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CSIR

our future through science

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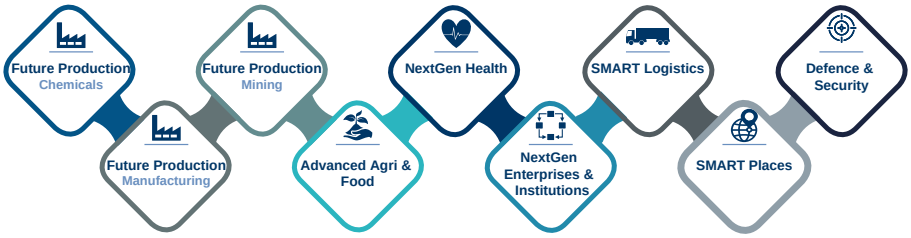
ACCELERATING SOCIOECONOMIC PROSPERITY IN SOUTH AFRICA THROUGH LEADING INNOVATION

The CSIR aims to be a high-impact contributor in improving the quality of life of South Africans. Our ambition is to contribute to alleviating South Africa's triple challenge of unemployment, poverty and inequality.

Having formulated the vision of accelerating socioeconomic prosperity in South Africa through leading innovation, we are bolstered and inspired by the potential of our contribution.

The CSIR has adopted the new vision as one of the outcomes of a strategy review, known as Project Synapse. While the CSIR's mandate commits the organisation to fostering industrial and scientific development to help improve the lives of South Africans, we realised that we were coming up short in respect of industrial development. So, to stay true to our mandate's dual calling, and respond to the national priority of reindustrialisation for economic growth, the organisation assessed its industrial development portfolio – looking at ways to amplify the 'I' (for Industrial) in 'CSIR'.

The CSIR's strategy emphasises a focus on nine clusters and enabling initiatives to deliver the desired impact. These span several industries and rely on collaboration with public and private sector stakeholders, funding partners, industry associations, higher education institutions and innovation partners.



> **The nine clusters of the CSIR's strategy**

The clusters focus on health, chemicals, advanced food and agriculture, manufacturing, mining, defence, security, smart logistics (including transport), smart places (such as the built environment and the natural environment), and next-generation enterprises and institutions (broadly classified as digital transformation).

Of course, it would be of no value if we managed to better our focus on industrial development, but sacrificed the work we did to contribute to societal development. Our public good science, predominantly undertaken for the public sector, continues to be an important part of our work. In implementing the strategy, the CSIR will leverage emerging technologies, especially those rooted in the fourth industrial revolution, as well as its current capabilities and those of its partners.

We also identified a new set of values to underpin our organisational culture. These are not only intended to enhance work ethic internally, but to also hold the organisation accountable externally. We pursue **E**xcellence, celebrate **P**eople, personify **I**ntegrity and welcome **C**ollaboration – an EPIC team with epic beliefs and principles.

We are on a mission to collaboratively innovate and localise technologies, while providing knowledge solutions for the inclusive and sustainable advancement of industry and society. We look forward to you joining us on this journey.

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

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ON THE COVER

A South African team has developed a new prototype system that enhances originally fitted systems in submarines to help ensure the safety of submarine crews. Full story on page 17.

Images courtesy of SA Navy. Photographer: Byron Lombard, Deputy Editor: Navy News: Warrant Officer Class Two.

SINGLE-MINDEDLY IN PURSUIT OF SUPER-SENSITIVE GAS SENSORS

Zamaswazi Tshabalala is pursuing a PhD in physics and specialises in solid-state semiconductor physics – studying smart materials that can be used to enhance gas-sensing properties such as sensitivity and selectivity. Specifically, her research looks at which materials will improve the gas-sensing mechanism employed to detect toxic gases. Tshabalala was named the CSIR's best doctoral student at its 2018 Excellence Awards.

Solving a life or death problem

Gas sensors have broad application, such as detecting and monitoring gases in our living and working environments. They are also used for medical diagnosis and monitoring in the form of breathalysers; determining and measuring air quality in the automotive and aerospace industries; and monitoring industrial processes in the brewing, mining and food sectors.

King's Pawn opening

Tshabalala recalls how her career in science began on the chess board. "When I was in Grade 6 at Qophumlando Senior Primary School in KwaZulu-Natal, you had to excel in mathematics to be allowed to take chess as a sport code. Mathematics teachers Messrs Zulu and Mbonane were chess masters and before you could even sit down to face an opponent, you had to solve a math problem." Tshabalala went on to obtain a BSc Hons in applied physics and mathematics from the University of KwaZulu-Natal and an MSc from the University of the Free State.

Problem-solving has since been part of her repertoire. "Doing a PhD has been a roller-coaster ride; I have grown a lot as a person, a researcher and as a professional. The support and mentorship from my supervisor, CSIR principal researcher Prof. David Motaung, has been outstanding and I am really grateful. Since joining the CSIR, I have completed training in state-of-the-art equipment such as the Kinosistec UHV and thin film gas sensing system, Panalytical X'pert PRO X-ray diffractometer, and the ZEISS focused-ion-beam field emission scanning electron microscope. I've managed to author and co-author nine articles in peer-reviewed journals such as *Sensors and actuators B*."

Obstacles are part and parcel of the journey. In her case, a major setback presented itself in the form of a major equipment failure. "The gas sensing system, the core instrument in my study and the only one in the country at the time, was down." Like any grand master, Tshabalala's will to excel pulled her through and she will soon submit her thesis. She is also preparing innovation disclosures to create international patents for her work on the simple synthesis of metal oxides with novel properties.

QUALIFICATIONS

> **BSc Hons (Applied Physics and Mathematics)**
University of KwaZulu-Natal, 2014

> **MSc (Physics)**
University of the Free State, 2016

ACCOLADES

- **Best Doctoral Student**
  CSIR Excellence Awards, 2018
- **Frank Nabarro Prize for Outstanding Oral Presentation: Condensed Matter Physics**
  South African Institute of Physics, 2018
- **Best Poster Presentation Award**
  Photonics Conference, 2017
- **Best MSc Publication Award**
  South African Institute of Physics Conference, 2016
- **Best MSc Student**
  CSIR Materials Science and Manufacturing Excellence Awards, 2016

"When you do something that you like, finding meaning in life becomes easier. Knowing that the work I'm doing has the ability to touch a person's life, making their homes and work safer, keeps me going."

- **Preparation and preliminary testing of the gas-sensing performance of nanostructured metal oxides using the Kinosistec gas sensing system.**

MASTERING CHEMISTRY AND BIOLOGY FOR PHARMACEUTICAL DEVELOPMENT

Dr Jenny-Lee Panayides' research started with a focus on drug discovery approaches to combat deadly diseases prevalent in Africa and has shifted to chemical process development for the local production of active pharmaceutical ingredients for the South African market. Panayides was named a joint winner of the Emerging Leader Award at the CSIR Excellence Awards in 2018.

Dr Jenny-Lee Panayides' journey began with drug discovery research, targeting multi-drug resistant tuberculosis (TB) strains that have vastly complicated the fight against TB in South Africa, and then moved on to identifying compounds that could treat drug-resistant malaria and to the eradication agenda for this disease.

A path of constant discovery

Panayides says it was an easy choice to go into this field, "As a young child I was always curious about the environment and how things worked. My interest in science was sparked when my father taught me how to use a microscope he had from his childhood. It sounds crazy, but being able to see inside an onion skin and the contents of my own blood was awe-inspiring – there was this whole world out there that I couldn't see with the naked eye and wanted to explore."

At school, her passion for science made choosing her degree an easy one, but a chat with a university professor about her curiosity about what makes people sick and the ingredients that went into medications to treat these infections, gave her the direction to choose molecular and cellular biology and chemistry as her majors.

Nurturing a chemical and biological mindsets

Panayides joined the CSIR's drug discovery group for postdoctorate work on secondment from the Medical Research Council. She worked as a synthetic chemist on a large consortium project to identify novel anti-mycobacterial agents for the future treatment of multi-drug resistant TB. Thereafter she took up a second CSIR postdoctoral position, working on another large consortium project to identify compounds for further lead development as anti-malarial drugs. When she was appointed as a senior researcher at the CSIR, she continued to work in the malaria research space, focusing on assay development, small-molecule library screening and automated high-throughput screening.

"I found moving between two very different science fields for the postdoctorates both an extremely challenging and very humbling experience; one for which I am eternally grateful as it allowed me to advance the skills developed during my PhD in these two unique areas. It also set me up for the opportunity to take the role of research group leader for pharmaceutical technologies, for which both the chemical and biological research mindsets are required," she says. She now supervises biochemists, medical microbiologists and synthetic chemists, working on a wide range of projects from hit identification using

"I remind all my postgraduate students that a large part of what we do is funded by taxpayers and that we should invest the contributions of our own parents and grandparents into solid science and real-world impact that we can all be proud of."

high-throughput in vitro screening, computer-aided drug design, catalyst development and more recently, chemical process development.

Lessons learnt

"Over the last few years, I have struggled with the frustratingly long timelines for translation of the excellent drug discovery research being performed in the country to achieving real-world social impact. Increasingly, we've shifted our focus to the development of novel processes to locally produce active pharmaceutical ingredients for the South African market. Although challenging in its own ways, this has been an exciting transition and I strongly believe that, through our collaborations with academia and industry on this goal, we will be able to have rapid impact and address some of our nation's critical drug shortages."

QUALIFICATIONS

- **PhD (Synthetic Organic Chemistry and Microbiology)**
  University of the Witwatersrand, 2012
- **MSc (Organic Chemistry) (with distinction)**
  University of the Witwatersrand, 2006

ACCOLADES

- **CSIR Outstanding Contribution by a Team Award**
  CSIR Biosciences, 2018
- **CSIR Emerging Leader Award**
  CSIR Biosciences, 2016

MASTERING THE USE OF LASER PHYSICS IN BIOLOGICAL SYSTEMS

> **CSIR researcher Lebogang Thobakgale with a custom-built femtosecond optical system used for phototransfection, during which DNA is inserted into cells by means of a laser.**

A chemistry experiment in a grade-10 science class first sparked Lebogang Thobakgale's passion for all things science related, and later compelled him to pursue a career in this field. A decade later, the 29-year-old's passion and commitment to science earned him the CSIR 2018 Best Master's Award for his Master's degree in physics (cum laude).

QUALIFICATIONS

- **BSc (Chemistry)**
  University of Limpopo, 2011
- **BSc Hons (Chemistry)**
  University of Limpopo, 2014
- **MSc (Physics) (cum laude)**
  University of South Africa, 2018

CSIR researcher Lebogang Thobakgale focuses on biophotonics under the leadership of Dr Patience Mthunzi-Kufa. Biophotonics has its roots in photonics, a technology based on the manipulation of photons (the quantum units of light), and biology, the study of living organisms. In biophotonics, optical techniques are used to study biological molecules, cells and tissue.

Thobakgale started his career as an intern at the CSIR in 2011. "My journey at the CSIR, particularly under the supervision of Dr Mthunzi-Kufa, has been one of professional growth and knowledge expansion. During my Master's studentship, I was introduced to the application of laser physics to biological systems, which expanded my knowledge in both physics and biology," he says. His Master's focused on using custom-built laser-coupled microscopes to insert DNA into stem cells, demonstrating how lasers can be used to direct cell division towards making selected types of tissue, a step towards producing organs for medical transplant operations.

