our environment worldwide. Inspiration came from both my difficulties and successes throughout my PhD studies. Negative feedback just motivated me to work harder at finding a solution," says Ramdas.

"I am proud of this achievement, particularly because it confirms the importance of improving the quality of our roads, especially in rural South Africa," says Ramdas.

Working with Dr Martin Mgangira, a civil engineer by training and CSIR research group leader for pavement design and construction, Ramdas set out to help develop a cost-effective bio-based stabilisation product that uses microbes as additives. This process involves the creation of microbial bio-stabilisers using admixtures produced via a process of industrial fermentation that employs bacteria such as the *B. Lichenforms* strain. *B Lichenforms* is a bacterial strain that occurs naturally in soil; the bacteria can produce extracellular polymeric substances resistant to adverse environmental conditions such as soil erosion caused by heavy rainfall.

"This type of bio-based soil stabilisation is effective as it improves the longevity of road surfaces by maintaining soil moisture levels by acting as a waterproofing agent. It also increases the strength of roads, contributing to road longevity and a reduced need for repairs. Further, it lessens the dust associated with gravel roads and lowers the number of road accidents caused by dust hampering the sight of motorists," adds Ramdas.

Ramdas has published four peer-reviewed articles and co-authored a book chapter. Over and above her award from L'Oréal-UNESCO, Ramdas has several accolades under her belt. In 2020, she was one of four nominated as best doctoral student at the CSIR Excellence Awards, and in 2021 she was named best doctoral student at the CSIR Future Production: Chemicals Excellence Awards. She was also awarded second prize for poster presentation in 2019 at the South African Society for Microbiology conference.

"I am grateful that I had mentors who equipped me to make a difference, such as my main supervisor and research group leader, Dr Santosh Ramchuran. I am also grateful for mechanisms such as the CSIR/Department of Science and Innovation Interbursary Scholarship, which enabled my development as a researcher. The inherent value of collaboration was one of my biggest lessons, as working with experts in pavement engineering and polymers and composites greatly enhanced my research," she says.

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Our WORK

The rope cutting process at the CSIR's rope testing laboratory is an established rope preparation method used as part of rope condition monitoring for mines. Contributing to the critical issue of safety and compliance in the South African mining industry, the rope-cutting process employs critical steps in getting mine ropes adequately ready for assessment. The rope cutting process requires a cut-off machine to cut the rope to size, enabling an assessment of the rope's material stiffness and evaluating its ability to elongate. Key to this process is an intricate inspection of broken wires along with historical data analysis, providing an indication of the rope's remaining life.

Dr Jayita Sinha Roy working with her team at the CSIR Nanomaterials Industrial Development Facility, while supervising the quality of the polymer composite/nanocomposite-based packaging film.

A sample of the bag-in-box packaging solution aimed at preserving the flavour of wine, while extending its shelf life.

Pellets used in the development of the CSIR polymer-based food packaging technology.

OUR WORK | *FUTURE PRODUCTION: CHEMICALS*

KEEPING OXYGEN **OUT AND FRESHNESS IN**

NOVEL FOOD PACKAGING SET TO EXTEND FOOD SHELF LIFE

The CSIR, in collaboration with the Technology Innovation Agency, has developed a novel polymer composite packaging solution that is set to prolong the shelf life of food.

Food insecurity is a national concern linked to economic decline. It has been further exacerbated by the Covid-19 pandemic, as well as climate change. Related to the concern about food security, is ineffective food packaging, which compromises the quality of food. It is estimated that, in South Africa, 30% of food losses or wastage are linked to inadequate packaging solutions.

"Using our skills in advanced polymer formulation and drawing on our well-equipped Nanomaterials Industrial Development Facility (NIDF), we were able to develop a packaging solution that prolongs food shelf life. It features a nanocomposite technology that confers a superior passive oxygen barrier property to packages, and an active composite liner technology that interacts with packaged foodstuff to help preserve its quality over extended periods," says CSIR senior researcher Dr Jayita Sinha Roy.

The locally developed technology solution has been incorporated into a bag-in-box packaging solution for wine. The new technology could potentially improve the taste of wine and extend its shelf life. According to Sinha Roy, passive oxygen

The film that was produced from pellets before being integrated into a packaging solution.

treatments can be extended to food packaging for spices and nuts.

The technology has gone through several trials with different industrial partners to validate the manufacturability and quality of the formulated pellets, which are used to make film and, thereafter, integrated into the packaging design. This was followed by the productisation of the technology by designing and manufacturing 100 3L bags for wine packaging, featuring the novel active liner technology.

"The manufactured samples will be subjected to user testing to ascertain their acceptance. Other end-use applications in different market segments are also lined up for testing," says Sinha Roy.

An industry partner has shown interest in commercialising this technology. Once commercialised, the locally developed technology will offer the food industry an alternative and innovative solution to extend the shelf life of food products – one that will also benefit the end-user.

The project began in 2018 with laboratory validations of the nanocomposite technology, which is based on locally sourced minerals. Following lab validations and production processes for the formulated polymer nanocomposite, the active composite and the various film constructions were carried out at the NIDF.

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Thandiwe Mchunu, a CSIR bursar and small-scale farmer, produces organic manure and biogas using a CSIR-developed approach.

EVERY **MORSEL COUNTS**

THE VALORISATION OF FOOD WASTE IN A CIRCULAR ECONOMY

The CSIR has collaborated with the United Nations Development Programme to create a hub where technologies to beneficiate and extract maximum value from food waste are tested, developed and transferred to startups.

Substantial food losses and wastage in the fresh fruit and vegetable supply chain, from farm to fork, are a major concern worldwide. These losses are largely due to the lack of required market infrastructure; appropriate transport and storage; as well as improper handling, packaging and processing. Food losses and waste in South Africa were estimated at 10.3 million tons in 2021, or 34.3% of local production.

UNLOCKING THE VALUE OF WASTE FROM FRESH FRUIT MARKETS

CSIR experts in chemicals and advanced agriculture and food research have developed a three-pronged approach to maximising the value of the waste created at fresh fruit markets by converting the waste into biomethane that can be harvested for energy use in households; converting the waste into high-quality compost using the Bokashi process to replace current chemical-based fertilisers; as well as by transferring these technologies for uptake by a small, medium and micro enterprise.

A pilot project looking at the amount of food waste generated at the Durban Fresh Produce Market revealed that over 50 tons of fruit and vegetable waste is disposed of on a weekly basis, with spikes of 150 to 200 tons during the Easter and Christmas seasons.

In the first intervention, researchers used different combinations where food waste was mixed with two harvested invasive species, namely *Syringa spp* and Spanish reed, combined with spent grain and effective micro-organisms to absorb the high moisture content of the food waste. The mixture was allowed to ferment for six weeks and applied as compost two weeks before planting. Crops such as tomato, spinach, chilli and bell peppers, lettuce and cabbage, which are commonly grown in communities, were selected and cultivated, using the compost in the pilot project. The second part of the project involved the conversion of food waste into biogas. Researchers found that the food waste contained components that are ideal for conversion into biogas under anaerobic conditions, using cow dung as biomass.

The CSIR has successfully transferred the technology to a young female-led startup in Umkomaas, KwaZulu-Natal, where a digester capable of generating enough biogas to support a family of five, was set up. This will be used to demonstrate the technology for further uptake by rural communities.

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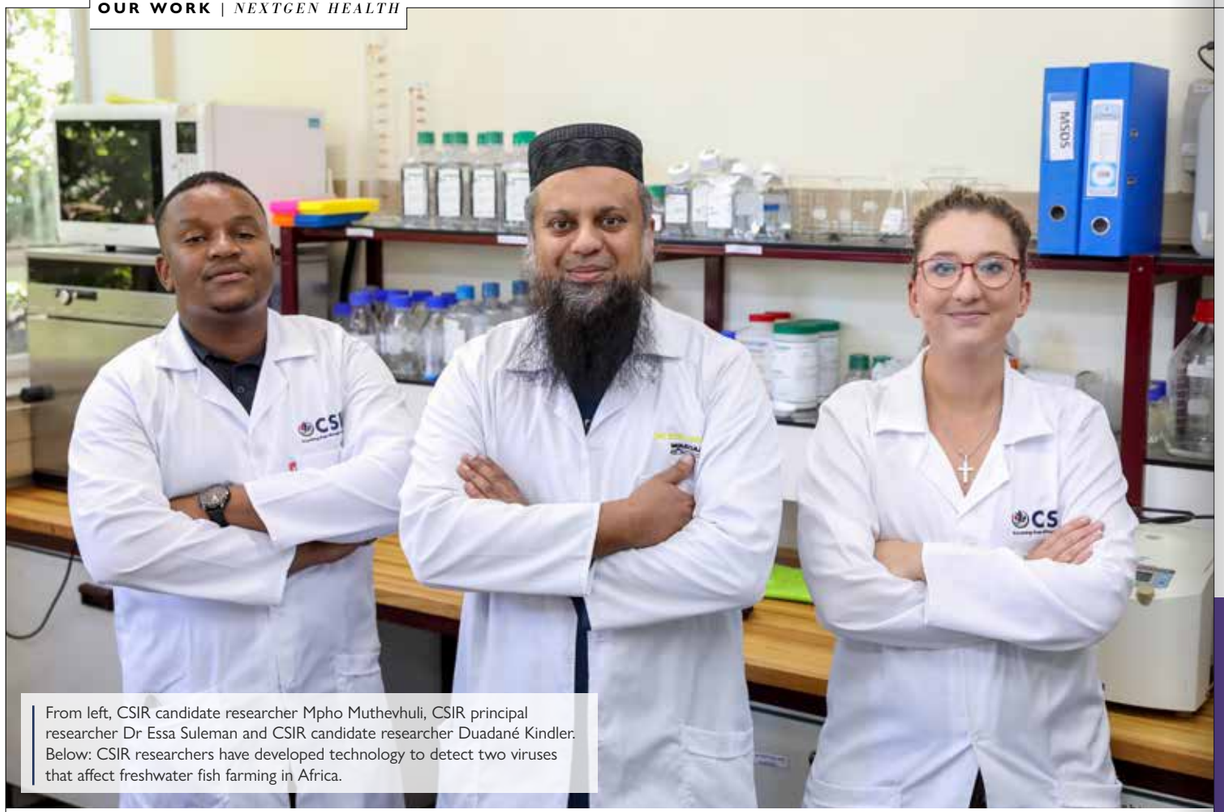


From left, CSIR candidate researcher Mpho Muthevhuli, CSIR principal researcher Dr Essa Suleman and CSIR candidate researcher Duadané Kindler. Below: CSIR researchers have developed technology to detect two viruses that affect freshwater fish farming in Africa.

DETECTING THE CULPRITS **PLAGUING FISH FARMING IN AFRICA**

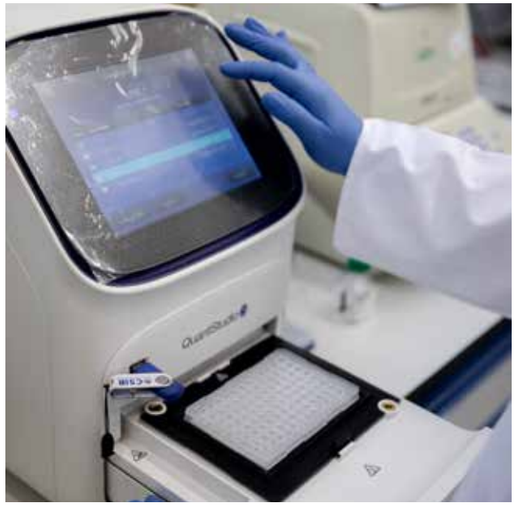
RESEARCHERS DEVELOP NEW TECHNOLOGY TO DETECT VIRAL DISEASES AFFECTING AQUACULTURE INDUSTRY

The aquaculture industry – across the African continent – is set to benefit from novel diagnostic assays that are being developed by the CSIR to detect viral diseases caused by the infectious spleen and kidney necrosis virus and the tilapia lake virus.

The infectious spleen and kidney necrosis virus and the tilapia lake virus are posing a threat to the aquaculture industry across the African continent, particularly the freshwater fish farming industry.

"Freshwater fish farming has become increasingly important in Africa because it is an affordable and sustainable source of animal protein and a boost for the economy. However, as production is increasing, the industry has been negatively affected by the emergence and spread of viruses such as the infectious spleen and kidney necrosis virus and the tilapia lake virus," says Dr Essa Suleman, CSIR principal researcher and research group leader.

"Although there have been bacterial, fungal and parasitic infections threatening the industry, these can be treated with appropriate therapeutics or vaccines. In recent years, however, viral diseases like the infectious spleen and kidney necrosis virus and tilapia lake virus have become the major threat for the global aquaculture industry, resulting in very high mortality rates and severe economic losses," he says.



In a project funded by the Department of Science and Innovation and the CSIR, Suleman and his team of experts in veterinary molecular diagnostics and vaccines have successfully developed real-time polymerase chain reaction (RT-PCR) and traditional PCR assays for detection of the two viruses.

PCR and RT-PCR are technologies that enable the detection of the genetic material from a specific organism, such as a virus and can thus be used as diagnostic tools to detect positive infections, in other words, the presence of the target virus or pathogen.

The next phase of the project involves a training workshop, field trials and validation of the technology for licensing and commercialisation, in collaboration with principal scientist Dr Ruby Asmah and other scientists from Ghana's Council for Scientific and Industrial Research – Water Research Institute. Other collaborators/partners include the Lilongwe University of Agriculture and Natural Resources in Malawi, and others from across Africa.

"The availability of these diagnostic assays or kits will greatly improve the surveillance and detection of the viruses, which pose a serious threat to Africa's aquaculture industry," Suleman says.

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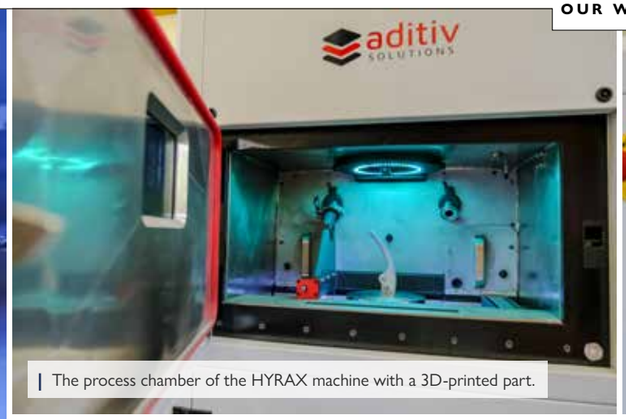
The process chamber of the locally developed HYRAX machine, showing a part that was 3D printed directly in stainless steel.



The process chamber of the HYRAX machine with a 3D-printed part.

The interface and monitoring panel of the HYRAX machine.

SUPPORTING A LOCAL COMPANY IN DEVELOPING **THE FIRST LOCAL COMMERCIAL METAL 3D PRINTER**

The CSIR assisted Aditiv Solutions in the testing and calibration of a high-power optical system for use in its first commercial, additive manufacturing machine for printing metal parts.

A team of CSIR researchers has supported a local tech start-up in the development of a 3D printing product that is able to print metal parts.

The laser-based powder bed fusion system allows for 3D printing of parts directly from metal powder. The benefit of this technology is that it allows for the manufacturing of highly complex parts directly from computer-aided design data.

"The CSIR is the only local research institution with the capabilities and equipment required to test the optical subsystem of our machine. The organisation has been instrumental in the success of this project. With the help of the CSIR and the equipment it has available, we were able to assemble, test and characterise our optical system in a safe and controlled lab environment. Ultimately, with this development, we hope to contribute towards growing the South African manufacturing industry," says Jacobus Prinsloo, chief engineer at Aditiv Solutions.

The assembly, testing and calibration of this system were performed at the CSIR's Photonics Prototyping Facility, which was established for this type of project. It offers state-of-the-art cleanroom facilities where the environment is controlled and contaminants are removed from the air.

Aditiv Solutions' first system has now been completed and was launched at the 2021 Rapid Product Development Association of South Africa conference. The company is manufacturing several systems that will be deployed at local organisations.

"The CSIR team uses its combined backgrounds in novel laser engineering and photonics prototyping to improve manufacturing processes. Advanced manufacturing is one of the CSIR's key capabilities, and this is a great example of an interdisciplinary effort to advance the field," says Dr Hencharl Strauss, manager of the CSIR Photonics Centre.

Aditiv Solutions is a local upcoming company that specialises in developing and manufacturing high-quality and affordable additive manufacturing equipment.

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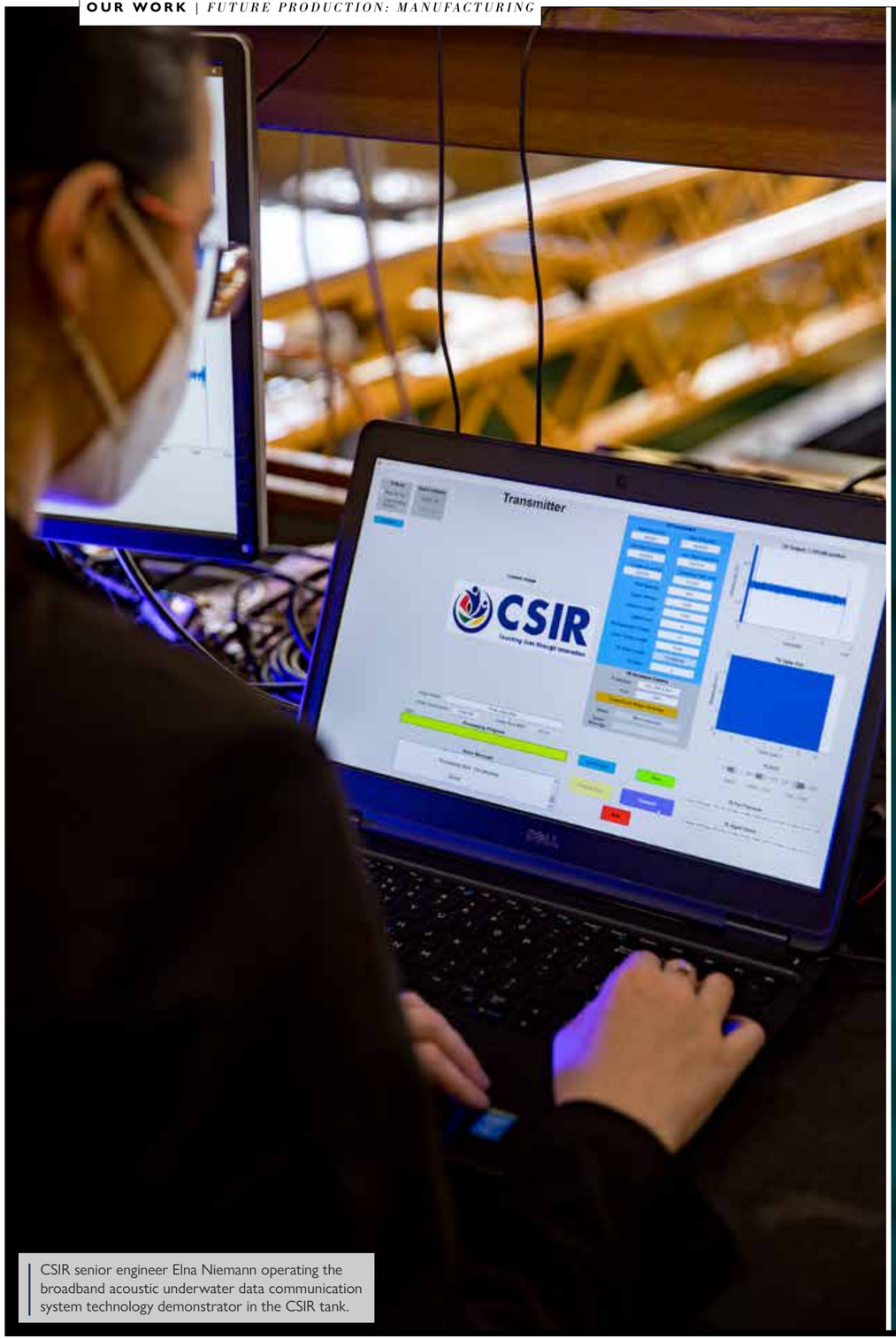
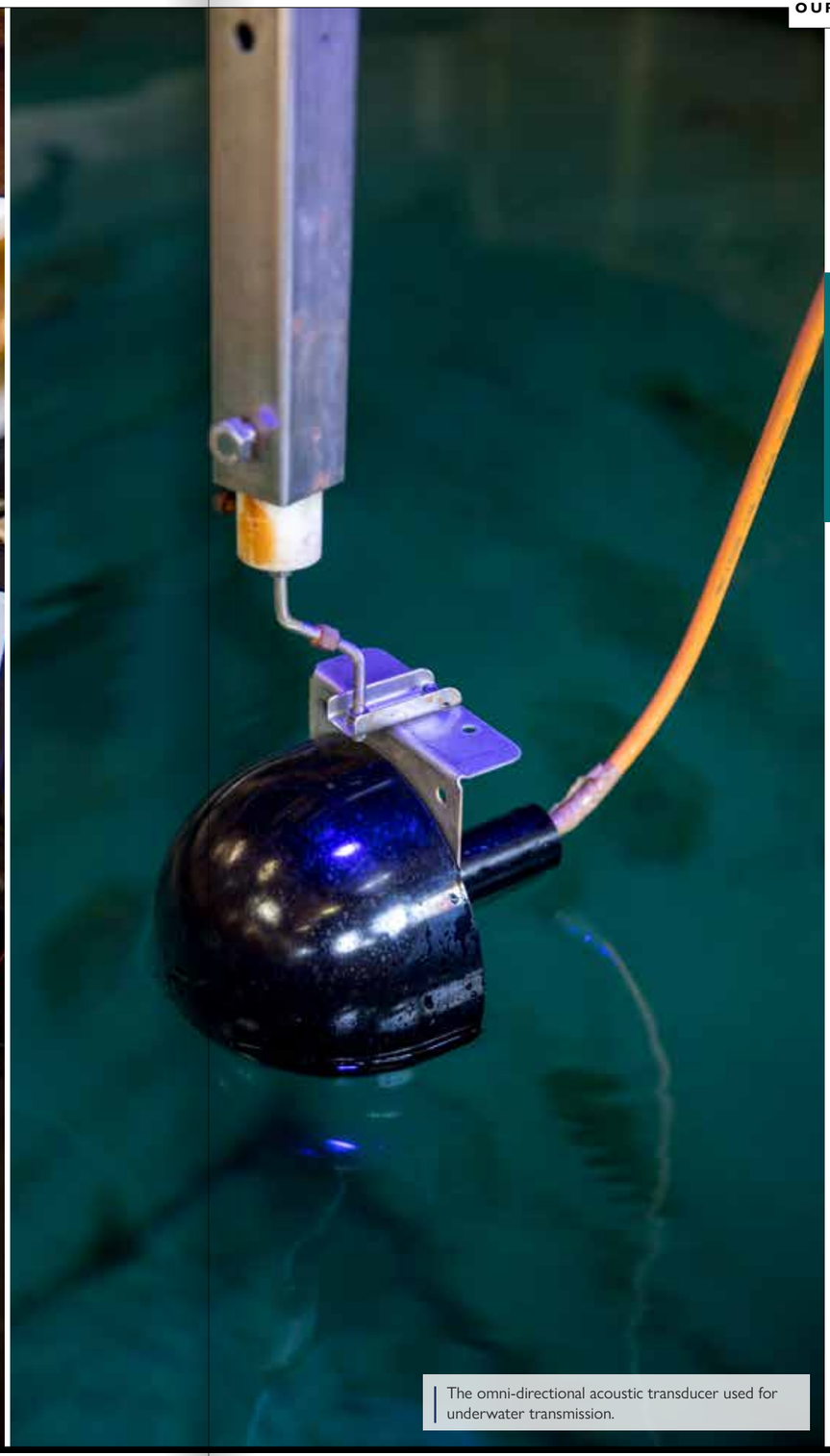


CSIR senior engineer Elna Niemann operating the broadband acoustic underwater data communication system technology demonstrator in the CSIR tank.



The omni-directional acoustic transducer used for underwater transmission.

FAST, RELIABLE **UNDERWATER COMMUNICATION**

The CSIR has developed prototype technology for an advanced wideband ultrasonic transducer that enables unmanned underwater vehicles and sensors to communicate with surface vessels wirelessly, at a bit rate of over 200 kbps.

The increased use of unmanned underwater vehicles that use a communication cable that, among others, limits the manoeuvrability of the vehicle, has highlighted the need for an innovation that enables large, high-speed data transfer over shorter distances.

The broadband acoustic underwater data communication system allows for large data rates and reliable near-real-time data transmission from an unmanned underwater vehicle to a surface vessel.

Currently, commercial underwater acoustic systems offer low data transmission rates, mainly for control signals, and allow for sensor telemetry data transfers from significant depths and over large distances.

Introducing a real-time wireless innovation enables the naval and maritime industries to use unmanned underwater vehicles more effectively, as data can be continuously monitored to pilot such vehicles towards the desired location. The transmission of data in real time requires a high data transmission rate, and this is only possible through a broader system bandwidth.

Application areas of this technology include an array of military uses, oceanographic research, underwater mining, and the oil and gas industry.

The CSIR invites entities with an interest in developing commercial applications based on this technology to contact the organisation.

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FIRST LOCAL HOT ISOSTATIC **PRESS FACILITY FOR TITANIUM PROCESSING**

The CSIR is setting up a hot isostatic press facility to support industry, science councils and institutions with research and development, as well as industrial-level production.

Hot isostatic pressing is a critical step in several manufacturing processes being developed under the Advanced Materials Initiative of the Department of Trade, Industry and Competition's Advanced Manufacturing Technologies Strategy, which highlights the need to move from raw material-intensive manufactured goods towards increasingly knowledge-intensive goods and services, as well as in processes being developed for the beneficiation of titanium under the Titanium Centre of Competence.

Nearly all titanium components used in applications that require high structural integrity, including castings, metal injection moulding and additive manufactured components, must be treated with a hot isostatic press. This will be the first local industrial hot isostatic press facility suitable for the processing of titanium products. The treatment is not solely used in the manufacture of titanium components, it can also be used extensively for other metal products where structural integrity is of critical importance, such as nickel, aluminium, cobalt and iron-based alloy components.

The facility is funded by the Department of Science and Innovation through the High-End Infrastructure Programme. It is set to be launched by September 2022.

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LOWERING ENTRY BARRIERS FOR **NEW MEDICAL SECTOR DEVICES**

The CSIR has assisted 18 small, medium and micro enterprises that are new entrants in the medical sector with customised product lifecycle management.

This follows the earlier formation of a collaborative programme, the Medical Device and Diagnostic Innovation Cluster programme, to help create a competitive local medical device sector.

This collaborative service intervention between the CSIR, the Technology Innovation Agency (TIA) and the South African Medical Research Council is part of TIA's Technology Cluster Innovation Programme.

The programme drives technology localisation and alleviates common industry challenges, thereby lowering the barriers to innovation in the medical sector. This is enabled through the provision of specialised regulatory and technical support, as well as business-enabling services, including access to a network of product development service providers.