Thobakgale is no stranger to excellence. In grade 12 he received the highest achievement award in mathematics and science, and consistently maintained a high standard of academic performance from his undergraduate years to Master's level. In the process of establishing himself as an emerging researcher, his work was included in two conference proceedings, one reviewed publication and four presentations at two international conferences. He was also selected to represent the country at the BRICS young scientist conference in Durban in 2018.

"I am truly blessed to have experienced steady growth in my academic and professional career but, I would not be a scientist had it not been for my family who introduced me to maths and physical science from a very early age, and my late science teacher, Mr Selomo, who always made the learning process of these subjects an adventure. Also, my father is involved in the optometry industry – he built a laboratory in the backroom at home, where, during school holidays, I would work with him to make spectacles for school children and the elderly. During this time, I developed a passion for using science to help the community, not knowing that my path would one day lead me to the CSIR, where our mandate is about improving and uplifting society through science and technology innovations," he says.

Thobakgale, who is now aspiring to pursue his PhD in physics, continues to sharpen his skill in developing technologies and optimising techniques.

"Currently, the country's ability to develop medical devices is being hindered by imports from other countries. I would like to use my expertise to positively impact limited-resourced communities by developing a biosensor system that will diagnose and screen the progression of cancers in patients undergoing therapy. At an advanced stage, my wish is to see such a project bring out a new photonics screening database that will help scientists and medical doctors to better understand such diseases," he says.

"Science is the language of nature and since we are natural beings, we should all aspire to understand at least one aspect of science. This means encouraging a child from an early age to approach the sciences with gusto, not fear."

Over and above his commitment to his work, he dedicates his time to the CSIR Optics Student Chapter, a programme funded by the Optical Society of America to foster impactful outreach programmes.

THE LAW OF SCIENCE

For the CSIR to succeed in its vision of accelerating socio-economic prosperity in South Africa through leading innovation, it requires a strong science, engineering and technology base. It also requires a resilient support cadre. One such support area is legal matters. CSIR senior legal advisor Lusani Nelufule-Mugivhi has made her mark in this domain and received the Emerging Leader Award at the organisation's 2018 Excellence Awards.

Lusani Nelufule-Mugivhi is an admitted Attorney of the High Court of South Africa, with 13 years' post admission experience. She joined the CSIR in 2015 as a senior legal advisor.

"Science found me. I've always been drawn to economics, environmental management and law. In this context, ending up at the CSIR was not that surprising."

She admits that the size of the organisation was daunting at first. "Another challenge I initially encountered was to memorise and get to understand the multidisciplinary work undertaken in different groupings of the organisation. Not to talk about the abbreviations of the various disciplines," she recalls.

As an attorney and compliance specialist, expertise in protecting the intellectual property (IP) of the CSIR is key. "Many complications in establishing IP ownership can arise nowadays because of the sheer volume of patent claims. This has made keeping track of the specifics of each invention difficult for both researchers and regulatory bodies."

Nelufule-Mugivhi supervises and oversees the review, negotiation and drafting of major contracts, tender documents and other legal documents, as required by research groupings across the CSIR.

Her diligence was recognised at the 2018 CSIR Excellence Awards, where she was a joint winner of the Emerging Leader Award for demonstrating the leadership qualities of influencing, motivating and enabling others in order to contribute towards the effectiveness and success of the organisation.

> **CSIR senior legal advisor Lusani Nelufule-Mugivhi.**

"To excel, you need to know what you want. Sheer determination got me to where I am today."

QUALIFICATIONS

- **Bachelor of Law (LLB)**
  University of Limpopo, 2004
- **Postgraduate Diploma in Compliance Management**
  University of Cape Town, 2015
- **Postgraduate Certificate in Intellectual Property Law**
  World Intellectual Property Organisation and the University of South Africa, 2016

PROTECTING INTELLECTUAL PROPERTY (IP)

1
IDENTIFY THE IP

2
IDENTIFY CREATORS

3
IDENTIFY OWNERS

4
PROTECT IP

A LIFE-TIME COMMITMENT TO A NEW-GENERATION OF LASER EXPERTS

A wealth of knowledge and experience in the field of science, engineering and technology have earned him a string of awards over the years, a confirmation of his brilliance and passionate approach to scientific research. In the latest acknowledgement of his contribution, Prof. Sisa Pityana was awarded the CSIR Career Achievement Award for 2018 in recognition for 19 years of translating scientific research work to commercial engineering, as well as training and developing young professionals in the field of laser materials processing.

Prof. Sisa Pityana hails from the Eastern Cape and studied at the University of Fort Hare, a historically black university attended by African political leaders such as Seretse Khama, Robert Mugabe, Govan Mbeki and Oliver Tambo. The unstable political landscape at the time led him to complete his PhD in laser physics and laser waveguide technology at the University of Sussex in the United Kingdom. Upon his return to South Africa in 1996, he completed his postdoctoral studies at the University of Cape Town.

"The political climate during that time was not favourable for an aspiring black scientist like me, but fortunately in 1973, the Nelson and Winnie Mandela Scholarship fund was established by the Sussex Student Union to provide tuition for students from Southern Africa who were denied the right to access education," says Pityana.

Pityana has since played a significant role in the development of laser-based solutions for industry. He has been instrumental in developing new laser technologies and transferring these technologies to industry, specifically in the field of laser hardening, a surface treatment process that is applied to steel. He has long-established working relationships with metallurgy and engineering groups at the University of Pretoria that work closely with the steel industry. He also works closely with metallurgy experts at the University of the Witwatersrand and with the Tshwane University of Technology.

"I am a firm believer that South Africa needs to build a knowledge-based economy with the ability to develop cutting-edge industrial solutions for local industry," he says.

Pityana says that the first step to achieving this is to establish a pool of young people in science, engineering and technology.

In an effort to strengthen Africa's offering in laser-based manufacturing, Pityana, alongside experts from Stellenbosch University and the Botswana International University of Science and Technology host an interdisciplinary graduate school in laser-based manufacturing technologies. Funded by the African Laser Centre, the programme transfers laser-based knowledge and the skills required by postgraduate students, to respond to the current needs of African industries.

"Currently in Africa, there is a lack of equipment and knowledge of laser technology in the manufacturing

> **Prof. Sisa Pityana (right) lending a helping hand to CSIR researcher Thabo Lengopeng, a former Tshwane University of Technology student.**

"We need to develop people with skills who can go out and build our industrial capacity."

sector, coupled with a lack of support from these governments. However, through this programme, a concerted effort is being made to ensure that Africa is not left behind in this space," he says.

Pityana has overseen 18 doctoral studies to date. With additive manufacturing being one of the key technologies that will revolutionise and transform the manufacturing space, he ensures that young scientists develop the skill of operating the laser-engineered net shaping equipment through the student teaching programme. This laser-based additive manufacturing machine generates complex geometries from computer-aided designed data by means of laser metal deposition.

Pityana is listed as the joint-inventor on two CSIR patents. The first covers the detection of diamonds using coherent anti-stokes Raman spectroscopy, while the second, a provisional patent, describes a process for the manufacture of titanium composites.

ACCOLADES

- **CSIR Business Growth Award (Awarded to the surface modification group)**
  CSIR, 2004
- **CSIR Centre Manager's Award**
  CSIR, 2006
- **Professorship (Honorary)**
  Tshwane University of Technology, 2007
- **Human Capital Development Award**
  CSIR National Laser Centre, 2014
- **Finalist: Lifetime Achievement Award**
  National Science and Technology Forum, 2018

INVESTIGATING MATERIALS FOR HYDROGEN STORAGE TO HELP MAKE SA LESS RELIANT ON FOSSIL FUELS

Dr Nicholas Musyoka is an expert in the development of porous materials for use in hydrogen storage, catalysis and other energy-related applications. Hydrogen is touted as the future of clean and sustainable energy, since its only waste emissions are water and heat. Musyoka was recently appointed as a research associate at the University of South Africa.

Dr Nicholas Musyoka has been involved in the development of materials-based hydrogen storage technologies for the last five years. His contribution, and that of his peers working in this field, is crucial in making South Africa less reliant on fossil fuels.

He has successfully used locally available feedstock precursors, such as zirconium, aluminium and chromium metals, as well as beneficiated industrial waste materials, such as coal fly ash, waste plastic bottles and waste tyres, for hydrogen storage materials development.

He is also involved in the championing of solar-based methanol production technology, which provides a pathway for the use of hydrogen that is produced by renewable energy sources, such as wind or solar.

Doing what it takes to advance in research

This winner of the 2018 CSIR Excellence Awards' Emerging Researcher category started his career with a two-year postdoctoral contract. He had just landed in the country from France, where he was attending a bilateral research collaboration meeting, when he ascended the podium to receive his award at the biennial CSIR Excellence Awards. "I decided to attend the event, oblivious that I was a winner. I was overjoyed. The award also affirms the 2017/18 Kambule-National Science and Technology Forum (NSTF) Awards finalist recognition I received earlier."

His hard work paid off, not only resulting in the awards, but also in continued advancement on the career ladder with the help of 60 presentations at key international and local conferences, 47 peer-reviewed articles and four patent applications (two having been granted to date).

Musyoka is a member of the South African Chemical Institute and the Royal Society of Chemistry; a registered Professional Natural Scientist; and is also a National Research Foundation-rated scientist. In addition to his research activities, he also supervises and mentors MSc and PhD students. Three of his MSc and one of his PhD students have graduated, with another six currently working on their PhDs under his supervision. He has also mentored five interns.

He is a reviewer for several scientific journals, including the *Journal of the American Chemical Society, Nature Scientific Reports* and the *International Journal of Hydrogen Energy.*

“Let’s embrace science! To our young people – consider taking up a role in science, technology, engineering and mathematics to help tackle the challenges that society faces.”

ACCOLADES

- **Emerging Researcher finalist in the TW Kambule-NSTF Awards, 2018**
- **Emerging Researcher Award, CSIR Materials Science and Manufacturing, 2015**

> **The CSIR’s Dr Nicholas Musyoka preparing a sample for characterisation using a Micromeritics ASAP 2020 instrument.**

HIGH-TECH STEM CELLS PROMISE BETTER DRUGS FOR AFRICA

Tiny artificial livers, grown in a petri dish, could soon replace human and animal subjects for drug-safety testing. CSIR researchers grow these mini-livers, known as spheroids, from induced pluripotent stem (iPS) cells, which are a cutting-edge, ethically acceptable type of stem cell that is not extracted from human embryos; and they are using them to make prescription medication safer for South Africans.

> **From left: CSIR acting research group leader Dr Janine Scholefield, PhD candidate Ezio Fok, Master's candidate Brian Kariithi of the University of the Witwatersrand, CSIR candidate researcher Dimakatso Gumede and CSIR senior postdoctoral researcher Dr Jerolen Naidoo.**

Making safer prescription medication matters because one in 12 patients in South African hospitals is there because of drug side effects rather than a disease. This is according to Dr Janine Scholefield, acting research group leader of the growing stem cell platform at the CSIR, who adds that unintended side effects from prescription drugs are a huge, unspoken problem in South Africa and across Africa.

"The first phase of testing a new drug is about making sure that your liver can break that drug down," says Scholefield. "But most pharmaceutical companies are based in the Northern Hemisphere, and so they are testing their drugs on Caucasian populations. Unfortunately, African populations have much greater genetic diversity, which includes variations in how the liver breaks drugs down."

She cites the case of the antiretroviral (ARV) drug Efavirenz, one of the most common ARVs used in South Africa – a single genetic variation prevents 40% of Africans from breaking the drug down, leading to a wide range of harmful side effects.