The CSIR's group for industrial sensors has long-standing experience in the development of medical devices and their certification to both the ISO 9001 and ISO 13485 (medical device) quality management standards.

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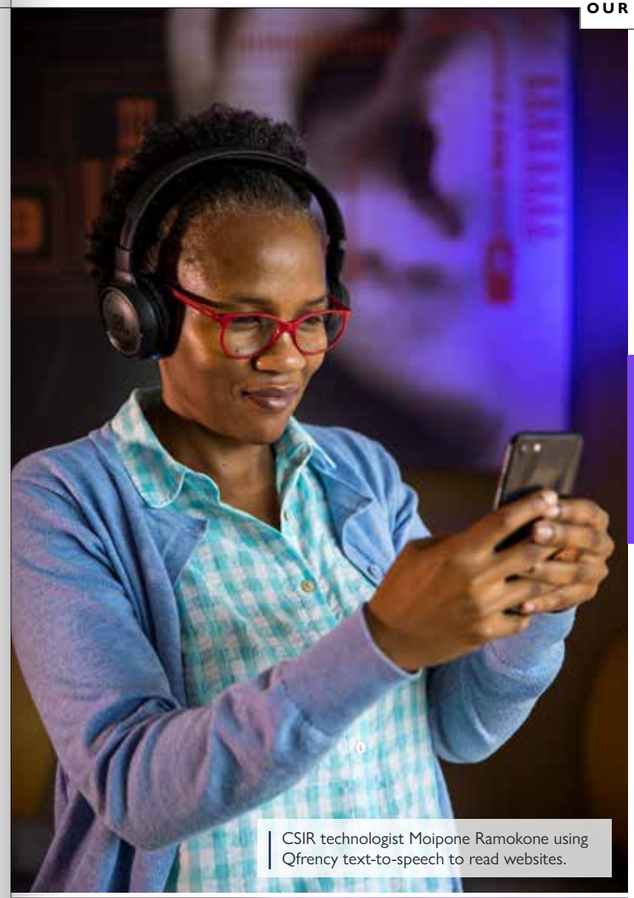

CSIR technologist Moipone Ramokone using Qfrency text-to-speech to read websites.

CSIR SIGNS INTERNATIONAL AGREEMENT **FOR ITS TEXT-TO-SPEECH TECHNOLOGY**

The CSIR signed a licence agreement with ReadSpeaker Holding BV, a global voice specialist, for its Qfrency text-to-speech technology.

The CSIR's text-to-speech system consists of a text-to-speech engine and voices that enable a computer to create and reproduce human-like (synthesised) speech from written text. The text-to-speech voices can be used to read out text in all official South African languages on a wide range of devices (cell phones, tablets and computers) and platforms (Windows, Android, iOS, MacOS) for a variety of clients, including industry, developers and individuals.

Applications range from providing dynamic content in audio format, such as through screen readers, in interactive voice response systems, to audiobook production, navigation and literacy development.

"The Qfrency text-to-speech engine is in a binary compiled form, in other words, a complete and installable software package, while the Qfrency voices give the engine the capability to speak in a particular language, with each voice having its own unique personality and characteristics," says CSIR principal engineer Aby Louw.

ReadSpeaker will utilise the technology by including the Qfrency system into its offerings, which can be summarised as online services for streaming audio and audio production.

"The CSIR is excited about the collaboration prospects with ReadSpeaker and looks forward to the socioeconomic impact that the successful deployment of South African text-to-speech voices in ReadSpeaker's offerings may have," says CSIR acting impact area manager Karen Calteaux.

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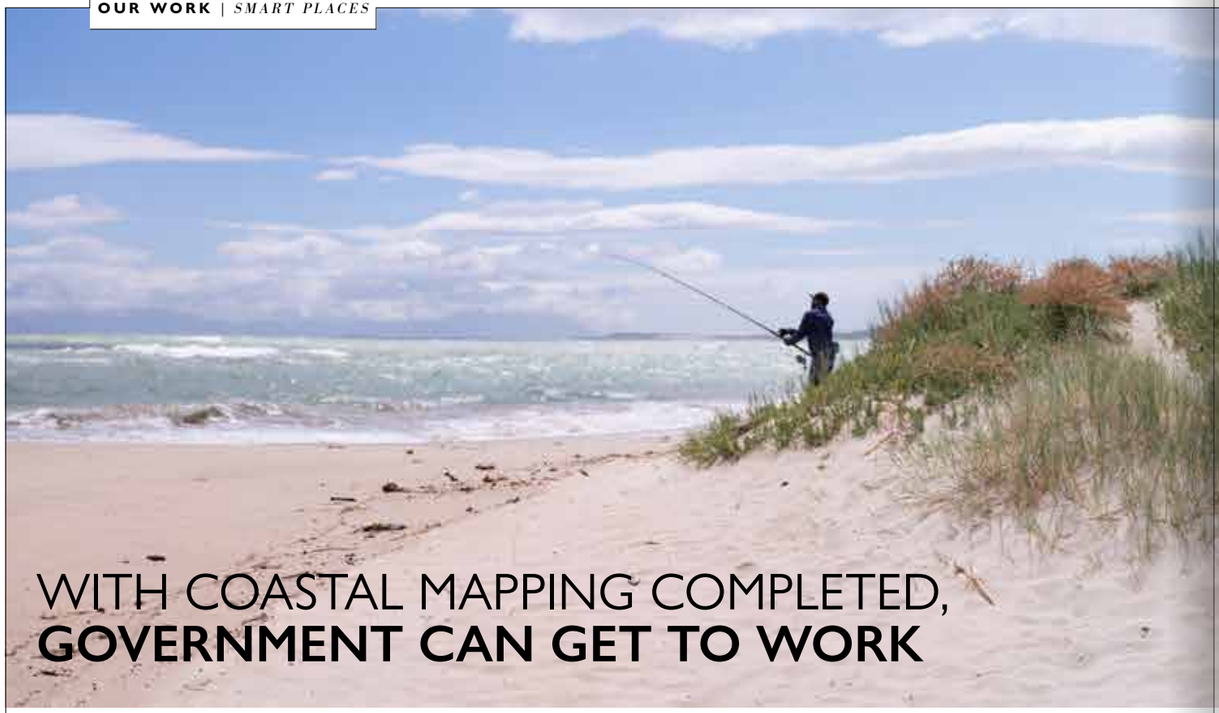

WITH COASTAL MAPPING COMPLETED, **GOVERNMENT CAN GET TO WORK**

South Africans are mining right next to marine protected areas and we are expanding cities into delicate estuaries. We are also living in dense coastal settlements, which generates more pollution along our 3 000 km of coast than we can handle. This while global change is leading to sea level rise and an increase in the occurrence and severity of coastal storms.

The CSIR has completed two projects of national interest documenting activities and vulnerabilities along the coast. The assessments will be used to advise government on how to manage the potential risks and assets of our coastal areas.

CSIR senior researcher Dr Melanie Lück-Vogel worked with academics at Nelson Mandela University and Stellenbosch University to complete two national assessments relating to vulnerabilities along South Africa's coast, both commissioned by the national Department of Forestry, Fisheries and the Environment.

The National Coastal Assessment project assessed a large variety of environmental and socioeconomic data to identify flood risk and pollution hotspots, access to beaches, conservation of sensitive and unique habitats, fishing, as well as the sensitivity of coastal populations.

Lück-Vogel says managing coastal spaces is complex and requires an integrated management approach because these spaces are very diverse and management challenges vary around the coast. As a baseline, a comprehensive assessment of all aspects relevant for coastal management was needed and this is what the project tried to achieve.

To identify areas of potential land use conflict, Lück-Vogel and her colleagues analysed coastal data from numerous sources with varying detail. This included geographic information system (GIS) data on topography and geology; sources of marine pollution from industry, stormwater and offshore oil spills; location and density of settlements; sensitivity of its population and economic activities linked to recreation and ports; as well as the sensitivity, threat and protection status of coastal natural resources.

"We found that lack of coastal access was perceived as a challenge in the Northern Cape, while coastal pollution was a priority problem in other parts of the country, especially in the vicinity of settlements and metropoles," she says.

They also found that stormwater drainage is a major pollution factor on the urbanised coast, but no data on the actual location and amount of stormwater outlets are available to map this problem. To solve this problem, Lück-Vogel used population density data as a proxy to estimate the stormwater pollution that each community may produce.

Coastal mapping collaborators (from left), Melanie Lück-Vogel, CSIR; Jessica Eichhoff, Centre for Geographical Analysis, Stellenbosch University; Dr André Theron, Department of Civil Engineering, Stellenbosch University; and Gert Wessels, CSIR.

In the Northern Cape, mining and its impact on the natural environment is one of the most controversial topics. "On satellite imagery, I saw a lot of pathways in some coastal areas that are fenced off for mining, and we have to wonder if they were created for the mining activities, perhaps even dating back decades," she says, citing ox wagon trails from 1920 that still scar the lichen fields in Swakopmund in Namibia, as an example of how slowly the sensitive desert environment recovers from disturbance.

In contrast, Google Earth data revealed that in the Addo Elephant Park in the Eastern Cape, pathways through the densely vegetated dunes that were not accounted for in municipal data were most likely made by wildlife.

Lück-Vogel also led the department's National Coastal Climate Change Vulnerability Assessment. She used climate change scenarios to show the vulnerability of South Africa's coast and 300 estuaries.

"We predicted the effects of worsening storms and rising sea levels for 10 years, 30 years, 50 years and 100 years into the future," she says. They could then assess the risk of storm-related flooding and erosion, as well as the expected rate of coastal recession due to sea level rise.

The main beneficiaries of the results of this project, as science-based support for coastal spatial planning, climate change adaptation and disaster mitigation, are local government authorities.

"It turned out that many municipalities do not have sufficient Internet access to use the data online or sufficient GIS capabilities to analyse the data. We, therefore, created an offline tool where all relevant data are included and provided training workshops to government personnel to allow them to effectively use the data," she says.

During the training sessions, shortcomings of the data were identified, which largely resulted from the input data being outdated. "The oldest coastal elevation dataset we included was from 2011 and, because the coast is so dynamic, it had changed so tremendously in some parts that the value of the vulnerability assessment was reduced," she says. This highlights the need to update crucial coastal information regularly.

Both these coastal assessments are now key in implementing South Africa's Integrated Coastal Management Act, 2008 (Act 24 of 2008), as well as the National Climate Change Adaptation Strategy.

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Tourism is one of the sectors that generates solid waste on beaches in the West Indian Ocean. Below: Coastal lakes and estuaries are sensitive to pollution impacts that impair the ability of these systems to provide ecosystem services and provide local populations with the natural resources they depend upon for their livelihoods.

IMPROVING WESTERN INDIAN OCEAN **MARINE AND COASTAL WATER QUALITY**

Five African mainland and five island states in the Western Indian Ocean have become allies in their vision for healthier coasts and oceans. Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa, Tanzania and Reunion (France) share an understanding of the economic value of their region's coastal and marine resources. Coastal and marine experts at the CSIR, in partnership with the Nairobi Convention Secretariat, proposed a strategic framework to improve marine and coastal water quality management in the region.

The Western Indian Ocean (WIO) region's coastline spans more than 15 000 km, with over 60 million people living within 100 km of the coast. An annual gross marine product of about US $20.8 billion is testament to the significant economic value and investment opportunities of the region's coastal and marine resources. However, many problems, such as climate change, destructive fishing practices, coastal degradation and marine pollution are threatening coastal and marine ecosystems in the region, with negative impacts on its marine diversity, food security and economic development.

A situation assessment found that marine pollution in the WIO stems from several root causes, including population growth, poverty and inequality, inappropriate governance, inadequate knowledge and awareness, and lack of financial resources. While these root causes characterise the indirect underpinning societal dynamics causing ecosystem deterioration, the CSIR found that the major sectors contributing directly to marine pollution are urban development and tourism, agriculture and forestry, fisheries and aquaculture, industry and mining, marine transportation, and energy production.

The Nairobi Convention is a regional treaty and one of 18 initiatives under the United Nation's Regional Seas Programme. Its primary aim is to promote the sustainable development of marine and coastal environments of the WIO region, pursuing a vision of healthier coasts and oceans. The five African mainland and five island states join more than 140 countries that participate in the larger Regional Seas Initiative. The Convention offers a regional legal framework and coordinates the efforts of member states to plan and develop programmes that strengthen their capacity to protect, manage and develop their coastal and marine environments. Contracting parties considered a regional strategic framework for coastal and marine water quality management as an essential tool to address marine pollution threats. It is needed to fast-track coordinated implementation, building on previous initiatives undertaken.

"Our proposed strategic framework calls for more holistic, ecosystem-based approaches to management responses, rather than the fragmented, silo-based approaches that are currently applied in most countries," says Dr Susan Taljaard, CSIR principal researcher and expert in coastal and marine water quality. The strategic framework underpins the contracting parties' objective for water quality in the WIO region to meet international standards by 2035. A set of key guiding principles provides broad direction for the implementation of water quality management, while regional support and guidance, through the Convention Secretariat and partners, remain essential to harmonise management initiatives across countries in the region.

"The development of regional water and sediment quality guidelines, as developed by the CSIR, in collaboration with the Nairobi Convention Secretariat, is an example of such support," says Taljaard.

Another key element in the strategic framework addresses the constitution of appropriate institutional structures and arrangements necessary to execute such ecosystem-based implementation processes. Taljaard emphasises that, "Effective ecosystem-based marine and coastal water quality management cannot be achieved without dedicated institutional bodies to drive implementation."

"The CSIR will continue to play its role in the WIO region through ongoing scientific research, sharing scientific information and learning with key strategic partners to enhance and explore innovative solutions to eradicate both indirect and direct causes of marine pollution. This will help the region achieve its objective of being on par with international best practice in water quality by 2035," Taljaard says.