This is why Scholefield and her team are building a high-tech drug testing platform that has never been seen in Africa before.

She brought her expertise in iPS cells to the CSIR six years ago, and has since drawn on the pioneering CRISPR/Cas9 genome editing technology to create liver tissues that genetically match those of African populations.

"We have to figure out a way of developing drugs that suit African people," she explains. "It's hard and expensive to redo clinical safety trials. So, instead, we make liver cells in the lab, and use genome engineering to add mutations. We can thus study the effect of a drug on one African genetic variation at a time."

iPS cells were invented as recently as 2006, when a researcher realised that skin cells could be convinced to turn back into stem cells. They carry all the potential of embryonic stem cells, but they do not have to be extracted from embryos as stem cells were in the past.

"Embryonic stem cells come with a lot of ethical dilemmas," Scholefield explains. "Induced pluripotent stem cells can do everything an embryonic stem cell can do, but they lack that ethical dilemma – they're ethically green."

Like embryonic stem cells, iPS cells hold the potential to become any type of cell that researchers want them to be (that is what pluripotent means – the cells can turn into any one of the many different types of cells found in the body).

The real innovation of the CSIR's stem cell platform comes from combining this iPS technology with the notorious CRISPR/Cas9 genome editing technique – this gives researchers the power to rewrite the genetic code of iPS cells at the scale of a single DNA base pair.

The CSIR research group is currently focusing on using this method to create three-dimensional liver spheroids with specific genetic profiles that reflect different African populations. Once these are created, various drugs with potentially harmful side effects can be tested quickly, safely and relatively cheaply.

Scholefield envisions that this drug safety platform will be used by government and pharmaceutical companies to ensure that important prescription drugs, like Efavirenz, are safe for all African populations.

The researchers are currently collaborating with other research groups across South Africa, and while they are focusing on two platforms – liver cells and white blood cells for HIV testing – they have also made other types of cells, including brain cells and beating heart cells, in a dish.

"One in 12 patients in South African hospitals is there because of drug side effects rather than a disease. Unintended side effects from prescription drugs are a huge, unspoken problem in South Africa and across Africa."

> DR JANINE SCHOLEFIELD

They also work with collaborators investigating mesenchymal stem cells to treat chronic wounding in diabetes patients. Scholefield says that this is just the start of the staggering potential that these technologies represent.

"We know that this platform is going to be useful; we know that this is one of the only ways in which we can address the really serious issue of drug safety for Africa. We have to get on top of the problem and make sure that we make the biggest impact we can, as soon as possible."

ENQUIRIES

> **Dr Janine Scholefield**
jscholefield@csir.co.za

FINDINGS ON HOW IMMUNE GENES ARE REGULATED, PUBLISHED IN *NATURE GENETICS*

In a groundbreaking study published in* Nature Genetics*, a team of scientists from the University of Cape Town (UCT) and the CSIR, has detailed – for the first time – the mechanism of how the immune system remembers prior exposures to, for example, pathogens (micro-organisms like bacteria, causing infection), to then trigger the right response to reinfection.

New research findings contribute to the fundamental understanding of immunology and gene regulation in general by indicating how gene expression can be influenced and maintain a persistent and heritable memory of environmental exposures. This memory can be 'written' and 'erased' continuously via environmental exposures over the lifetime of an individual.

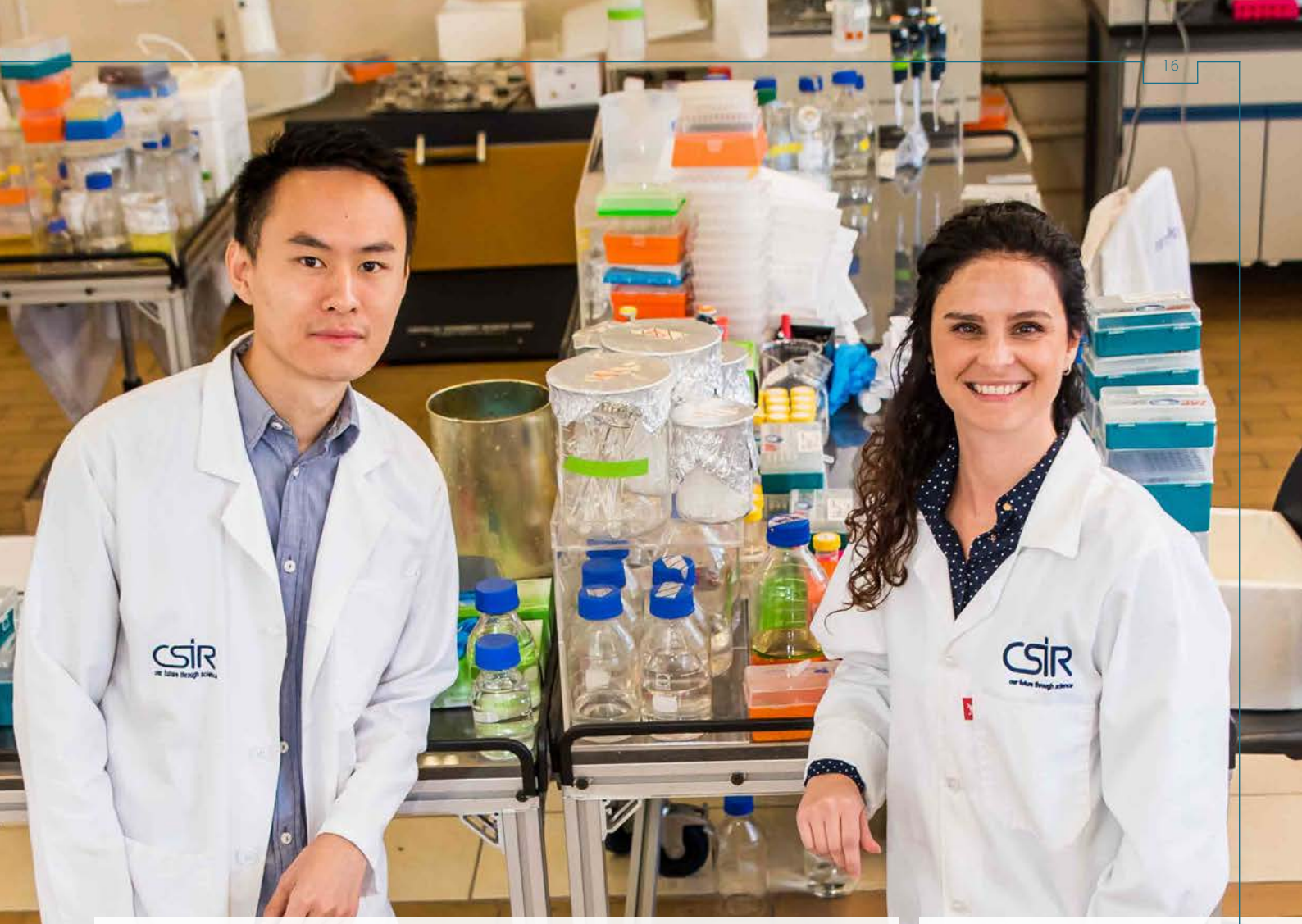
CSIR senior researcher and first author of the published research, Dr Stephanie Fanucchi, says that the immune system sits at the apex of mankind's protection against all diseases, ranging from infectious diseases to chronic diseases, such as cancer and diabetes.

"Within the immune system reside two important actors; the innate and adaptive immune systems. The adaptive system is made up of lymphoid cells (T-cells and B-cells) which retain a memory of prior exposures to pathogens, infections and diseases. This memory can be 'written' to lymphoid cells by vaccines, for example, resulting in accelerated responses by the immune system to re-exposure to the infection or pathogen or even chronic diseases like cancer. The innate immune system is made up of myeloid cells (monocytes and macrophages) which historically have been thought to possess no such memory of prior exposures to pathogens, infections or disease," she says.

In recent years, a phenomenon termed 'trained immunity' has been discovered and described by the laboratory of Prof. Mihai Netea in The Netherlands. Prof. Netea and others have observed that myeloid cells also retain a memory of prior exposures, though the mechanism was unknown. This memory appeared to be 'written' in chemical changes at the level of proteins associated with DNA encoding individual genes regulating the immune system in myeloid cells.

In this study, the scientists, with international collaborators from China, Germany, Italy, Singapore and the United States of America, unraveled and clarified the mechanism. Using the tools of genomics, bioinformatics, single-molecule imaging and gene editing, the authors demonstrated that another recently discovered group of biological molecules, called long non-coding RNAs (lncRNA), regulate the epigenetic acquisition of memory at immune genes that occurs during trained immune responses.

In its study, the UCT/CSIR research team characterised an example of one lncRNA called UMLILO, aptly named after the isiZulu word for fire, which regulates how inflammatory genes retain a memory of prior exposures. These genes regulate inflammatory responses implicated in several major



diseases including tuberculosis, chronic obstructive pulmonary disease, ischaemic heart disease, cystic fibrosis and autoimmune disease.

Fanucchi says, "This groundbreaking discovery of these lncRNAs can now be exploited therapeutically to discretely alter the immune response to treat a plethora of inflammatory-based diseases such as cancer and inflammatory bowel disease. Alternatively, this knowledge may be useful to boost the training of the immune system, to enable individuals with weakened immune systems to clear infections."

Second author Ezio Fok, a PhD student at UCT and the CSIR, who, under the supervision of UCT's Prof. Musa Mhlanga, significantly contributed to the study, sees the very immediate practical result pertinent to South Africa from the study. "Recent studies have, for example, implicated trained immunity in the mechanism by which yellow fever vaccine and BCG (a tuberculosis vaccine) work. This indicates that measuring specific lncRNA levels may be a useful biomarker for assessing effective innate immune activation (for example, BCG-induced vaccination). This could be of major importance in public health today in assessing vaccine efficacy."

The study is the product of numerous fruitful international collaborations, as well as the continued financial support from the South African Department of Science and Technology, the South African Medical Research Council and the CSIR.

The paper is online at ***https://www.nature.com/articles/s41588-018-0298-2***

> **Ground-breaking research led by South African scientists was recently published in *Nature Genetics*. Above: First author Dr Stephanie Fanucchi of the CSIR (right) and second author Ezio Fok, a CSIR-based PhD student from UCT, who, under the supervision of UCT's Prof. Musa Mhlanga, significantly contributed to the study.**

ENQUIRIES

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NEW SUBMARINE TOWER ESCAPE SAFETY SYSTEM TESTED IN SIMON'S TOWN

A South African team has developed a new prototype system that enhances originally fitted submarine systems to help ensure the safety of submarine crews.

> **Escapees and support crew proudly holding up the South African flag after the successful harbour trials of the Tower Escape Safety System.**

System to help ensure the safety of submarine crews

> SA Navy Diver Able Seaman Lindokuhle Ngidi and Petty Officer Eric Luvhengo signal that everything is okay.

The safety of submariners at sea is closely linked with their ability to successfully escape from a stricken submarine on the seabed. Most submarines are designed to allow members to escape using various means, depending on the depth at which the submarine came to rest under water.