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FIRST EXPERIMENTAL ECOSYSTEM ACCOUNTING METHODOLOGY **FOR SOUTH AFRICA'S ESTUARIES DEVELOPED**

The CSIR, Nelson Mandela University and the Department of Forestry, Fisheries and the Environment have jointly developed an ecosystem accounting methodology for South Africa's estuaries. The team mostly used country-level information generated as part of the recently completed National Biodiversity Assessment 2018 of the Estuaries Realm, which was led by the CSIR team.

South Africa has 290 estuaries and 42 micro-estuaries that have been classified into 22 estuarine ecosystem types and three micro-estuary types. This represents a high diversity of estuary types, stemming from our wide array of climatic, oceanographic and geological influences. Some ecosystem types and estuarine species only form in South Africa, with some species confined to a few systems.

The research aims to contribute to advancing the knowledge of natural capital accounting through application in a developing country context. It is envisaged that the research will be used for and enriched by further engagement with global and local national capital accounting processes.

The research also aims to unlock the potential of South Africa's estuaries ecosystems to contribute to food security, job creation and economic development.

"Estuaries are super ecosystems. Although they comprise less than 2% of South Africa's territory, these highly productive ecosystems contribute R4.2 billion per annum to the South African economy. They are focal points for development, tourism and recreation, and they are important for supporting biodiversity, livelihoods and marine fisheries," says CSIR senior researcher Dr Lara van Niekerk.

Natural capital accounting is a growing field globally and in South Africa. It includes accounting for environmental assets such as water, minerals and energy, with an international standard, the System of Environmental-Economic Accounting, in place for these accounts. A more recent aspect is ecosystem accounting, which focuses on accounting for ecosystem assets and ecosystem services. Since 2014, Statistics South Africa (Stats SA) has been co-leading projects with the South African National Biodiversity Institute (SANBI) and the Department of Foresty, Fisheries and the Environment on ecosystem accounting as a subset of natural capital accounting. These projects have contributed to global experimentation and learning around ecosystem accounting, informing global guidelines.

"Thus far, the South African Natural Capital Accounting initiative has not included estuaries. Stemming from their disproportionally high socioeconomic value, it is critical to prepare their ecosystem accounts separately and not aggregate these systems within larger freshwater or marine ecosystem accounts – running the risk of grossly under-valuating or masking their ecosystem service benefits to society," says Van Niekerk.

The study was undertaken in consultation with SANBI and Stats SA through a range of interactive workshops and reviews, including presenting preliminary results (such as the National Estuarine Condition Index findings) for discussion at the first Natural Capital Accounting Forum hosted by Stats SA in 2019.

Van Niekerk highlights that the development in estuaries and their catchments has come at a cost of about R700 million per annum in terms of lost fishery benefits, as well as unknown costs to society from the overexploitation of resources and loss of biodiversity. This has reduced the diversity of benefits delivered by estuaries, as well as the diversity of beneficiaries enjoying their services. Moving forward, development and resource use need to be balanced to ensure the equitable sharing of benefits derived from these highly productive systems.

The high-level National Estuarine Ecosystem Condition Index developed as part of the estuaries ecosystems accounts was rated at 64 (out of 100), indicating a severe decline in the overall estuary condition of South Africa's 200 730 hectares estuarine estate. Van Niekerk pointed out that an integrated approach is needed to address the ongoing decline in condition.

"Complex ecosystems, such as estuaries, require an integrated approach to address the ongoing decline in condition, including increasing estuarine protection levels and sharing the benefits of estuarine protected areas equitably among coastal communities. Extractive activities, such as mining, need to be carefully examined to ensure that ecological, social, economic and access issues are addressed sustainably. Overall, an investment in solutions to restore estuarine ecological infrastructure to strengthen climate resilience and sustain ecosystem services is needed. There is a pressing need for national estuary restoration programmes that focus on degraded and novel systems, with an emphasis on the larger systems of high biodiversity importance and the socially important urban systems. An opportunity exists for flagship programmes that could be developed collaboratively between government agencies and civil society," Van Niekerk says.

"The CSIR will continue to collaborate with other strategic entities, as an integrative research project like estuaries accounting requires a range of specialist input. The Nelson Mandela University (which led the biotic habitat component) and the Department of Forestry, Fisheries and the Environment (which led the fisheries and nursery function) were key partners in this project as they assisted in mainstreaming the pilot testing of ecosystem services. Working with these entities ensured that the CSIR frames the ecosystem services correctly in the accounts. It also ensured that the CSIR is aligned with ongoing research in these organisations, such as the development of a national blue carbon register," concludes Van Niekerk.

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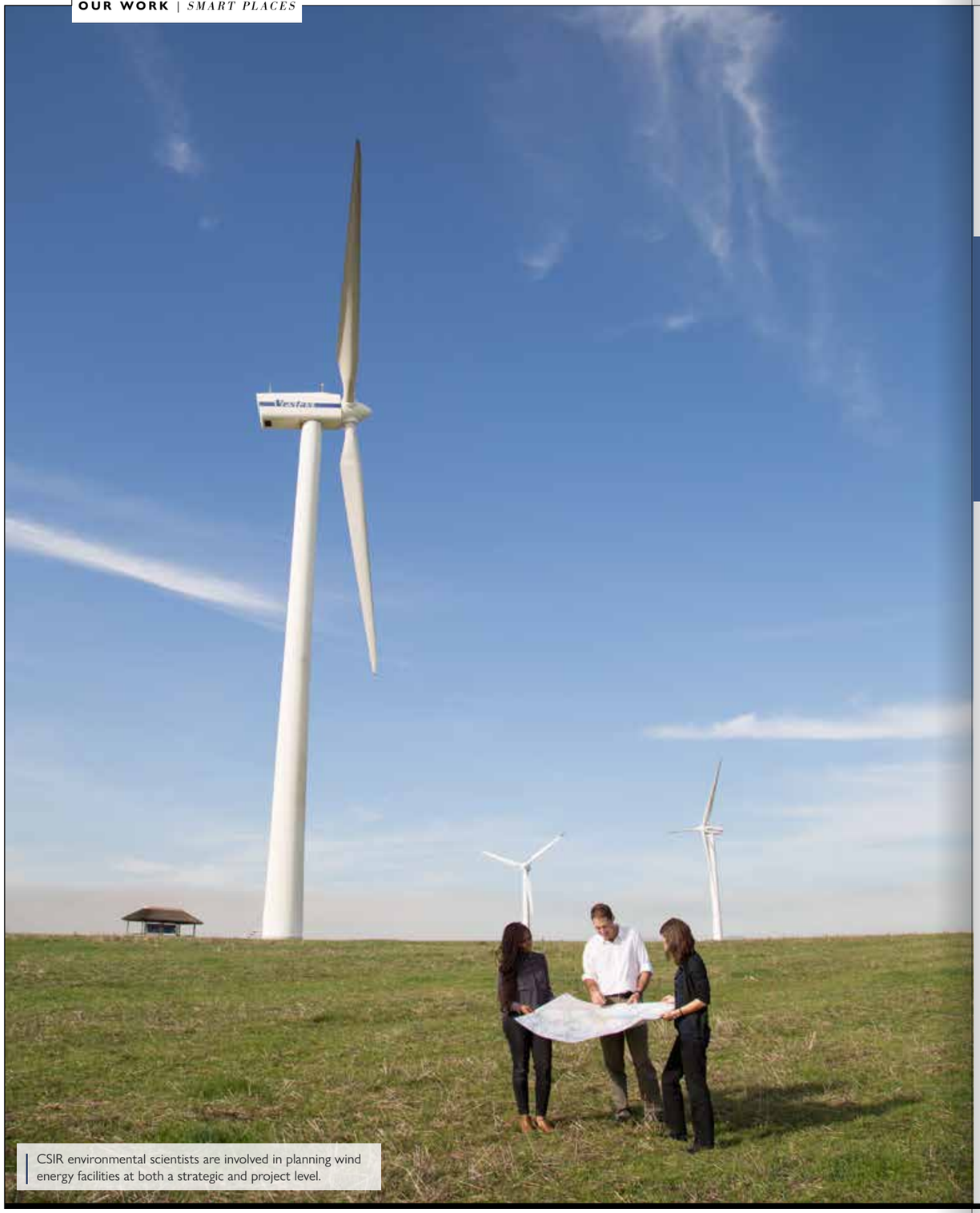
Aerial view of the Uilenkraalsmond estuary just outside Gansbaai in the Overberg region in the Western Cape of South Africa.

The Touw/Wilderness Estuarine Lake near the town of Wilderness in the Western Cape. Less than 4% of South Africa estuaries are estuarine lakes, but they comprise more than 60% of the country's estuarine estate as they are the largest type of estuary in South Africa.



CSIR environmental scientists are involved in planning wind energy facilities at both a strategic and project level.

OUR WORK | SMART PLACES

ASSESSING FUTURE ENERGY-GENERATION **SCENARIOS FOR SOUTH AFRICA**

The CSIR has provided environmental assessment expertise to 11 of the 25 successful preferred independent power producer bidders announced on 28 October 2021. The announcement resulted from the fifth round of the Renewable Energy Independent Power Producer Procurement Programme of the Department of Mineral Resources and Energy.

The CSIR played a significant role through conducting strategic environmental assessments (SEA) to improve the environmental planning for national wind and solar photovoltaic development. The CSIR ran a holistic assessment that incorporated a full range of relevant aspects, such as availability of wind and solar resources, environmental sensitivity, agricultural land-use, heritage and landscape features, socioeconomic development needs, grid connection, and technical and engineering suitability. In addition, the CSIR has conducted SEAs to support the responsible development of electricity grid infrastructure, such as transmission lines, at a national scale.

"The series of SEAs conducted by the CSIR has provided a well-informed basis for the responsible planning and development of renewable energy projects in South Africa," says Paul Lochner, CSIR research group leader for environmental management services.

"The SEAs provided a platform that brought together key stakeholders in a transparent process and improved the integration and quality of decision-making by the wide range of authorities involved. To conduct effective national-scale planning, it is important to understand the environmental issues at a project scale. Consequently, we are also involved with the renewable energy industry, at a project level," Lochner adds.

The CSIR has been one of the key players involved in assessing a range of future energy-generation scenarios for South Africa and providing an evidence-based view of long-term power system expansion options. The research includes the analysis of decarbonisation scenarios to assess the options, costs and impacts of the accelerated decommissioning of ageing coal-fired power stations.

The continued cost reductions of renewable energy options align with the CSIR's modelling and analysis of the need for further renewable energy deployment to address the power system constraints, the debilitating impacts of load shedding and the decarbonisation of the energy system – which is a local and global imperative.

"The CSIR's analysis has confirmed that South Africa is in a fortunate position to be able to transition to renewable energy sources as part of a least-cost power system. The outcome of the Renewable Energy Independent Power Producer Procurement Programme is aligned with our analysis of job creation opportunities and how renewable energy deployment can contribute towards economic growth and a just energy transition from coal to a blend of renewable energy complemented by energy storage and demand response," says Dr Clinton Carter-Brown, CSIR Energy Research Centre head.

Additionally, many studies are ongoing, including a research programme to incorporate systems-thinking tools into the practice of impact assessment. As part of the research, the CSIR intends to conduct a pilot study that uses systems thinking to assess and portray the strategic implications of South Africa using renewable energy to develop a green hydrogen economy, both for domestic use and export. The systems-thinking research will link with the CSIR's current research on the potential for South Africa to optimise its abundant wind and solar resources to produce green hydrogen.

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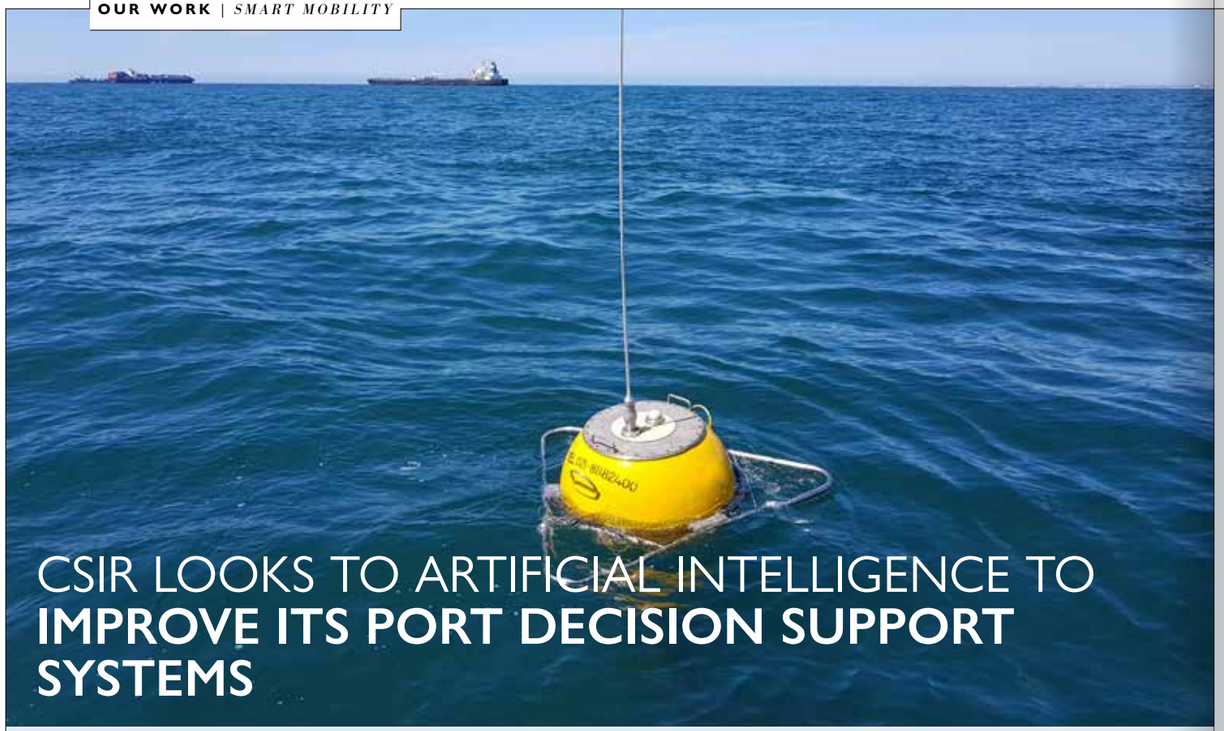

CSIR LOOKS TO ARTIFICIAL INTELLIGENCE TO **IMPROVE ITS PORT DECISION SUPPORT SYSTEMS**

The CSIR is investigating artificial intelligence and machine learning for real-time forecasts of wave conditions, pattern recognition and extreme event notifications. Researchers are drawing on advances in artificial intelligence for automatic recording processes and algorithms to improve information needed in the decision-making processes of marine-based industries.