If the submarine happens to lie in shallow water (with water entering the hull), the hatches are opened and the sailors swim to the surface. Another means of escape, normally practised at an average depth of about 100 m, is the tower escape system. This system allows for two members at a time to climb into the conning tower of the submarine, wait for the tower to be flooded, and then rise to the surface. The tower is then refilled with air, ready for the next two escapees. Shortcomings in this two-man escape procedure were discovered during trials conducted after the Class 209 Type 1400 submarines were commissioned. The escaping submariners wear specially designed suits, filled with air, which allow them to rise rapidly to the surface. Wearing these suits, the submariners line up on the ladder and wait for the tower to be flooded. The challenge is that, as the tower floods, the bottom sailor is forced upwards by the air in his suit, causing both submariners to get stuck at the hatch opening.

Recently, a South African-developed and produced prototype system that enhances the originally fitted system, was tested onboard the SA Navy submarine, SAS MANTHATISI. The successful test was conducted at a depth of 20 m.

Project TESS, an acronym for submarine Tower Escape Safety System, was initiated by the South African Navy in 2009, in conjunction with ARMSCOR, the Institute of Maritime Technology and the CSIR.

The new system comprises a special mechanical rail system fitted on the inside of the tower. Each submariner hooks, or clips onto this rail system, below each other. As the tower floods, the rail system keeps the submariners fixed in position, despite the air in their suits. The submariners are released by means of a hold-trigger and release mechanism that is automated upon opening the tower upper hatch. This system works even if the submariners are unconscious. The entire procedure takes approximately three to ten seconds for both submariners to surface at a depth of 10 metres. The escape cycle is repeated until the complete crew has escaped.

In preparation for the testing, the SA Military Health Service Institute for Maritime Medicine played an extensive role in the planning phase, and also provided medical support during the testing due to the risks associated with quick ascents, such as barotrauma (decompression sickness), hypothermia or carbon monoxide poisoning. Divers from the SA Navy were close at hand to assist the members as they reached the surface.

It is envisaged that the TESS will eventually be incorporated into all SA Navy submarines. The successful completion of the system will be included as an additional requirement to qualify as a submariner.

Images and text courtesy of SA Navy. Photographer: Byron Lombard, Deputy Editor of Navy News: Warrant Officer Class Two.

ENQUIRIES

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UNBOXING AFRICA'S MACHINE INTELLIGENCE REVOLUTION

> CSIR principal researcher Dr Benjamin Rosman.

Africa's capacity in machine learning is growing rapidly. CSIR principal researcher Benjamin Rosman is at the centre of the action, having presented his group's advances in the transfer of knowledge between machines internationally and having lectured at the African Masters of Machine Intelligence programme in Rwanda.

If we understand that a box has a top and a bottom, and four perpendicular sides in between, we should, in theory, be able to solve most problems involving boxes. For instance, big blue boxes stack or open or move across a floor in the same way as small brown ones.

It has been difficult to teach machines this kind of 'knowledge transfer', a simple enough concept that humans use to solve never-before-seen problems every day. However, Dr Benjamin Rosman, principal researcher in the CSIR's group for mobile intelligent autonomous systems and senior lecturer and director of the Robotics, Autonomous Intelligence and Learning lab at the University of the Witwatersrand, is part of the team that is tackling this.

Together with his PhD student, Ofir Marom, he designed a machine learning system that is capable of playing a game in which a character needs to move boxes in increasingly complex ways to progress. In other words, the system has to transfer the general knowledge it has about how the boxes move to new specific problems at each new stage of the game.

Rosman says this level of machine intelligence has major implications for skills shortages on the African continent.

"We could build systems that augment people and give them new capabilities without having to go through intense training," he says. Ultimately, this smart technology has the potential to find solutions to complex problems in ways that humans may never be able to, like how best to treat people, or how to improve education.

This leap in machine learning was the very first African contribution to the field's most important international meeting, the Conference on Neural Information Processing Systems (NeurIPS), held in Canada in 2018.

"For an entire continent to have never appeared was pretty terrible," says Rosman. But he believes that Africa has much to offer, and that Africans will come to rely heavily on machine learning to solve major socioeconomic challenges. "We cannot afford for Africa to be sitting back as a consumer of these technologies and not be part of their development."

Rosman and the CSIR are certainly not sitting back. In March 2018, Rosman was awarded a Google Faculty Research Award in machine learning, the first and only one to be given to an African researcher thus far.

He says the award shows that it is possible to do quality work in Africa, and he is very passionate about growing Africa's machine learning capacity. "Machine learning is the field of the future and we need more people; we need more diverse talent; we need more thinking around its implications," he says.

In May 2018, Rosman and his CSIR colleagues proposed to solve the problem faced by robots that have to learn new physical environments by using transferable knowledge. Using robotic arms, the team accelerated the speed at which a robotic arm can be trained by about 60% by transferring knowledge learned by another robot instead of training them from scratch.

In January 2019, he was an invited lecturer at the African Masters of Machine Intelligence programme in Kigali, Rwanda. This is a prestigious, high-quality Master's programme that selected only 31 students out of thousands of applications from across Africa, nearly half of them being women.

There he gave lectures on reinforcement learning, the overarching concept that helps machine intelligence systems make decisions and about which he wrote his NeurIPS paper.

During the course, Rosman saw raw African talent, first hand. "They were impressive students, and many of them already hold Master's degrees," he says. "They are very motivated students, working on cutting-edge techniques in machine learning."

With such talent and skills alive and well, Rosman is certain that the African continent, left behind during the first three industrial revolutions, could be at the forefront of the fourth. These efforts have the potential to improve the diversity of talents and ideas in the field of machine learning.

ENQUIRIES

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RESEARCH INFORMS WATER REQUIREMENTS OF SA'S DECIDUOUS FRUIT INDUSTRY

In a study that shows that high apple yields can be produced sustainably without using excessive amounts of water, the CSIR and its partners have presented several recommendations that have a direct impact on the deciduous fruit industry.

A four-year study, published in the *Agricultural Water Management Journal*, found that crop load has a very low impact on orchard water requirements. Instead, canopy size is the major driver of water use and canopy management is extremely important.

These results emanate from a collaborative study between the CSIR, the Water Research Commission, the Agricultural Research Council, the South African Apple and Pear Producers Association, represented by Hortgro Science, the University of Pretoria and Stellenbosch University. Given the industry's importance in the country's economic development, the researchers also deemed it important to determine how crop load affects fruit quality, which influences the fruit's selling price.

The study was conducted in the Koue Bokkeveld and the Elgin/Grabouw/Vyeboom and Villiersdorp regions of the Western Cape – a prime apple producing province. To determine the water productivity in full-bearing orchards expressed in rand per cubic meter of water consumed, the researchers sought to obtain accurate quantitative information on the water use of unstressed high-performing apple orchards, from planting to full bearing. Determining this will improve irrigation scheduling and water allocation decision-making for water licensing and for the development of water-saving strategies to cope with water shortages induced by droughts. The study also provided insights on the income generated per unit volume of water used in the orchards.

The widely planted Golden Delicious and the blushed cultivars were studied. They both produce a yield exceeding 100 tons per hectare. All the orchards were irrigated using one micro-sprinkler system per tree, delivering between 30 and 35 litres of water per hour. The frequency of irrigation ranged from two to three times per week, lasting one to two hours early in the season. During the hot summer months, the frequency increased to daily or several times a day.

The study showed that the maximum unstressed seasonal total orchard water use in the high-yielding orchards ranges from a little under 8 000 to just over 10 500 m^3/ha, depending on canopy size. Golden

PREPARING FUTURE WATER MANAGERS FOR A WATER-SCARCE SOUTH AFRICA

Developments in water management, particularly in the sustainable agriculture space have been vast, with the CSIR leading some of the country's ground-breaking research in crop water management. A new book on water management for sustainable agriculture features some of the CSIR's research in this domain.

CSIR principal researcher Dr Nebo Jovanovic, senior researcher Dr Sebinasi Dzikiti and former research group leader, Dr Mark Gush were invited to contribute a scholarly chapter in a volume on *Water Management for Sustainable Agriculture*. Their contribution, titled, 'An integrated approach for the estimation of crop water requirements based on soil, plant and atmospheric measurements', highlights the importance of an integrated approach for estimating consumptive water use of crops that accounts for atmospheric conditions, plant water status and soil properties.

Referencing a collaborative study showing that high apple yields can be produced sustainably without using excessive amounts of water, the authors illustrate how a comprehensive approach to crop water management that provides a complete picture of the effects of evaporative demand and soil water supply, as well as the physiological response of plants, can be employed.

The authors believe that this volume will be invaluable to young researchers and new students to get up to speed with agricultural water science and practice.

"The invitation to contribute to this volume is a reflection of the long term investments made by the CSIR, the Department of Science and Technology and industry partners in the last decade in enabling the CSIR to develop theories and introduce new methods for estimating crop water use," says Jovanovic.

ENQUIRIES

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Delicious orchards, which tend to have larger canopies to protect the fruit from sunburn damage, used the most water. However, the smaller canopies of the red cultivars, normally kept open to improve light penetration to promote the development of the red fruit colour, had significant water-saving benefits.

CSIR senior researcher Dr Sebinasi Dzikiti explains that high crop loads in this study did not necessarily have a negative effect on most fruit quality attributes in the high-yielding orchards. The study made several recommendations, which have a direct impact on the deciduous fruit industry.

Firstly, careful crop load management in the Golden Delicious cultivar is important as high fruit numbers reduce fruit size and hence the quantity of export quality fruit, he says. Secondly, growers should consider using dwarfing rootstocks to reduce canopy size and hence minimise orchard water use. Dwarfing rootstocks control wood production in the tree, directing its energy into fruit production. And finally, cultivars that are susceptible to sunburn, such as Golden Delicious and Granny Smith, should be grown under shade nets, where small canopies can be maintained to reduce orchard water use.

ENQUIRIES

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> **While international research shows that high crop loads are associated with high water demands, there is currently no information on the water requirements of high-yielding apple orchards in South Africa. This lack of information, given the country's water challenges, prompted this study.**

FINDING VALUE IN WASTE

We're only scratching the surface of the heap when it comes to turning rubbish into resources. This is according to CSIR principal researcher Prof. Linda Godfrey, an expert in unlocking the opportunities in waste, who is charting the way along the South African Waste Research, Development and Innovation (RDI) Roadmap.

South Africa has been implementing the 10-year Waste RDI Roadmap since 2015, and Prof. Linda Godfrey, Manager of the Waste Roadmap, hopes it will help guide the country to a point where as little as 10% of the country's waste goes to landfills.

"For the other 80% to 90%, we can unlock the potential of waste as a resource through technological and social innovation," she says. This includes opportunities for reuse, recycling and recovery.

An example of social innovation that the University of Witwatersrand is looking into is how to integrate informal waste pickers into the waste disposal and resource recovery sector. This is one of over 20 grant projects currently funded through the Roadmap.

"Instead of throwing our waste away in landfills where it serves no purpose, we have to ask how we can redirect those resources back into South Africa's economy where it can create benefit," says Godfrey.

A strong focus of the Roadmap, and of the current batch of government-funded grant projects, is for technologies that can better recover such valuable resources from waste.

One of these projects is a CSIR effort to extract high-value products like pine oil, and a sugar substitute called xylitol from waste sawdust. "This is incredibly exciting research, and there is already a lot of interest from business," says Godfrey, who also serves on the International Advisory Board of the United Nation's International Environmental Technology Centre.

She was appointed to lead the implementation of the Roadmap by the Department of Science and Technology (DST), which wants South Africa to innovate and attract greater investment into the waste sector.

"Unfortunately," explains Godfrey, "in this sector, especially in municipalities, we don't always have the capacity that we need, with the number of people and the skills level available."

She says it is time to develop more skilled, competent graduates for the sector, and, also in line with the Roadmap's goals, to create jobs for those graduates to move into. As such, the DST provided seed-funding for Africa's first ever postgraduate degrees in waste management, including an honours degree programme at North-West University (NWU), and an upcoming Master's programme at the University of KwaZulu-Natal.

Godfrey says they've also relied on NWU's experience with part-time degrees to upskill those who already work in the waste sector, including those who have decades of experience.

"We have found that often, people responsible for waste management in municipalities do not have the necessary undergraduate degrees to give them access to these new honours and master's programmes." She is working with the DST and Roadmap partners to close this gap.

Despite these and other challenges, economic opportunity abounds in the quest to find value in South Africa's waste. Godfrey says the Roadmap's capacity building efforts will transform the industry, from the inside out.

"It is a very exciting time to be in the waste sector as we see this paradigm shift from waste to resource; but we need competent people and sound scientific evidence to drive this transformation."

ENQUIRIES

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FACTS AND FIGURES FOR 2017/18

Master's and PhD students were supported
9 through scholarships and 41 through grant projects

Researchers at South African universities and science councils were supported through grant projects

Research grant projects were funded

R54.6 MILLION

Public and private sector funding was invested in waste RDI within the national system of innovation

A strong focus of the RDI Roadmap, and of the current batch of government-funded grant projects, is for technologies that can better recover valuable resources from waste.

CSIR-DEVELOPED TOOL ASSISTS INDUSTRY IN MANAGING ITS WASTE

The CSIR's separation of waste at source costing model proved instrumental in the development of waste management plans for the paper and packaging industry.

Following a call for selected industries to prepare and submit waste management plans to the Department of Environmental Affairs for approval, as gazetted in December 2017, the CSIR's expertise in waste management was called upon to assist the paper and packaging industry to develop its plans.

In developing their plans, the industries involved were requested to heed the extended producer responsibility principle, decrease packaging, create employment and be a catalyst for transformation, amongst others.

Packaging SA – an industry body representing the various packaging industries – appointed a consultant to assist in developing its Federation of Plans, representing the sector as a whole. The CSIR's waste experts participated in the development of these plans, using its separation of waste at source costing model.

"We were requested to provide information on the indicative costs of implementing different separation at source options at the municipal level, in order to determine the potential for collaboration between the packaging industry and municipalities," says CSIR research group leader for sustainability science and research economics, Anton Nahman. The tool is the brainchild of Nahman, and, given the financial constraints of municipalities, he believes that collaboration between industry and municipalities is crucial in advancing the development of a viable recycling economy. The instrumental role played by the CSIR-developed tool demonstrates the relevance of CSIR technologies for industry needs.

The separation of waste at source cost model is a decision-support tool for assessing the costs and benefits of alternative systems for the collection of source-separated recyclables; and therefore for identifying the most feasible option for implementation of a separation-at-source recycling programme.

ENQUIRIES

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CSIR HELPS TAILOR SA'S FIRST POSTGRAD DEGREE IN WASTE MANAGEMENT

Globally, the waste sector is undergoing a paradigm shift from waste disposal predominantly via landfill, to waste as a valuable secondary resource. Given the increasing complexity of waste and the growing waste management challenges facing South Africa, the waste sector is increasingly one where a degree will not go to waste.

In its role as an implementation agency for the Department of Science and Technology (DST) Waste Research, Development and Innovation (RDI) Roadmap, the CSIR has significantly contributed to the design of a Master's degree specialising in waste management.

The development of this degree stems from a series of workshops held in 2012 as part of the development of the Waste RDI Roadmap. Through engagement with experts from the waste and skills development sectors, it was agreed that it is imperative to boost skills development to strengthen and innovate the South African waste sector.

"At the time, waste management was only offered as short modules in degrees such as engineering or environmental sciences. These graduates often lacked sufficient specialised skills and practical knowledge in integrated waste management to be immediately functional in the waste industry," says CSIR principal researcher Prof. Linda Godfrey, who also manages the DST Waste RDI Roadmap.

> **CSIR researcher Sihle Matinise (centre) with the co-supervisors of her research, CSIR principal researchers Profs Linda Godfrey and Suzan Oelofse (right).**

"While the Honours and Master's degrees provide an excellent overview of integrated waste management, making these graduates sought after in business and government, it is hoped that this degree will find traction in the local government sphere," says Godfrey, "especially given the changing legislative environment and the solid overview of waste legislation provided for in this degree.

ENQUIRIES

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RESEARCH ON WASTE MANAGEMENT IN COMMERCIAL FOOD SERVICES SECTOR EARNS MATINISE HER MASTER'S

> **Sihle Matinise recently graduated with a Master's degree in Geography and Environmental Management from the North-West University. Her thesis, titled: *Understanding waste management practices in the commercial food services sector*, sought to understand waste management practices in the commercial food service sector to identify opportunities for waste reduction and recovery of resources through source separation.**

Matanise collected data at two malls in the eThekwini Municipality. The composition of waste and current waste management practices by restaurants in both malls highlighted the need for improved waste management practices.

GROWING THE BLUE ECONOMY: IMPROVING DECISION-MAKING IN COASTAL AREAS

The CSIR has developed an Oceans and Coastal Information Management System that provides a real-time picture of South Africa's maritime zones.

The Oceans and Coastal Information Management System (OCIMS) collates and synthesises a variety of complex data and information into tools that are becoming key in supporting maritime industry and the state. The tools help to identify and understand economic opportunities in these maritime zones, while highlighting risks and threats to maritime economic activity, human wellbeing and ecosystem health.

Recently, the system has been used to track a number of vessels of interest and has been able to provide data linking certain vessels to irregular activities. OCIMS also supported government law enforcement interventions around the South African maritime coast.

Towards an ocean's economy

In South Africa, 30% of the population lives within 60 km of our oceans. The Departments of Environmental Affairs and Science and Technology initiated the development of OCIMS because many marine industries and coastal communities are dependent on our oceans and coasts for economic activity. The core system allows the user access to a variety of oceans and coastal-related data sets, decision-support tools, documents and other related

systems to support the unlocking of the oceans economy. It also assists with enhanced planning for integrated vessel tracking, harmful algal bloom detection, coastal flood hazard monitoring, operations at sea, bilge dump detection, fisheries, water quality monitoring and marine spatial planning.

Integrated vessel tracking

The tool that enabled South African authorities to act on irregular activities of vessels in South African waters is an integrated vessel tracking tool that has been incorporated into OCIMS. It allows authorised users to monitor vessel activity within South Africa's full exclusive economic zone, including the Prince Edward and Marion Islands. The tool can, in real time, monitor vessels that transmit their positional information at regular intervals using vessel-tracking technologies, such as the Automatic Identification System or Vessel Monitoring System. The tool can also track those vessels that do not transmit their positions by making use of additional data sources, such as terrestrial radar and satellite-borne synthetic aperture radar. It is currently being used operationally by a number of government agencies to monitor vessels and the effect they have on South Africa's maritime environment, safety and security.

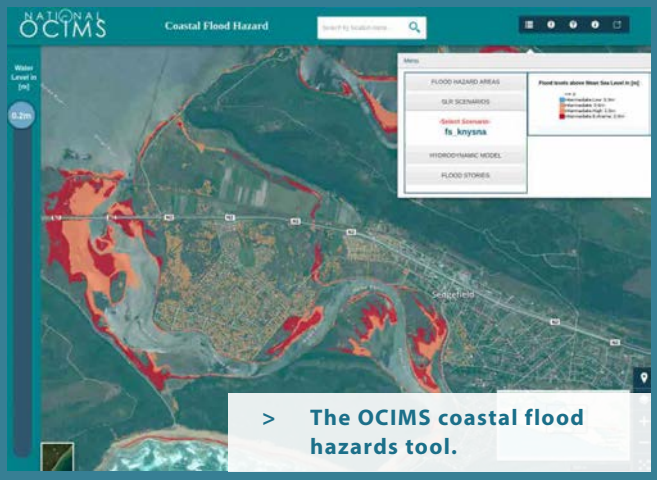
Harmful algal blooms decision support

A harmful algal blooms detection tool has also been incorporated into OCIMS and forms part of government's Operation Phakisa Oceans Economy policy implementation. The remote sensing products used in the system provide a capability for the daily monitoring and risk assessment of harmful algal bloom events and aquaculture operations along the 3 200 km of South African coastline, extending to approximately 50 km offshore. The tool detects these blooms, often known as 'red tides', which can cause substantial damage to aquaculture operations and coastal fisheries, and impact coastal infrastructure, such as desalination plants, negatively. The tool is operationally used by the aquaculture industry, desalination plants and disaster management agencies.

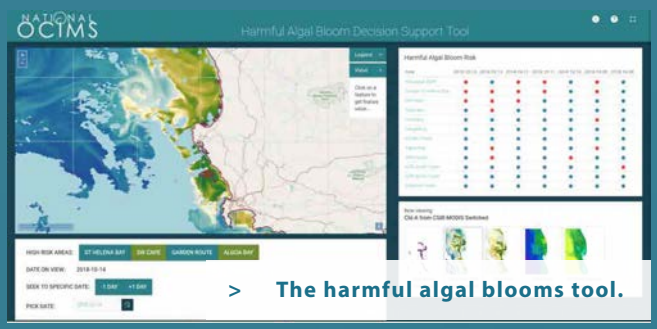
Operations at sea

A three-way collaboration between the CSIR, National Sea Rescue Institute and the South African Weather Service has led to the successful development of the OCIMS - Coastal Operations at Sea decision-support tool. The tool contributes towards search and rescue operations and recovery of missing persons or property at sea, using a combination of mathematical computations, weather forecast models and satellite remotely sensed environmental data. The successful contribution of the tool lies in the ability to predict search areas rapidly and accurately, thereby saving critical emergency response time and minimising error in a context where time is of absolute importance.

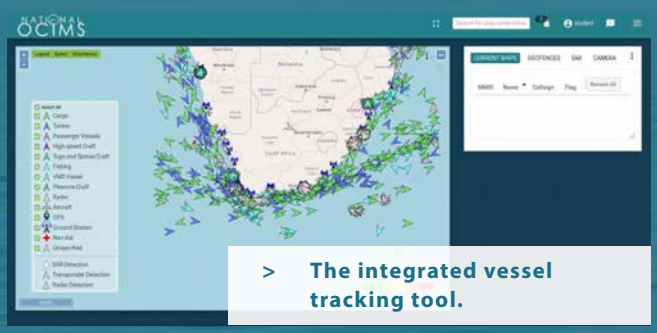
Visit **www.ocims.gov.za**



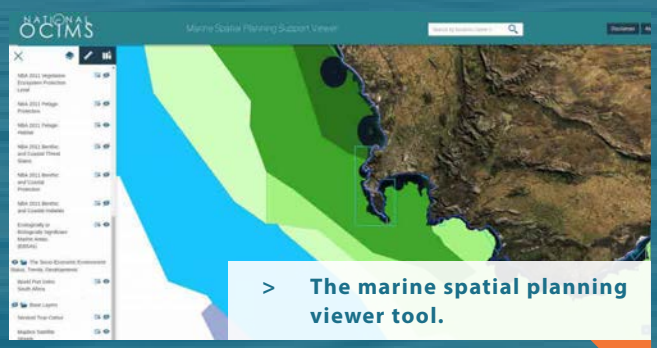
> **The OCIMS coastal flood hazards tool.**



> **The harmful algal blooms tool.**



> **The integrated vessel tracking tool.**



> **The marine spatial planning viewer tool.**

> **OCIMS helps decision-makers to manage South Africa's 3 200 km coastline.**

ENQUIRIES

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USING SATELLITE DATA FOR SURFACE MONITORING

Azimuth is a system used to monitor small-scale movements of the Earth's surface through satellite imaging technology. It provides early warning of surface instabilities, thereby minimising human health and safety risks, and infrastructural damage through proactive monitoring. This precise small-scale measuring can have a massive impact.