For more than four decades, the CSIR has been a major technology partner to the Transnet National Ports Authority of South Africa (TNPA), which is the operator of South Africa's major ports, namely Cape Town, Durban, East London, Mossel Bay, Ngqura, Port Elizabeth, Richards Bay and Saldanha Bay.

These ports, and their efficient operation, are crucial to the South African economy. The smooth movement of goods leaving the country contributes to a flourishing and competitive export industry, while goods entering the country are often an important component of successful local businesses. But managing these ports is challenging, with maritime traffic from around the world, and loading and unloading cargo in an environment affected by waves, wind and currents.

In 2021, South African President Cyril Ramaphosa announced that government is working on an infrastructure build plan of R100 billion over a 10-year period. He indicated that government would focus on critical infrastructure such as ports, roads and rail, all of which are key to the economy's competitiveness. The expansion at South African ports will create a need for more accurate and reliable information at different locations, inside and outside the ports, for better decision making. Currently, the wave buoy network is limited to being close to shore; extending this network further offshore would increase the accuracy of forecasts and provide additional surface current data to ships.

At the request of the TNPA, the CSIR developed an Integrated Port Operation Support System (IPOSS) to fulfil TNPA's requirements for a wave recording system that provides real-time wave information. The system records, analyses and disseminates data on waves, wind and currents. Wave data are collected from Waverider™ wave recording buoys, the first of which was deployed at the Slangkop station in 1977. The network has since been expanded to all eight national ports. All this real-time information is fed to the respective port control centres at each port to assist with operational decisions.

The CSIR-developed port operation system is not only operationally essential in terms of assisting decision making on berthing and sailing, but the archived data have significant value in port design and modification. From a legal perspective, too, the archived data have value in the event of an incident to fully understand the root cause. Ultimately, access to the data gives the port control operational staff confidence in their decision-making processes and increases operational safety and efficiency.

The IPOSS also plays a huge role in cargo management across all eight national ports as it provides the ports with National Centers for Environmental Predication forecast data together with the measured real-time environmental information. This combination makes it possible for the ports to verify forecast information and plan with confidence. Overall, the system enhances port safety as it assists marine pilot transfers, as well as vessels entering and departing from the entrance channel.

THE EVOLUTION AND HISTORY OF WAVE RECORDING BUOYS

- **1969** – Paper chart recordings.
- **1976** – Digital cassette tapes.
- **1980** – Software programs to check the quality of taped wave recordings.
- **1985** – Solid-state dataloggers connected to a personal computer with a dial-up modem. Data stored on hard discs.
- **2015** –The integrated ports operations system connects directly to the Internet via the Transnet LAN as the CSIR adapts to the Internet of Things (IoT), a system of interrelated computing devices and programs. The ports operation system serves as the IoT, connecting the sensors with the ports authority, which can then remotely access real-time environmental data on a website (dedicated to the system) via a personal computer or smartphone, or any Internet-connected device.
- **2021** – The CSIR makes use of the latest communications technologies, including (high frequency, GSM/EDGE, Wi-Fi, LAN and short burst data satellite) for sensors to send the data to the operating system.

"The CSIR operating system has always been ahead of its time in terms of the technology that was integrated to deliver an all-in-one environmental monitoring system, and this has been one of the key enablers for our partner, TNPA. It has enabled Transnet to be more efficient, agile and responsive to contribute to the growth and development of South Africa," says Sarel Haasbroek, CSIR senior technologist for coastal engineering and port infrastructure.

Over the years, several big waves have been recorded by the buoys across South Africa's coastal region, but the highest significant wave height recorded was 11.48 m at Slangkop, just off Cape Point, in June 2017. It was measured by the CSIR-owned Datawell DWR-MKII Waverider buoy. During the same recording period of 20 minutes, the single highest wave of 20.5 m was also recorded.

Haasbroek explains, "The 11.48 m wave was measured based on significant wave height, which is used for design purposes by consultants and engineers, whereas the 20.5 m wave is a single wave from crest to trough (maximum wave height) recorded by the buoy."

Wave measurements at Slangkop have been ongoing since 1977, resulting in an excellent dataset for determining trends and other value addition. For machine learning applications, these large datasets are invaluable, and the intention is to use these to enhance the current decision support systems. This highlights the importance of ocean observations and data collection to ensure the safety of the ports and protect the marine industry and the marine recreational community.

The CSIR's intent is to be a key player across Africa through collaboration with key strategic partners across the continent.

"Our port decision support system is critical in the South Africa port operations context as it ensures the safety of our ports, as well as port efficiency; factors that play a vital role in the SADC's economic development. We are looking to expand our service offering to other African ports in the future as there is a lot to benefit from our experience and expertise in wave recording systems and processes," says Eugéne Mabille, CSIR research group leader for coastal engineering and port infrastructure.

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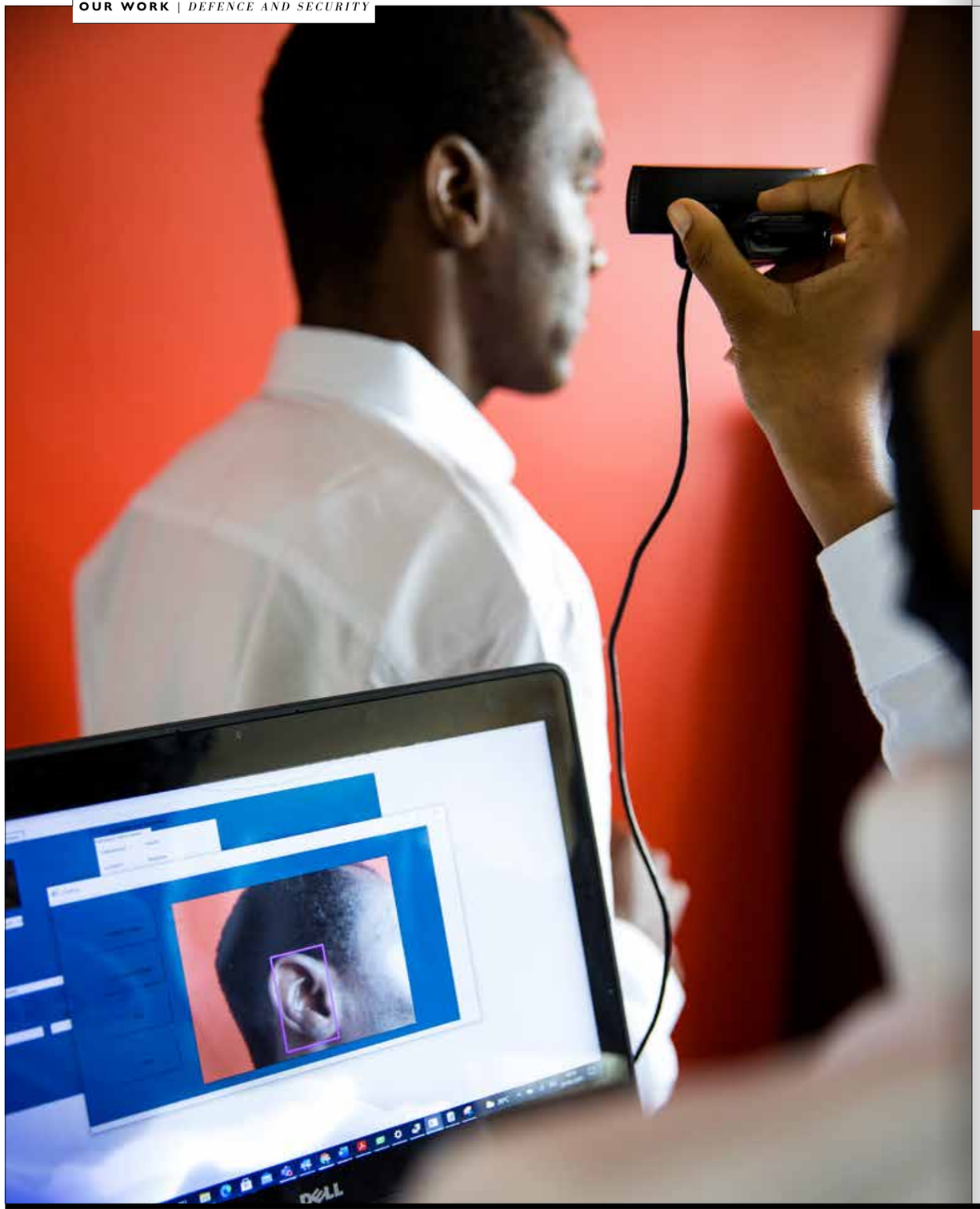

EAR RECOGNITION BACKED TO BECOME BIOMETRIC SOLUTION **FOR CHILD IDENTIFICATION IN SOUTH AFRICA**

Drawing on its skills and innovation track record in biometrics, the CSIR has developed ear recognition technology through which the identity of an individual can be verified using the shape of their ears.

The development of biometric systems and solutions has revolutionised identification methods for industries around the world. Recognised for its accuracy, integrity, accessibility and multifunctional traits, biometrics has been adopted in healthcare, banking, security, electronic manufacturing and many more. With this growing trend in the information technology space, experts predict that the demand for biometric solutions will grow significantly in coming years.

The CSIR is specifically interested in biometric recognition for children. The technology has been developed to perform a live image capture of a child's ear, followed by processing of the image for verification. The captured ear image and the child's biographical details are then registered in a database or registry. Therefore, upon presentation of a child's identity document to a system, and verification of the ear biometric in person, a child can be positively identified and linked with her/his parents, reducing the chances of child abduction or identity theft.

"The technology will significantly reduce the problem of child trafficking and undocumented children in South Africa," says CSIR researcher Sthembile Ntshangase. The complete system would mean that even without an official birth certificate as documented proof, a mere presentation of the ear to a capturing device could facilitate the child's identification and verification by the system.

The relevance of the ear recognition technology is particularly evident in the era of the Covid-19 pandemic, in which the World Health Organization and health experts globally are encouraging minimalising person-to-person contact. The system's contactless features enable the technology to accurately verify a child's identity, while being less reliant on their cooperation, as opposed to other biometric modalities that require some level of cooperation from the individuals being identified.

The technology supports the CSIR's research and development objectives around issues of cybercrimes, threats and vulnerabilities. These objectives rely on the development of a national cybercrime combatting capability through the creation of capabilities for cybercrime intelligence; the development of tools that assist with the identification of organised crime social structures and child trafficking; as well as the development and support of the South African Police Service Cybercrime Centre. The ear recognition application will also contribute to the South African health sector by using a combination of ear and other biometric features for national patient registration and identification, which will be configured to suit both children and adults.

Uptake of the technology by numerous South African institutes could make a significant contribution to aspirations for a capable state, for example, the Department of Home Affairs (border control), the Department of Health (child recognition at clinics and hospitals), the Department of Social Development (distribution and management of social grants) and the South African Police Service (tracking missing children).

(Left) The CSIR's ear recognition technology, through which a child's ear can be captured electronically and synchronised against a recognised database, achieving a unique method of identifying and verifying children.

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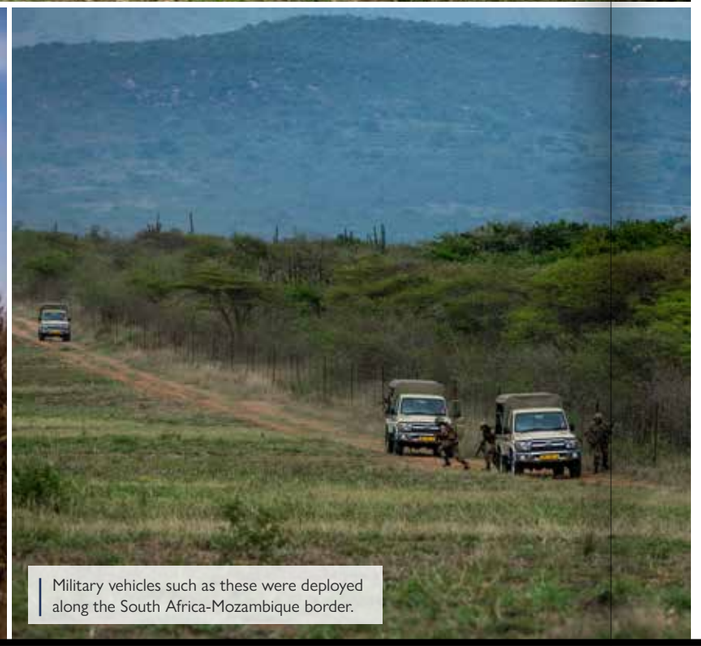

Military vehicles such as these were deployed along the South Africa-Mozambique border.