Globally, large areas are affected by surface movements caused by tunnelling, underground mining or natural geological processes, like sinkholes, earthquakes or landslides. The consequences of such surface movements are often severe, not only leading to damage to infrastructure and the environment, but also threatening the health and safety of human populations.

Azimuth operationally monitors small-scale movements of the Earth's surface, using satellite imaging technology.

One of the key figures in the development of Azimuth is Dr Jeanine Engelbrecht, whose interest in this work started with her PhD research, which focused on using satellite images to measure cm- to mm-scale movements of the Earth's surface.

"Since we use satellite data, we observe large areas anywhere on the globe and, since satellites

> **Azimuth provides web-based tools for data visualisation, enabling in-field risk assessment.**

The system is used operationally by mining companies in South Africa and can assist with the monitoring of high-risk infrastructure networks, potentially spanning large areas.

> **Dr Jeanine Engelbrecht focused her PhD research on monitoring small-scale surface movements using satellite imaging technology.**

orbit the Earth, we can derive measurements at very regular intervals. The system overcomes the limitations of conventional approaches to surface deformation monitoring, like field-based geodetic surveys," she says.

Engelbrecht obtained her BSc Hons in geology from Stellenbosch University. "During that time, I was introduced to the field of satellite remote sensing, a subject that I found fascinating. Therefore, my MSc dissertation focused on using satellite data for surface monitoring." She entered the workforce and, while working as a scientific officer at the Council for Geoscience, completed her PhD through the University of Cape Town.

"As a teenager, I did not know exactly where I was heading in terms of a career. Admittedly, I most certainly never thought my future would involve a career in science. After flirting with courses in the arts – drama and photography specifically – I realised that I was about as creative as a piece of quartzite and enrolled at the university in the general sciences field. I was hooked. I attribute my interest in science to passionate teachers and mentors who encouraged the diversification of subjects into the fields of geology and earth observation as complementary fields. In this way, my passion for science evolved purely through trial-and-error, as well as learning and experiences," she says.

I consider myself to be a curiosity driven researcher, responding to the question: 'Can {insert problem here} be solved using Earth observation technology?' with 'I'm sure we can find a way!' For me, science is an ideal career path since I enjoy the process of searching for solutions to problems, especially where there could be a down-stream benefit for society.

Challenges and triumphs in this kind of research

When I started with my research, I found it astonishing that such small movements could be measured by sensors 800 km above the Earth. During the course of the research, the maturity of the technology reached a stage where operational monitoring was possible. This is when I joined the CSIR and a team of scientists and engineers who could turbo-charge the research and evolve this idea into a semi-automated, operational system that could monitor small-scale movements, anywhere around the globe! That's how Azimuth, an operational system to monitor surface deformation, was born.

Today, the system is used operationally by mining companies in South Africa and can assist with the monitoring of high-risk infrastructure networks, potentially spanning large areas, including transportation corridors, power utilities and oil and gas pipelines.

ENQUIRIES

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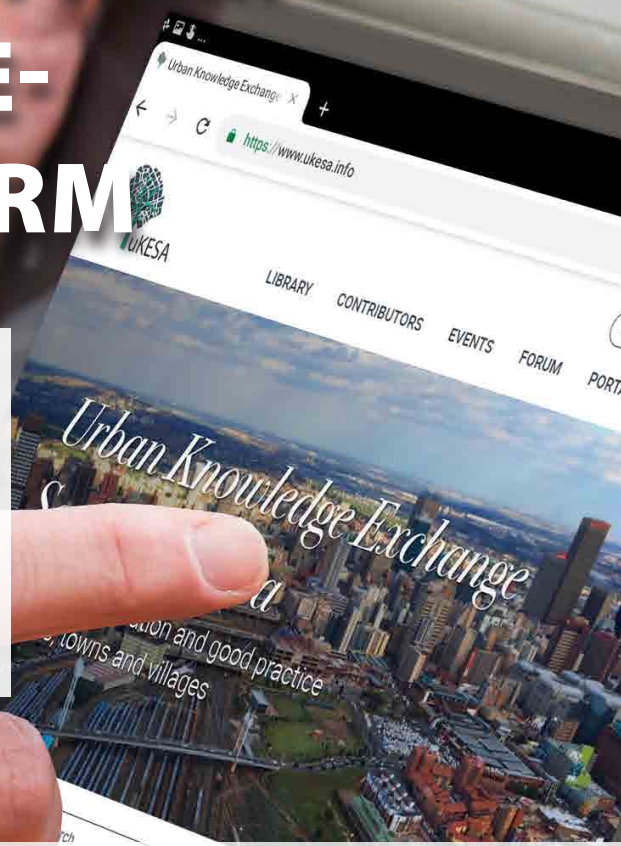
URBAN DEVELOPMENT IN SA TO BENEFIT FROM NEW KNOWLEDGE-SHARING PLATFORM

The CSIR has developed an online knowledge-sharing platform on urban development and human settlements to serve as a comprehensive source of information and access to expertise.



Although South Africa has made significant progress in urban development and housing delivery, the country has not, until recently, had a national, coordinated platform for sharing urban know-how.

Improved knowledge sharing for better human settlements

CSIR principal researcher Mark Napier says that the current system of knowledge exchange has had many limitations. "Within the built environment sector, the processes associated with knowledge generation, capture, and sharing are extremely important if the practice of building sustainable and inclusive human settlements and investing in physical infrastructure, are to continuously improve," he says.

"A user survey highlighted that over time, online information about urban development was either moved or lost as government and NGO websites were updated or closed down. In another instance it showed that where information was available online, it was often poorly or inconsistently classified," he says.

Many countries, including Brazil, China, India, Mexico and Singapore are developing urban innovation knowledge hubs for facilitating knowledge transfer and to assist with networking. There are also global knowledge hubs that have been developed by agencies such as UN-Habitat, the World Bank and other multilateral donor organisations.

"One component of knowledge management that can be directly addressed in the immediate future is improving online collaboration and knowledge exchanges between the 278 municipalities, the nine provinces, national government departments and agencies, and the many private sector organisations and non-government agencies working in the country to improve cities, towns and villages," says Napier.

The uKESA website

Working with a broad coalition of agencies and departments active in producing and maintaining the built environment,

Many countries, including Brazil, China, India, Mexico and Singapore are developing urban innovation knowledge hubs for facilitating knowledge transfer and to assist with networking.

ENQUIRIES

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the CSIR has developed the Urban Knowledge Exchange Southern Africa (uKESA) platform with funding from the Department of Science and Technology. The website has five key components, including an online library of resources; a directory of contributors and experts with relevant skills; a listing of upcoming events; a series of discussion forums; and a portal linking through to other knowledge platforms and information hubs.

"We believe that the uKESA website will facilitate decision support and the exchange of information between the public sector, private sector, civil society, and academic stakeholders in the urban development, land and housing sectors. We believe that it can help address the challenges associated with rapid urbanisation in Southern Africa. These challenges can include, for example, how to respond to the growth of informal settlements, how to improve housing programmes, better and more efficient infrastructure delivery, and ultimately the integration of poorer communities into more functional cities and towns," says Napier.

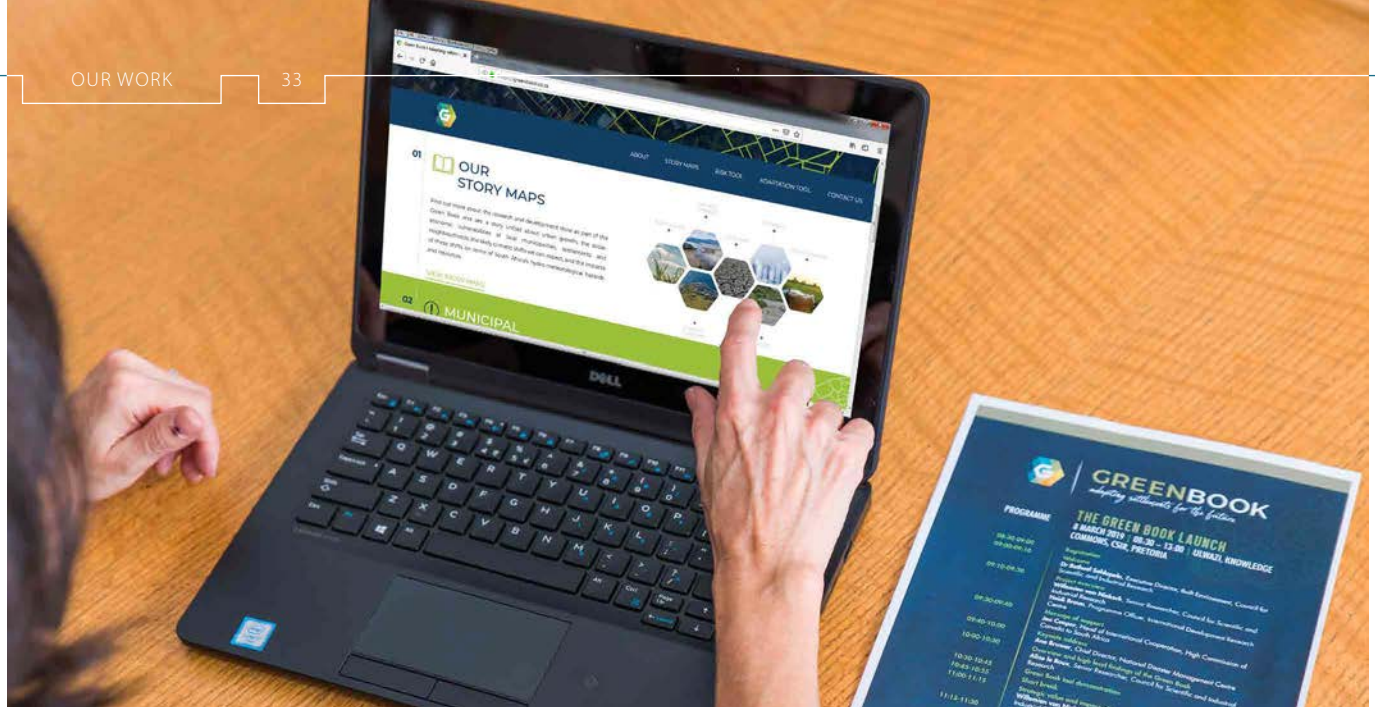
The site is hosted on CSIR servers – the content in the repository will therefore remain available and accessible over the medium to longer term. The resources that users contribute to the website have been assigned appropriate metadata to ensure that content is easily searchable and an editorial policy allows only resources that are of good quality.

Getting involved

To access knowledge products, events, forums and other repositories, or network with colleagues in the built environment, please visit www.ukesa.info. Those who wish to contribute their work, are invited to register on the site.

Meet the project leader

Mark Napier is an architect and a CSIR principal researcher with a Master's and PhD in housing and development from the University of Newcastle upon Tyne. He has numerous competencies including land and housing markets analysis and policy development, housing policy and programme analysis, evaluation and design, monitoring and evaluation of human settlement intervention.



ARMING MUNICIPALITIES FOR CLIMATE CHANGE: THE GREEN BOOK

A new online tool supports local government in South Africa with the planning and design of climate-resilient settlements. The depths and scale of information provided via the tool is unprecedented in South Africa.

www.greenbook.co.za
*A series of interactive national **story maps** provides information about the research methodology, findings and recommendations for 11 components of the project. An interactive **risk profile tool** empowers municipalities to assess their current and future climate risks, socio-economic and other vulnerabilities, population growth pressure and the impact of climate change on hydro-meteorological hazards and key resources. An **adaptation actions tool** provides municipalities with possible actions to adapt their settlements and environments to the likely impacts of climate change.*

Co-funded by the Canadian International Development Research Centre and the CSIR, *The Green Book* online tool is the result of a three-year initiative in which the CSIR collaborated with South Africa's National Disaster Management Centre and a number of stakeholders and reviewers.

Ultimately, the tool is set to contribute to resilient, sustainable and liveable South African settlements through climate change adaptation. Its multidisciplinary nature, which combines high-resolution scientific evidence with adaptation solutions, makes this one of the most novel, innovative and information-dense research outcomes about disaster risk and climate adaptation planning on the African continent.

Key research findings incorporated into the tool include:

- Projections of future climate change covering South Africa at an 8 x 8 km^2 resolution – the most detailed projections of future climate change ever available for the entire country;
- New models to quantify the exposure of South African

settlements to various hazards, including drought, wildfires, inland floods and coastal flooding;

- A vulnerability assessment framework and set of indicators to profile all 213 local municipalities in South Africa, based on four unique statistically developed indicators; the 1 637 settlements across South Africa, based on six unique indicators; and two spatial multi-criteria indicators that capture vulnerability on a neighbourhood level;
- A population potential growth model that was developed to forecast settlement growth across South Africa at a 1x1 km^2 resolution;
- Risk profiles that provide temporally dynamic risk profiles for each municipality and its settlements in South Africa for the present and a 2050 future;
- A menu of adaptation actions that brings together context-appropriate planning and design actions.

The Red Book
Complementary to *The Green Book* is *The Neighbourhood Planning and Design Guide (The Red Book)*, developed by the CSIR for the Department of Human Settlements. The Red Book is aimed at built environment practitioners and it supports the development of sustainable human settlements by providing practical information related to the planning and design of the services and infrastructure typically provided as part of a neighbourhood development project.

Climate change will continue to present a number of risks to South Africa's water resources, in particular. *The Green Book* analyses the impacts of climate change on ground- and surface water and translates them into the risks that municipalities will face to provide water. Water-sensitive urban planning and design principles are integral to the proposed adaptation actions.

ENQUIRIES

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> **The driving force behind *The Green Book*, CSIR senior researcher Alize le Roux, researcher Amy Pieterse and senior researcher Willemien van Niekerk.**

SHORT-TERM RENEWABLE ENERGY FORECASTING FOR SOUTH AFRICA

The CSIR and Eskom are developing a forecasting model to cater for the increased use of renewable energy, which tends to be variable in nature. This model will be incorporated into existing load forecasting models.

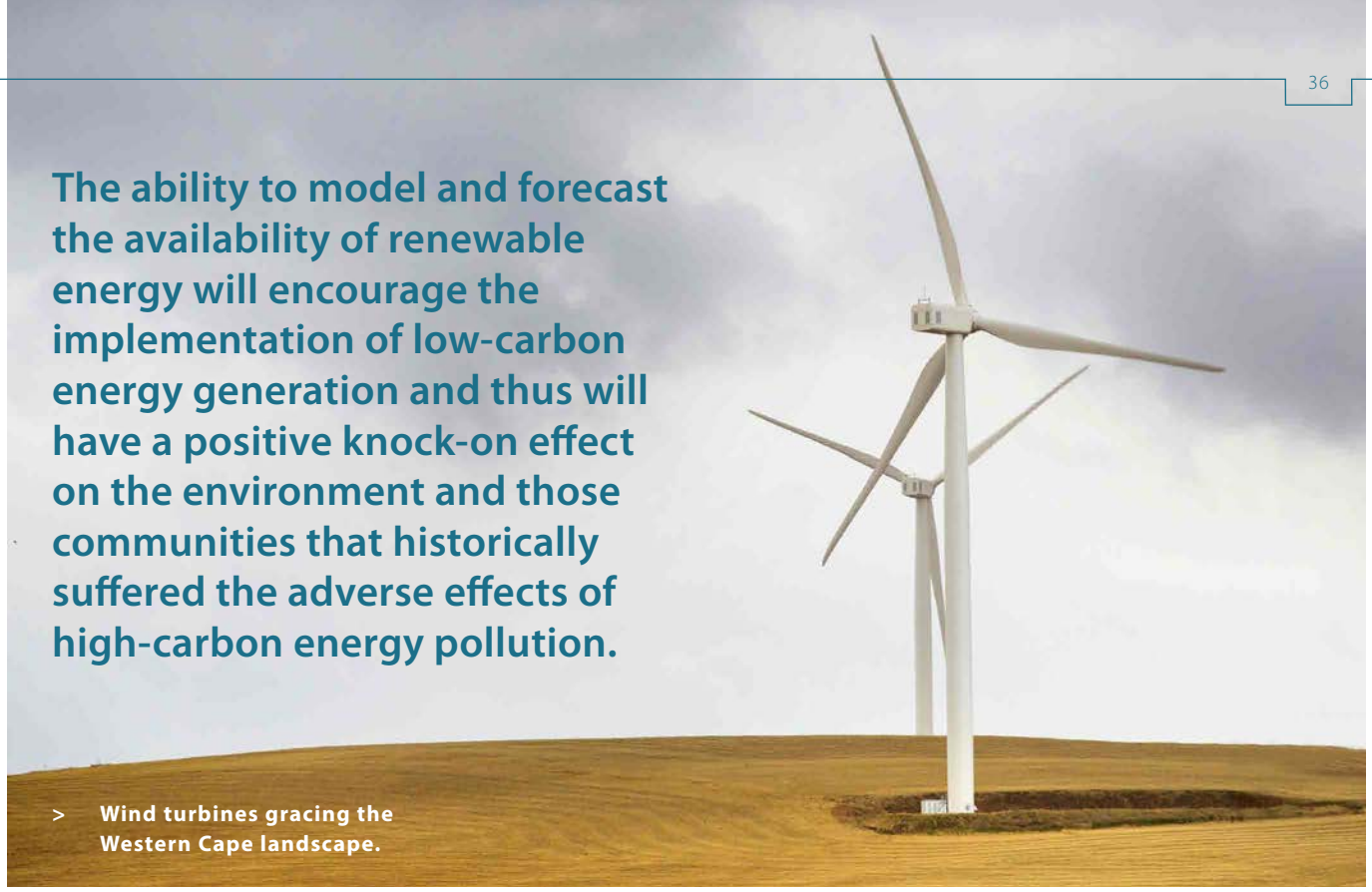
South Africa has one of the most carbon-intensive electricity supply systems in the world and is currently in a transition towards one which is less carbon-intensive. Its climate pledge was submitted for the Paris climate talks on 25 September 2015 with the commitment of peaking greenhouse gas emissions between 2020 and 2025, then to plateau for roughly a decade before starting to reduce emissions.

Less carbon-intensive energy sources tend to be variable in nature and it can be difficult to predict the amount of energy available on a very short-term basis, which in turn can lead to difficulties in assigning renewable energy generators to cater for future load requirements. To help address this problem, the CSIR and Eskom are developing a short-term variable renewable energy forecasting model to be incorporated into their existing load forecasting models.

The ability to model and forecast the availability of renewable energy will encourage the implementation of low-carbon energy generation

> **An outdoor solar photovoltaic module test bed installed on the roof of one of the buildings on the CSIR campus in Pretoria. (Inset) A dual-axis tracker used for measuring direct normal irradiation and direct horizontal irradiation. These solar resource measurements validate short-term energy forecasts.**

The ability to model and forecast the availability of renewable energy will encourage the implementation of low-carbon energy generation and thus will have a positive knock-on effect on the environment and those communities that historically suffered the adverse effects of high-carbon energy pollution.



> **Wind turbines gracing the Western Cape landscape.**

and thus will have a positive knock-on effect on the environment and those communities that historically suffered the adverse effects of high-carbon energy pollution. The project has been in co-development for a year, with the CSIR leading the project.

In the recent past, South Africa has developed 3.8 GW of combined wind power, solar photovoltaic (PV) and concentrated solar power (CSP). The South African Integrated Resource Plan (IRP) foresees a further growth of variable renewable energy generation sources in the future.

As a result, one of Eskom's most challenging issues, as the country's system operator, is maintaining grid stability and the security of supply as the energy mix diversifies. In the past, variable renewable energy was considered an unpredictable energy source, fully dependent on the varying weather conditions and has thus not contributed to the system reliability (adequacy or security). However, due to the increasing penetration of variable renewable energy into the grid, variable resource energy forecasting is becoming critically important in Eskom's scheduling of load requirements, ancillary reserve power and grid stability in a South African power system.

Collaboration with Eskom is essential for development, testing and integration of the model. The work is novel in South Africa in that existing methods will be built upon and tailored to the local meteorological conditions.

CSIR principal engineer and expert in energy supply forecasting, Greg Landwehr, says the impact potential of the project is immense in terms of cost saving for the South African power system. The development of the short-term variable renewable energy forecasting model for South Africa is set to achieve a massive cost saving for Eskom.

Initial results from a test version of the model show forecasting accuracies of 15% mean absolute error for solar PV and wind. The research team hopes to improve the results by, among others, making use of machine learning methodologies when the weather and energy production datasets are sufficiently mature enough and by spatially aggregating forecasts from plant level to national level.

The collaborative work is estimated to take up to three years before a robust variable renewable energy forecasting model is integrated into the existing load forecasting platform at the national utility.

ENQUIRIES

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> The Awezamed mobile app enables communication between healthcare providers and patients who do not speak the same language.

BUILDING HUMAN LANGUAGE TECHNOLOGIES FOR SOUTH AFRICAN LANGUAGES

CSIR researchers are developing language technology solutions for all South Africa's languages. In collaboration with the North-West University and the Department of Arts and Culture, the CSIR aims to support the digitalisation of South Africa's 11 official languages and offer language technologies that can be utilised by industry in a variety of localised information and communication technology solutions.

Human language technology

Human language technology (HLT) combines electronic engineering, computer science, computational linguistics and linguistics to programme a computer to process human language. It broadly involves text processing technology and speech processing technology.

Text technology is concerned with natural language processing and results in offerings such as spell checkers, machine translation systems, and translation memory systems where translators can store documents that they've already translated, aligned at sentence or phrase level, for use at a later stage.

Speech technology is concerned with automatically recognising human speech and converting it to text, as well as reproducing human speech by synthesising text into audio. Text emanating from speech recognition systems can be further analysed through data analytics and keyword spotting systems. Computer-generated audio can be used to provide access to information in a wide range of applications, including e-books augmented with audio.

A CSIR-North-West University collaboration

The CSIR has been collaborating with the North-West University on language technology for the past decade. The first instance of collaboration has been with the Centre for Text Technology (CTexT) which focuses on text processing. CTexT has developed machine translation systems for all South African languages using statistical models. Translations are generated by analysing bilingual text and checking probabilities as seen in predictive text. CTexT also has a broad suite of natural language processing offerings and data which the CSIR has accessed.