OUR WORK | *DEFENCE AND SECURITY*

OPTIMISING SOUTH AFRICA'S **GROUND FORCES**

EVALUATING MILITARY VEHICLES ON DEPLOYMENT

The recommendations of recent field evaluations of military vehicles deployed along the South Africa-Mozambique border will serve as input into future military vehicle configurations and help solve current mobility challenges.

The CSIR works hand in hand with the South African National Defence Force (SANDF) to optimise its performance through research and development in military mobility research.

South Africa has a long history of successfully developing and fielding military vehicles. On missions, the SANDF often needs to access hostile areas to deliver critically needed food and medical supplies to affected communities and to sustain peace keeping operations, as well as ensure the safety of civilian populations. To do this, protected vehicles that provide high levels of mobility and reliability are needed.

The CSIR conducts research and development in tactical vehicle mobility to contribute to the SANDF's capability readiness. Military mobility research includes the study of vehicle-terrain interaction through modelling and simulation, evaluation, verification and validation.

In a recent seven-day experiment, a CSIR team, together with members of the SANDF and Armscor, conducted vehicle mobility performance characterisation and evaluation within a deployment area in KwaZulu-Natal. This included the deployment of equipment and tools relating to mobility performance and evaluation.

The results of the field evaluation enable the team to advise on current mobility challenges and assist with developing solutions. The team can provide recommendations on the future selection of vehicle configurations to achieve the desired performance, based on the terrain.

"This work fuses terramechanics with vehicle and mapping data to develop verified and validated models. The models support required upgrades and predict the effect of new technologies on system capability improvement. This enables benchmarking with other role-players at local and international level," says CSIR research group leader for tactical vehicle mobility Dr Dithoto Modungwa.

"It is necessary for deployed vehicles to be optimised for terrain negotiability in specific areas of use. Tactical mobility across all types of terrain can deliver a critical advantage to the overall performance of a mission," she adds.

"These research and development efforts are a vital part of our support to the SANDF. We provide scientific, engineering and technology advice during the acquisition, evaluation, operation and employment of equipment," she says.

The overall benefit is that the SANDF team is empowered and able to ensure that the latest best practices and leading recommendations for military vehicle mobility requirements are met.

The CSIR has also collaborated with the SANDF and local companies to implement and develop locally tailored mobility mapping and prediction solutions. CSIR impact area manager for landwards sciences Dr Tleyane Sono says that local and international collaborations are leveraged to support local industry. "Such collaborations also expose young researchers to international best practices, enabling capability building and facilitating knowledge exchange," he says.

OTHER WORK IN VEHICLE MOBILITY

The CSIR team also maintains and updates the SANDF military mobility modelling software, MOBSIM. The team focuses on vehicle instrumentation, parameterisation and characterisation, off-road autonomous navigation, as well as updating of the SANDF mobility standards and handbook. The handbooks, initially developed by Armscor, capture the learning and history of the South African military vehicle technology development. The standard defines which tests are required to quantify and assess the performance of military vehicles to be used or considered by the SANDF.

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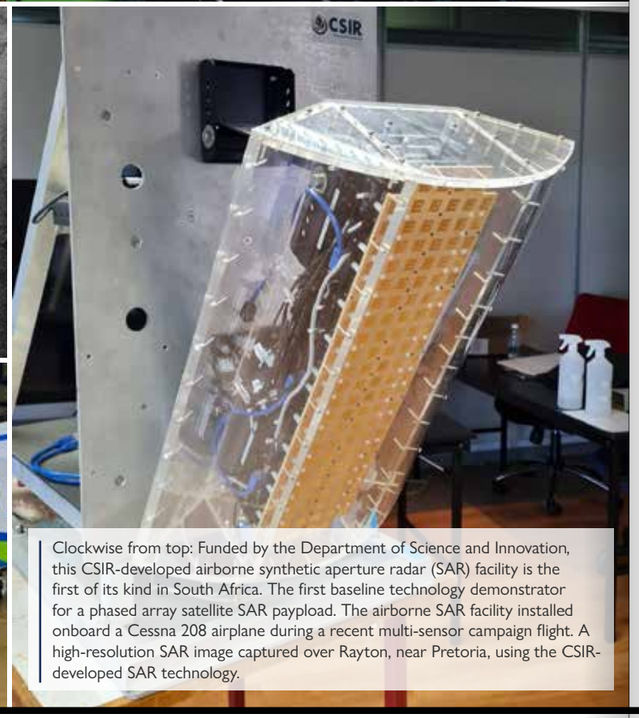

Clockwise from top: Funded by the Department of Science and Innovation, this CSIR-developed airborne synthetic aperture radar (SAR) facility is the first of its kind in South Africa. The first baseline technology demonstrator for a phased array satellite SAR payload. The airborne SAR facility installed onboard a Cessna 208 airplane during a recent multi-sensor campaign flight. A high-resolution SAR image captured over Rayton, near Pretoria, using the CSIR-developed SAR technology.

SEEING THE WORLD USING **SYNTHETIC APERTURE RADAR**

The CSIR is working with industry to design and create bespoke synthetic aperture radar sensor solutions for unmanned arial vehicle and spaceborn use cases. The organisation's radar systems research team is in the development phase of proof-of-concept versions for both unmanned aerial vehicle and spaceborne synthetic aperture radar payloads.

The CSIR has undertaken pioneering work in radar development in its 76-year history. Radar technology has seen many advances over this period and, today, one of the flagship radar projects at the CSIR focuses on synthetic aperture radar (SAR). The CSIR team is utilising its wealth of radar knowledge and experience, as well as innovative solutions, such as employing commercial-off-the-shelf technology developed for the communication market, to provide competitive, cost-effective sensor solutions that are at the forefront of technology for the targeted price-performance point that the technology is aimed at.

WHAT IS SAR?

"Radar is an active remote sensor, which means that it provides its own illumination of a scene, thus allowing it to operate in the day or night. It can also be operated in any type of weather, as it can image through obstructions such as fog, smoke and clouds, making it advantageous for various applications," says CSIR senior radar engineer Ciara Blaauw.

She says SAR can be used to produce high-resolution images of large scenes by simulating a big antenna aperture, while still using small, cost-effective and practical antennas. This is achieved by placing the radar sensor on a moving platform, such as an airplane, drone or satellite. SAR sensors can play a vital role in numerous applications, such as border surveillance, infrastructure monitoring, mine activity and safety monitoring, disaster management and precision agriculture.

CSIR SYNTHETIC APERTURE TECHNOLOGY

The CSIR developed an airborne SAR facility with funding from the Department of Science and Innovation to serve as a national testbed for SAR application and technology research and development. The facility is highly flexible and modular in its setup, allowing experimentation with various advanced modes and technologies. It has been used in numerous successful measurement campaigns towards application development, such as border surveillance for the South African National Defence Force and a number of commercial applications; and for spaceborne and unmanned aerial vehicle (UAV) technology testing and development. As an example of the latter, the system has been modified to achieve a new baseline serving as a first-order concept demonstrator for a C-band phased array UAV SAR technology demonstrator. It is also being used for initial tests towards a spaceborne SAR payload.

"The phased array technology, utilised for both these UAV and spaceborne SAR sensors, is the first of its kind in South Africa," says CSIR chief engineer Willie Nel.

COLLABORATIONS

The SAR team is collaborating with various partners from the remote sensing community, including industry, research groups, government groups and universities active in remote sensing and Earth observation, on a large multi-sensor measurement campaign. The campaign aims to facilitate and enable the development of remote sensing (including SAR) applications, skills and innovations in South Africa, aimed at stimulating high-tech industrial development.

In the spaceborne SAR area, the CSIR is pursuing several opportunities with South African space industry players such as SCS Space and Dragonfly Aerospace. The C-band phased array SAR satellite payload, currently in the proof-of-concept phase, is well positioned to establish a South African SAR satellite constellation. This will have a wide range of remote sensing applications, including oceanography, topography and forestry, as well as the monitoring of urban growth and infrastructure.

In a bid to support small, medium, and micro enterprises (SMMEs), the manufacturing of the phased array panels has been outsourced to an SMME.

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The 200 m test tunnel offers trainees a live explosion experience, equipping them with techniques to apply in instances of real explosions.

The CSIR Fires and Explosion Research Testing and Training Facility hosts weekly seminars for mineworkers, offering training in methodologies that foster safer and more compliant working environments.

TRAINING AND DEVELOPMENT: **THE ANSWER TO SAFER MINING IN SOUTH AFRICA**

The CSIR is expanding and enhancing its mine health and safety training offering to include immersive, experiential training in emergency response procedures, including the use of self-contained self-rescuers. A rise in the training demand from mines has prompted the organistion to develop new methods and opportunities to host more trainees.

Training is an integral part of mining. With hazardous incidents, accidents and fatalities marring the track record of the sector, it constantly faces demands to upskill mineworkers to adhere to health and safety regulations.

South African mines employ an estimated 450 000 people, all of whom need to be trained to offer the best possible protection against incidents that may be hazardous or even fatal. The global drive to modernise mining through the application of relevant technologies further compels South African mines to prioritise training and development for their workers. Research studies have indicated that mineworkers regard training in health and safety as a crucial aspect of their operations.

Aligned to the CSIR's drive to contribute to a capable state, the CSIR's Fires and Explosion Research Testing and Training Facility at Kloppersbos offers mines, mining companies and universities safety awareness training to assist in the prevention of disasters caused by underground fires and explosions. These seminars address a wide range of factors that are of concern in the mining industry, including hazards associated with methane in underground mines. The training focuses on methane ignition prevention, the application of fire prevention principles, as well as small- and large-scale demonstrations of methane and coal dust explosions. Through the safety awareness training seminars, the CSIR equips mineworkers and university students with awareness of the threat of underground fires and explosions and knowledge of the techniques they can apply to prevent such incidents from occurring in mines.

The CSIR Fires and Explosion Research Testing and Training Facility demonstrated increased relevance and effectiveness in the Covid-19 era, with the demand in training escalating significantly. The facility, which previously hosted seminars twice a week, currently hosts five seminars a week. Furthermore, the organisation is expanding and enhancing its training to include immersive, experiential training in emergency response procedures, including the use of self-contained self-rescuers.

The importance and relevance of our training facility and its unique capabilities and offerings are recognised in South African mining. The continued collaboration between the sector and the CSIR will benefit overall mine safety," says CSIR mining impact area manager Riaan Bergh.

The CSIR typically trains some 5 000 mineworkers annually from companies and institutions such as SeritiCoal, Sasol Mines, Anglo American, Exxaro, Colliery Training College and smaller mines.

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GREENBOOK METROVIEW FOR RESILIENT **METROPOLITAN MUNICIPALITIES**

The first of South Africa's metropolitan municipalities are now benefiting from an online planning tool for climate resilience that has been developed specifically for their context. The first metro to benefit was the City of Tshwane, while work for the eThekwini Municipality has started.

The GreenBook (**www.greenbook.co.za**) was first launched in 2019, offering planning support and evidence around climate change, risk and vulnerability to all local municipalities in South Africa. Funded by the CSIR and the International Development and Research Centre, the tool supports local government in South Africa with developing climate-resilient cities and towns. Its research methodologies were all co-developed with stakeholders from government and the scientific community.

Since the launch of The GreenBook, the research team, together with stakeholders, identified a need for a more detailed view for metropolitan municipalities. Given the uniquely complex nature of metropolitan municipalities, a different approach to planning support is needed in these spaces. The GreenBook MetroView was conceptualised to address metropolitan planning needs and developed for the City of Tshwane as a proof of concept in 2020/21 through CSIR research and development funding, in close collaboration with the City of Tshwane, and with input from National Treasury's Cities Support Programme.

The investment resulted in The GreenBook MetroView, a planning support system that provides spatialised and quantified scientific evidence of climate change projections, multidimensional vulnerability indicators, population-growth projections and climate hazard risk modelling to assist practitioners, policymakers and decision-makers to effectively inform and support climate risk and vulnerability assessment-related planning processes.

"The GreenBook MetroView creates a shared understanding, across the different sectors and departments in a city, as well as other stakeholders, of the possible impacts of climate change and the decisions that need to be made to respond to it. The spatialised communication of climate-related risks and vulnerabilities will primarily inform land-use planning and spatial investment targeting processes, while the adaptation and mitigation actions speak to the responsibilities across all sectors and departments in the metro," says CSIR principal researcher and urban and regional planning expert Willemien van Niekerk.

The MetroView edition comprises two tools. The Climate Risk and Vulnerability Profile Tool provides a current and 2050 picture of climate change and its related impacts on three levels, namely municipal, planning region and ward level. The tool consists of six sections, including an overview, a vulnerability section, climate information, a section on hazard and exposure, coping capacity, and climate risk zones. These zones provide spatialised and quantified climate risk for the city. The Tshwane climate risk and vulnerability profile is available online at **https://tshwane-riskprofile.greenbook.co.za/**

The Climate Action Tool consists of various adaptation actions, as well as greenhouse gas mitigation actions. Each of the actions within the tool speaks to themes that relate to specific city functions that should consider climate change adaptation, greenhouse gas mitigation and disaster risk reduction. The themes are linked to certain strategic priority outcomes as identified by the City. The City of Tshwane's Climate Action Tool is based on its Climate Action Plan and reflects on the functions, outcomes and actions as contained in the Climate Action Plan. The Tshwane Climate Action Tool is also available online at **https://tshwane-climateactions.greenbook.co.za/**

While each of the two tools in the MetroView can be used on its own, the two are complementary and were designed to be used together for maximum impact. "If you have explored the climate risk and vulnerability profile of a metro, you can also explore the range of adaptation actions available to be considered for integration and implementation in various local strategic and sector plans. Ultimately, you don't just want to know and understand the likely challenges, but consider the possible interventions as well," says Van Niekerk.

The second metro to benefit is the City of eThekwini. The CSIR, in collaboration with National Treasury's Cities Support Programme, Absa, and the City of eThekwini, is developing a MetroView for the City. As part of the GreenBook research and development programme, the team intends to develop a MetroView for each of the metropolitan cities in the country over the next few years, building on existing partnerships with government and industry.

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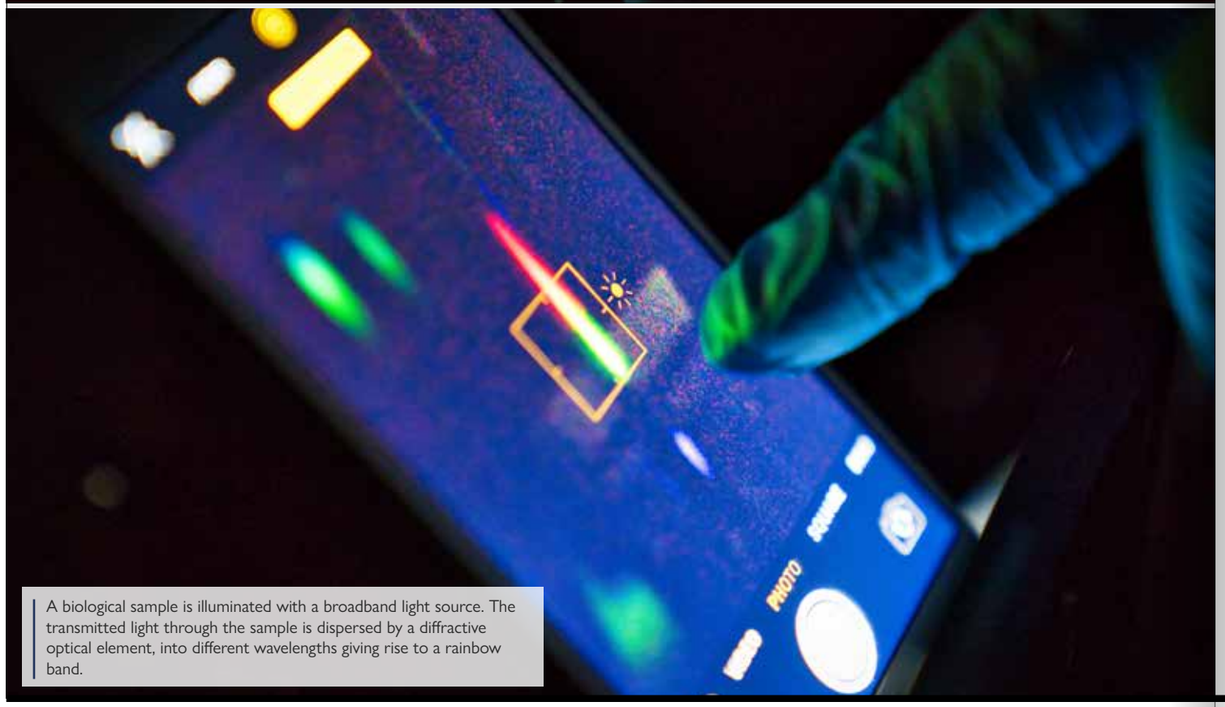
CSIR senior researcher Dr Saturnin Ombinda-Lemboumba and CSIR researcher Charles Maphanga capturing images of diffracted light using a smartphone and analysing the rainbow band image using a custom-built Python program. These rainbow images contain information about the properties of the sample.



A biological sample is illuminated with a broadband light source. The transmitted light through the sample is dispersed by a diffractive optical element, into different wavelengths giving rise to a rainbow band.

CSIR INVENTS TECH TO DIAGNOSE HIV, COVID-19, TB, HYPERTENSION AND DIABETES **USING ONLY A SMARTPHONE**

While global technology giants are aggressively competing to bring useful diagnostic tools to personal mobile devices, the CSIR has just about done it. Dr Patience Mthunzi-Kufa, a biophotonics expert at the CSIR, says her team has created a diagnostic tool that can detect illnesses in bodily fluid samples like urine, saliva and blood.

The intention is to complete trials of the technology at the CSIR Medical Centre by the end of 2022 for final proof-of-concept testing, with plans to be market-ready with a product conforming to regulatory requirements as soon as possible thereafter.

The technology can distinguish between various classes of pathogens (HIV, SARS-CoV-2, TB), and non-communicable diseases, including high blood pressure and type 2 diabetes.

Back in 2019, Mthunzi-Kufa and her colleagues first presented an idea for a smartphone-based diagnostic to help tackle two of Africa's biggest disease burdens, HIV and TB.

When the Covid-19 pandemic hit, as has been the case for many technological leaps, crisis spurred innovation.

"We realised that we would need to add SARS-CoV-2 detection to the technology, but why stop there? Non-communicable diseases that have markers in bodily fluids, like glucose levels in diabetes patients, can also be measured using light," explains Mthunzi-Kufa.

Their technology detects diseases by measuring how much light a sample absorbs. The technical term for measuring light absorption and light emission is spectroscopy, and it is usually done in specialised diagnostic laboratories using large, expensive machines called spectrometers.

So, her team did not reinvent the wheel, but the researchers did make it small enough to fit in a smartphone – something that most people in the world now have access to.

"For patients and healthcare workers who live in remote areas in South Africa, Africa and many parts of the world, it can be an expensive logistical nightmare to get samples to a lab," she says.

Her team's innovation is that they miniaturised the hardware usually found in large spectrometers into a disc the size of a ten-cent coin, which can easily be built into any smartphone.

She says the disc works somewhat like a glass prism, which splits white light into the spectrum of colours that make up a rainbow. Each colour has a particular wavelength that can be measured. A sample that contains markers for illness would absorb light differently from a healthy sample, and this is what the technology measures to detect illness.

"The setup has a unique geometry and composition – that is our invention. But both the hardware and software behind this technology are brand new, and we are in the process of protecting our intellectual property," says Mthunzi-Kufa.

She says they are currently updating the app that works with the disc to allow more communication (via the Internet and the cloud) between doctors and patients, and to ensure that patient consent and other ethical issues are addressed. For instance, should a patient get a positive diagnosis, there will be a process to get advice and counselling from their doctor.

While the Covid-19 pandemic has delayed the project on many levels, such as backlogs of hardware supplies and illness among team members, Mthunzi-Kufa says they have already made it through the first seven levels of the internationally accepted technology readiness scale.

Being at technology readiness level 7 (TLR7) means their prototype is ready to be tested in a real environment, such as the CSIR's own medical centre. Once they have tested a minimal viable product there, they will make the necessary tweaks and take the technology into other health facilities, especially in low-income settings. This will take them to TRL8, and, finally, TRL9.

Mthunzi-Kufa says, ultimately, their vision is a multi-purpose diagnostic product that is inexpensive, easy to access, simple to use even by untrained patients or healthcare workers, and one that does not need a lab or lab reagents or technicians. She believes that local, African and international markets are more than ready for this technology.

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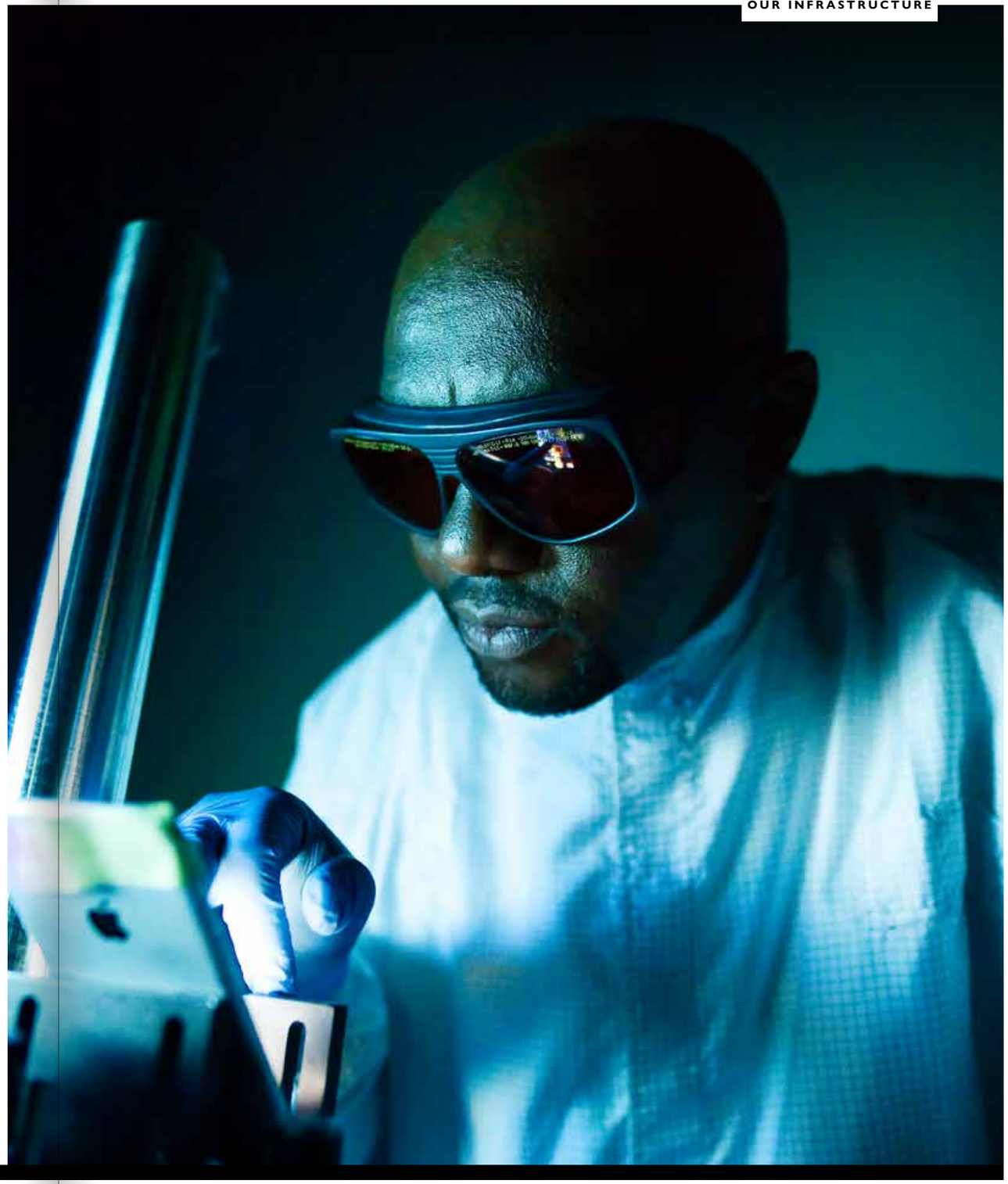
Our INFRASTRUCTURE

Point-of-care (POC) testing is becoming an attractive option in healthcare, promoted by the increasing introduction of mobile, portable and handheld diagnostic instruments. As such, more research is undertaken on the development of novel POC testing devices that will allow efficient diagnostics to be conducted in all kinds of environments, including the workplace, home, convenience clinics, disaster care settings and various resource-limited environments. Experts in biophotonics at the CSIR Photonics Centre use laser technology in the development of novel POC diagnostics and biosensors for application in HIV, TB and Covid-19 diagnostics, as well as substandard drug screening. Currently, the researchers focus on developing photonics-based technologies that allow early detection of diseases, as the use of light and optics affords many advantages because of the multi-dimensional data that can be collected and analysed.

(Right) CSIR senior researcher Saturnin Ombinda-Lemboumba at work in a refurbished laboratory taken into use to conduct this type of research. Also see page 52.



OUR INFRASTRUCTURE | *FUTURE PRODUCTION: CHEMICALS*

BIOREFINERY FACILITY COMMISSIONS NEW EQUIPMENT TO ADD **MORE VALUE TO AGRICULTURE AND FORESTRY**

Since its inception in 2018, the CSIR's Biorefinery Industry Development Facility has been providing support to industry partners in the biomass processing sector in developing, localising and implementing technologies to improve their competitiveness. The industry-facing facility is now ready to take its mandate a step further by providing industry access to its new equipment, which will be commissioned at its premises in Durban in 2022.

As a facility that develops technologies for the conversion of waste biomass into high-value products, the addition of new equipment at the CSIR Biorefinery Industry Development Facility (BIDF) diversifies its value offering to clients and ensures that it enhances the competitiveness of the agricultural and forestry industries.

CSIR chief researcher Prof. Bruce Sithole says the BIDF has added two new sets of equipment to its already well-equipped facility. These are the pyrolysis units, used for pyrolysis of lignocellulosic biomass to produce charcoal, biochar and wood vinegar; and a recycle digester, which is a compact digester system for the chemical fractionation of lignocellulosic biomass into lignin, cellulose, hemicellulose and extractives.

"The pyrolysis units produce biochar, a high-value component that can be of great value to the agricultural market as a soil amendment, especially for small-scale farmers who cannot afford chemical fertilisers; as well as wood vinegar, a condensate from the pyrolysis process, that can be purified and fractionated into high-value products for use in pharmaceutical applications and that can also function as an effective pesticide for use in organic farming," he says.

Sithole says the products derived from the extraction of waste biomass using the recycle digester include cellulose, hemicellulose, lignin and extractives. He says the biomass used includes wood waste (sawdust and chips), agricultural waste, and invasive plants that can be fractionated into high-value chain products that will add value to the forestry industry, farmers and small and medium enterprises working in the processing of biomass.

Using their new sets of equipment, the CSIR team will upscale low-cost technology for the conversion of sawdust into cellulose nanocrystals – a high-value material that can be used in the manufacture of high-performance biocomposites. The researchers also developed a technology to reduce costs in the production of chemical pulp.

Key CSIR biorefinery milestones

- Developed a low-cost technology for extracting a high-value material, cellulose nanocrystals, from sawdust waste at high yield (>40%).
- Demonstrated the production of high-quality starch from waste avocado and mango seeds.
- Work with 15 small, medium and micro enterprises to implement biorefinery technologies and initiatives, such as:
  - the beneficiation of waste biomass into wood vinegar and biochar; and
  - the development of special economic zones for processing biomass.

(Left) Prof. Bruce Sithole with a pyrolysis unit for conversion of waste woody biomass into high-value chains such as charcoal, biochar and wood vinegar used as nature-based solutions for improving farm productivity in place of fossil-based chemicals.

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IMPROVED HIGH-PERFORMANCE COMPUTING INFRASTRUCTURE **SHARPENS SA'S RESEARCH CAPABILITIES**

High-performance computing continues to add immeasurable value for South Africa. Not only does the country have the Centre for High Performance Computing to thank for the ability of South Africa's MeerKAT radio telescope, one of the most powerful telescopes of its kind, to deal with enormous amounts of data, but it has also been instrumental in Covid-19 sequencing and research.

As a key centre for large-scale computing in Africa, South Africa's Centre for High Performance Computing (CHPC) supports both academic and industry research. The centre's 1.3 petaflops Lengau cluster and its Lustre parallel file system cluster have been used on several flagship projects with supercomputing-level resources. These include regional-coupled ocean-atmospheric modelling at high resolutions, energy storage materials, and the MeerKAT telescope, among others. The CHPC has also contributed resources to commercial projects to support efforts through the South African Development Community (SADC) and in other countries in Africa, including Ghana and Kenya. The centre's user demand for computing and data resources over the last few years continues to accelerate.

In response to this increased demand, the CHPC designed its OpenStack Production Cloud to replace the VMware environment. The new private cloud was built on Supermicro TwinPro servers with 2nd Gen Intel Xeon Scalable processors and 3 TB of memory per chassis. Some 1.5 petabytes of mechanical disks and more than 220 TB of Intel SSD drives created an open-source software storage cluster with hierarchical storage architecture for short and long-term storage.

"The new cloud system was designed to support many virtual jobs related to ongoing research, such as custom workflows, pleasingly parallel workloads and web hosting," says Dorah Thobye, CHPC technical manager.

"CHPC systems administrators began migrating existing users to the OpenStack Production Cloud in March 2020. Three days later, the country was in lockdown due to Covid-19; everything changed, and the new production cloud was quickly overwhelmed. Government turned to us for high-performance computing support," says Thobye.

COVID-19 AND AN INCREASED DEMAND FOR COMPUTATIONAL RESOURCES

"Because of the pandemic and all the new users it brought to us, we were running out of computing and storage resources," says Thobye.

With support from two major local universities, the University of Cape Town and the North-West University, as well as Dell EMC and Intel's Pandemic Response Technology Initiative, the CHPC was able to expand the OpenStack Production Cloud.

The expansion was completed in mid-2020 and went into production with a total capacity of 780 compute cores, 480 TB of cold storage and 60 TB of hot storage (Intel SSDs).

With more storage and compute capacity, users are experiencing a much more capable system. "Instead of being far overprovisioned with continuous 100% utilisation, workloads now consume from 60 to 100% of the compute capacity, depending on the activities," says CHPC manager Dr Happy Sithole.

"OpenStack provides a vastly different offering for users of the data centre," says Sithole. "This is a step towards revolutionising our data centre as a converged environment. We see this as a continuum between compute-intensive and data-intensive computing. It allows us to easily support both high-performance computing research and general-purpose cloud computing using the same infrastructure."

With the original Supermicro cluster and the Dell EMC expansion, the expanded cloud can now support ongoing pandemic-related activities by the Department of Higher Education and Training, Department of Health, universities, and other public and private projects related to the pandemic. Compute- and data-intensive projects include sequencing and virus research, remote education and online learning, bandwidth analysis of remote communities that need remote learning, television whitespace analytics, and analytic epidemiology (including track and tracing), among others.

HIGH-PERFORMANCE COMPUTING KEY IN STUDY TO EXAMINE SA INDIGENOUS PLANTS FOR COVID-19 TREATMENT

The University of KwaZulu-Natal (UKZN) and the Durban University of Technology had teamed up to establish the potential of medicinal plants in the fight against Covid-19. During the first stage of the study, Prof. Mahmoud Soliman, Dean and Head of the School of Health Sciences at UKZN and head of the Molecular Bio-computation and Drug Design Laboratory, together with his doctoral student and laboratory assistant, Clement Agoni, had found 29 compounds in South African indigenous plants used in traditional medicine with such potential.

In September 2020, the World Health Organization (WHO) had announced that the Regional Expert Committee on Traditional Medicine for Covid-19 (formed by the WHO; the Africa Centre for Disease Control and Prevention and the African Union Commission for Social Affairs), had endorsed a protocol for phase 3 clinical trials of herbal medicine for Covid-19. Phase 3 clinical trials are critical in fully assessing the safety and efficacy of a new medical product.

"Just like other areas of medicine, sound science is the sole basis for safe and effective traditional medicine therapies," says Dr Prosper Tumusiime, Director of Universal Health Coverage and Life Course Cluster at the WHO Regional Office for Africa.

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OUR INFRASTRUCTURE | *NEXTGEN ENTERPRISES AND INSTITUTIONS*

INNOVATION FOR A **SUSTAINABLE BUILT ENVIRONMENT**

By Dr Coralie van Reenen

As a nation, we have set a goal to reduce greenhouse gas emissions to net zero by 2050 to combat climate change. Innovation in the built environment sector can significantly contribute towards this goal and ensure a more sustainable future through climate change mitigation and adaptation.

The built environment is a major greenhouse gas emitter and resource consumer in both the construction and the operational phase of buildings. However, by embracing innovation, the building industry can rapidly and effectively respond to climate change.

Mitigation means to reduce, stop or possibly even reverse the negative effects of climate change. In terms of the built environment, this means to stop designing, constructing and using buildings in a way that is carbon intensive. This can be achieved through the use of materials with a lower carbon footprint and that are locally sourced. Buildings in operation contribute to greenhouse gas emissions through the consumption of carbon-intensive energy. This is mitigated by improving the thermal performance of buildings, thus reducing the heating and cooling load, installing energy-efficient building fixtures, systems and equipment, and modifying user behaviour.

Adaptation means to design our buildings to be resilient against the inevitable effects of climate change, such as flooding, fires, extreme heat events and drought. Examples of interventions include wastewater recycling, rainwater harvesting, improving thermal comfort through smart design, and designing to withstand high intensity rainfall events.

To **innovate** means to introduce a novel *product*, *system* or *process*. Innovative products tend to receive the most attention, although it can be argued that processes have the most potential to bring about change.

Novel building products developed as mitigation innovations typically have a lower carbon footprint, a longer useful life, and are reusable or recyclable at end of life. Products or technologies that can improve building performance address adaptation and build resilience. Examples are geopolymer binders as a cement replacement, or renewable energy-generation technologies. There is a plethora of such innovative products entering the market.

A system is a set of items working together. Thus, an innovative system can include products or processes. A building is a system in itself, so an innovative system for addressing climate change could be a building design that responds to the climate. However, to evaluate the efficacy of this system, other systems can be useful, such as real-time building performance monitoring. This requires a physical product (the sensor), as well as a digital product (the data transfer and analysis) – together these constitute a system. Monitoring building performance and environmental conditions allows for a rapid and adaptive response to the environment and promotes the ongoing improvement of building performance.

Lastly, innovation can be in the form of a process – a series of steps to achieve an objective. Considering combatting climate change and reaching net zero as the objective, innovative processes are required to lay the path for implementing products and systems. The least celebrated, and yet possibly the most significant innovations, are those constituted by legislation. At a national level, there are commitments to effect climate change mitigation and adaptation. However, translating this high-level commitment into actual changes on the ground requires new policies, which, in turn, are translated into regulations, standards, guidelines and action. Without a legislative context that enables the production, certification and use of novel technologies, or the standardisation of systems, effective change in building design and use is not possible.

Energy-efficiency building regulations, by-laws, eco-label standards, green building guidelines and monitoring and evaluation frameworks are tools to activate a climate-responsive building industry. Although often viewed by designers and building owners as legislative hurdles, recent standards and regulations have proven to be effective guide rails to safely usher the market towards lower carbon, greener buildings. Innovation and novelty are usually recognised by the stir that they cause in industry. While the introduction of regulations such as Energy Efficiency in Buildings (National Building Regulations Part XA) and Energy Performance Certificates may not be commonly labelled as innovative, the stir that they have stimulated indicates the potential of these processes to redefine business as usual.

A culture of innovation, enabled through policies and supported by regulation, is the key to a sustainable built environment. The CSIR's research group for infrastructure innovation supports and develops novel products, systems and processes to achieve a climate-responsive built environment. With effective uptake of innovation, the built environment can become sustainable, resource-efficient and low-carbon by 2050.

"WITH EFFECTIVE UPTAKE OF INNOVATION, THE BUILT ENVIRONMENT CAN BECOME SUSTAINABLE, RESOURCE-EFFICIENT AND LOW-CARBON BY 2050."

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Photo credit:
Dr Quixi Sonntag, University of Pretoria

INCLUSIVE SYSTEMIC IMPROVEMENT:
THE FORGOTTEN VEHICLES OF RURAL TRANSPORT

By Isabel Meyer, CSIR principal researcher

The performance of the national logistics system has long been a constraint to growth – for manufacturers, exporters and anyone who needs to move something or someone from point to point. In the 2022 State of the Nation Address, President Cyril Ramaphosa brought the topic front and centre with a focus on port inefficiencies and congestion, private-public partnerships for container terminal improvements and third-party access to the freight rail network.

However, is this focus inclusive enough? In the towns and villages of rural provinces, logistics has a completely different face, where bakkies, trailers, taxis and, indeed, non-motorised transport such as bicycles and donkey carts form an integral part of the transport system. Approximately one-third of South Africans, representing the majority of the poor population, reside in rural areas (World Bank, 2021) where transport infrastructure and systems are limited. Here, animal traction (horse, donkey, and ox-drawn carts) remains an important transport mode. It is essential for the transport of water, firewood and building sand, and has an important role in household chores and income generation (Marufu, 2014).

This so-called *intermediate* transport mode (Starkey, 2014) forms the first- and last-mile leg of the logistics system and connects people and goods to bus- and taxi ranks, where intermodality is as important to the local economy as rail/road transitions in the formal context. While their low volume and small load would label these systems as inefficient in a commercial context, their value to the communities that they serve is significant.

It has been argued that intermediate transport mechanisms will always exist, regardless of the extent of modernisation and access to other transport methods, and that it should not be dismissed as a transition phase towards enhanced mechanisation (Starkey, 2001). Donkey cart transport connects people living in deep rural areas to the social and economic processes of society by being an "appropriate and affordable technology for people with minimal resources" (Fernando and Starkey, 2004).

CHALLENGES AND OPPORTUNITIES AT THE RURAL-URBAN INTERFACE

In spite of their economic importance, support for such transport systems is limited, leaving owners to their own devices for animal care and road safety. Research indicates that animal health and welfare are often compromised, and that improved access to veterinary services, training on donkey use and management, and health and welfare promotion programmes are essential (Marufu, 2014). Donkeys are at risk to the illegal skin trade, which has significant implications for them as household economic resources (Whittles and Sigauqwe, 2017).

Preliminary research with the Faculty of Veterinary Science of the University of Pretoria, in collaboration with the University of Cape Town and the OneR Foundation, in Limpopo's Blouberg District, points to the need for multistakeholder approaches to strengthen the role and performance of donkeys as socioeconomic contributors. From a logistics perspective, opportunities include expanding the reach of rural supply chains (access to veterinary services and medicines), road safety (where animals and motorised vehicles share the road network), transport equipment design (animal-friendly vehicles and harnesses) and lifecycle cost of assets (including premature deaths). From a veterinary perspective, primary animal healthcare and the integration of indigenous knowledge are of importance, and economic development opportunities include integration of small, medium and micro enterprises into the value chain. Pilot technology applications have included platforms to connect donkey cart owners to markets, remote support of animal health workers and incorporating indigenous knowledge into technology solutions. In a webinar co-hosted by the CSIR and the Limpopo Department of Transport and Community Safety during the 2021 Transport Month, MEC Mavungu Lerule-Ramakhanya confirmed support for further work in the province to exploit the animal-drawn transport value chain.

THE FUTURE IS INCLUSIVE, CONTEXT-APPROPRIATE INNOVATION

The ongoing use of animal-based traction provides local and provincial governments with the opportunity to achieve their socioeconomic development targets. While national and provincial policies address the importance of non-motorised and animal-drawn transport, implementation can be enhanced. Government can contribute by revitalising the focus on animal traction as an intermediate mode of transport, by supporting it as an integral part of the rural socioeconomic context and enhancing the systems that support animal-based transport.

Sustainable and impactful improvements to rural animal-based transport systems require evidence-based strategic approaches to develop solutions that can be incorporated into local development plans. The sustainability of enhancements to rural transportation systems should be rooted in co-creation and capacity building at community level.

The disparities between the formal and the informal economy, rural-urban divides, and the potentially catalytic effects of seemingly small improvements challenge us as scientists and researchers to ply our tools in a manner that considers the system as a whole, and that seeks opportunities for improvement that are context-appropriate. Improvements to the national logistics system should cross divides and care should be taken not to modernise the system into further inequality. This invites us to see technology in context and innovate for locally relevant impact.

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