The second area of collaboration is with the South African Centre for Digital Language Resources (SADiLaR). The centre supports research and development in the domains of language technologies and language-related studies in the humanities and social sciences. This is achieved through the creation, management and distribution of digital language resources, as well as applicable software, which are freely available for research purposes through a language resource catalogue. SADiLaR forms part of the new South African Research Infrastructure Roadmap and is supported by the Department of Science and Technology. The CSIR is the designated Speech Node of SADiLaR and as such contributes to developing speech resources to enable local researchers and developers to utilise state-of-the-art speech processing techniques, which require large datasets.

Human language technology at the CSIR

The CSIR's research on speech processing has seen the commercialisation of a text-to-speech system called Qfrency. The system, consisting of a text-to-speech engine and text-to-speech voices, produces human-like (synthesised) speech from written text. The suite of text-to-speech voices can read out text in multiple South African languages, on a wide range of devices and platforms, for industry, developers and individuals. Recently, the CSIR team has also been working on developing a machine translation system using a rule-based approach, which ensures high levels of translation accuracy. Research and development on speech recognition has recently seen it being implemented in a command-and-control system and a form-filling application, with integration into a speech-to-speech translation system planned for later this year.

CSIR research group leader for human language technology, Dr Karen Calteaux, says the CSIR has recently created a speech-to-speech pipeline that is agnostic in terms of the underlying human language technology components and can accommodate multiple implementations of the underlying technologies such as multiple and differing text-to-speech engines simultaneously. As a result, the CSIR has been able to create a new solution, called a speech-to-speech translation system.

"We have now combined our speech recognition, machine translation and text-to-speech technology. This means that a person can speak in one language (language A); the speech gets transformed into text; the machine translation component then translates that text (language A) into text in another language (language B), and the text-to-speech system then produces audio (in language B) from the translated text." The speech-to-speech translation system is being trialled in an application (known as AwezaMed) aimed at enabling communication between healthcare providers and patients who do not speak the same language.

Calteaux adds that the speech-to-speech pipeline is "a piece of software that allows for seamless switching of the underlying sub-system implementations, allowing the user to access one or all of the underlying human language technologies individually or in any combination required." It is anticipated that this system will enable the CSIR to deliver speech technology services to a wide range of clients.

> **A user interface showing medical questions with an isiXhosa language option selected.**

ENQUIRIES

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SMARTER ROADS FOR SUB-SAHARAN AFRICA

Collaborating for rural roads that can withstand the impact of climate change

The CSIR is helping to secure the welfare and adaptive capacity of vulnerable rural communities in Sub-Saharan Africa through design interventions that mitigate current and future climate impacts on low-volume roads. These roads are the lifeblood of rural communities, ensuring access to markets and services.

More than 1 400 weather-related disasters have affected 460 million people in Africa in the past 40 years.

Compared to other regions, infrastructure damage relative to population and gross domestic product (GDP) is highest in Africa. Yet, the capability to adapt and mitigate the effects of increasingly frequent climate events is limited, with rural populations at greatest risk.

Millions of rural communities in Sub-Saharan Africa rely on low-volume roads, which comprise the bulk of road networks across Africa. They have not been designed for future climatic conditions, making them very vulnerable to degradation – many already being impassable in the rainy seasons.

The CSIR is engaged in specific projects in four African countries: Ghana, Mozambique, Malawi and Tanzania.

ENQUIRIES

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GHANA

BUILDING CLIMATE-RESILIENT ROADS USING ALTERNATIVE SURFACING FOR STEEP HILL SECTIONS

The CSIR has recommended that cold-mix asphalt replaces thin hot-mix asphalt for the surfaces of steep hills in Ghana.

The CSIR, in partnership with the Building and Road Research Institute of Ghana, was appointed by the Africa Community Access Partnership (AfCAP) to undertake the second phase of a study on alternative surfacing for steep slopes on low-volume (feeder) roads in Ghana. This followed the first phase study to scope for and select suitable surfacing options for the current project. The principal project partner is the Ghana Ministry of Roads and Highways, represented by the Department of Feeder Roads.

Project leader Dr Joseph Anochie-Boateng of the CSIR says that rehabilitation and maintenance of feeder roads are seen as a crucial part of Ghana's efforts in agricultural development and in its strategies for economic recovery and growth, poverty alleviation, and food security.

Research has shown that most earth and gravel roads in Ghana are uneconomical and practically unsustainable. The identification of appropriate design options for higher risk sections of low-volume roads is seen as an important component of Ghana's strategy for improving sustainable all-season rural access.

"Steep slopes (gradients in excess of 12%) on low-volume roads are at high risk of slope failure, erosion and drainage-related problems that ultimately affect the rural communities in respect of traffic delays, safety, damage to natural resources, and access to social and economic activities," says Boateng. "These problems have been attributed mainly to prolonged rainy seasons, coupled with weak natural gravels that are commonly used as wearing course on the feeder roads."

A major outcome of the first phase of the study in 2016 was a matrix of three alternative surfacing options, namely concrete, bituminous and stone cobbles for comparison with the gravel-wearing courses currently used. The three surfacing types and two base/sub-base layer materials provided 18 different interventions for feeder roads in Ghana.

In addition, various options of erosion control treatments and alternative drainage structures to kerbs were identified.

> **Infrastructure development and capacity-building projects are being undertaken across the African continent, as seen in these projects undertaken in Mozambique.**

MOZAMBIQUE

FINDING SOLUTIONS FOR RURAL ROADS THAT CAN WITHSTAND CHANGING CLIMATIC CONDITIONS

CSIR engineer Julius Komba says road infrastructure on the continent is alarmingly vulnerable and unlikely to be able to continue to function under changing climate conditions. "Mozambique is a case in point; the country experiences floods almost every year," he says.

Researchers are helping to mitigate the negative and adverse effects of climate change on rural road infrastructure. The CSIR's Julius Komba says the challenge is that the existing rural access road design guidelines do not address issues related to climate change.

The CSIR is working on four demonstration sections on a 50 km stretch of road on the Mohambe-Maqueze road in the Gaza province of Mozambique.

The first section demonstrates a solution for soil erosion due to rainfall on planes, where the team is implementing a new adaptive procedure on a concrete crossing. "The concrete crossing has worn away (known as undercutting) as a result of overflows, leading to erosion and damage to the road," he says. "We constructed a vertical wall near the edge of the concrete crossing and extended the concrete slab to the wall in such a way that it does not get damaged."

The second solution was for damage on the approach fill near a crossing. According to Komba, soil erosion damaged the interface of the concrete crossing and the gravel road. "We designed an adaptive procedure to connect the two."

In the third section of road, overtopping – when water rises over the top of a barrier – resulted in damage to the road, culverts and protection works. CSIR engineers shaped and levelled the road; repaired the damaged protection works using an improved stone pitching design; and constructed an additional culvert to increase the capacity of the existing culvert.

The CSIR is upgrading a fourth section of road to illustrate how a well-constructed unpaved road can be climate resilient. The improvement is done by raising the level and applying a better wearing course, as well as improving side drainage. Having consulted with the local community, the side drains will be used for water harvesting for community use.

MALAWI
BUILDING CAPACITY IN ROADS RESEARCH

The CSIR's Dr Martin Mgangira is leading efforts that will see Malawi establishing its own road research centre.

The organisation is assisting the Malawi Roads Authority in collaboration with the Transport Technology Transfer Centre with the institutional set up for road research and to develop a strategic plan for implementation of road research. This required researchers to assess the existing policy and institutional framework for the management and implementation of road research.

"Barriers to the successful implementation of road research was identified. There is currently no institution offering training for laboratory technologists, specifically focusing on road construction materials testing, for example. Capacity in this area is one of the key factors in support of sustainable road research activities," says Mgangira.

Mgangira says a road research strategic plan was prepared and plans are underway to provide an appropriate environment to establish research as an important element of the core business of the Malawi Roads Authority.

TANZANIA
TRIAL ROADS FOR TRAINING

The CSIR is leading a project to address long-term road research sustainability in Africa Community Access Partnership (AfCAP) partner countries.

Demonstration sites are viewed as an effective way through which research-based knowledge is generated and research capacity can be built, while the performance of new technologies and/or design and construction methods are being validated. As part of the initiative, two road trials in Tanzania, the Bago to Talawanda road in the Bagamoyo District of the Pwani Region and the Lawate to Kibongoto road in the Siha District of the Kilimanjaro Region, serve as an in-training environment. Results from these trials can be adopted and influence future designs and specifications of low-volume roads in Tanzania, on the basis of long-term performance monitoring of the trial sections.

The CSIR was contracted by AfCAP to provide in-service training to selected transport sector practitioners to build the required capacity.

HELPING SOUTH AFRICA MAKE ITS OWN DRUGS

The CSIR is using its skills in biochemistry, enzymology and structural biology, and the application thereof in biomanufacturing, to develop production processes for biologics. Researchers hope to not only help stimulate the local pharmaceutical industry, but also to make drugs more affordable locally.

> **Sibongile Mtimka, who had completed her Master's degree on a CSIR studentship and is currently a visiting PhD student from the University of KwaZulu-Natal, loosens the soil during a sample collection at the Kogelberg Biosphere Reserve in the Western Cape. The reserve is known for its high plant biodiversity. Researchers had identified microbes from the reserve's soil for use in producing protein molecular biology reagents. This work has led to a licence agreement with Cape Bio Pty Ltd.**

> The CSIR is producing a biosimilar monoclonal antibody using fast-growing tobacco plants.

Production of a Trastuzumab biosimilar for African markets

The CSIR is assisting BGM Pharmaceuticals with the evaluation and localisation of a technology to manufacture a biosimilar to Trastuzumab. Trastuzumab is a cancer drug that is available in the local market but is prohibitively expensive for the poor.

PlantForm Corporation of Canada and the CSIR, in collaboration with BGM Pharmaceuticals, had entered into a research and licence agreement for the production of biosimilar Trastuzumab using PlantForm's vivoXPRESS® manufacturing system at laboratory scale.

The agreement makes it possible for the CSIR to produce a biosimilar monoclonal antibody (Trastuzumab) by using fast-growing tobacco plants to produce a wide range of biologic (large-molecule) drugs, including monoclonal antibodies and therapeutic proteins, at a fraction of the cost of manufacturing the same drugs using conventional methods.

Previous research has shown that PlantForm's plant-produced Trastuzumab drug candidate is equally effective at inhibiting the growth of HER2-positive breast cancer cells as the Trastuzumab commercial brand-name antibody.

The CSIR has demonstrated the production technology's utility in its facilities in Pretoria.

A local spin-out

The research team has also developed manufacturing technologies for the local production of DNA ligase and DNA polymerase enzymes. These have now been licensed to CapeBio Pty Ltd, a new Black-owned small medium and micro enterprise, for commercialisation.

The objective of the project is to develop and commercialise molecular biology enzyme reagents isolated from South Africa's indigenous biodiversity using metagenomics techniques. Molecular biology reagents are widely used in research and development and diagnostic laboratories globally. Biotechnology research and development activities rely heavily on the use of proteins and enzymes as reagents. Access to novel and newly developed research reagents is a major driver of improved competitiveness and productivity in the biotechnology research and innovation value chain.

BIOSIMILAR

A biopharmaceutical drug designed to have active properties similar to those of a drug that has previously been licensed.

ENQUIRIES

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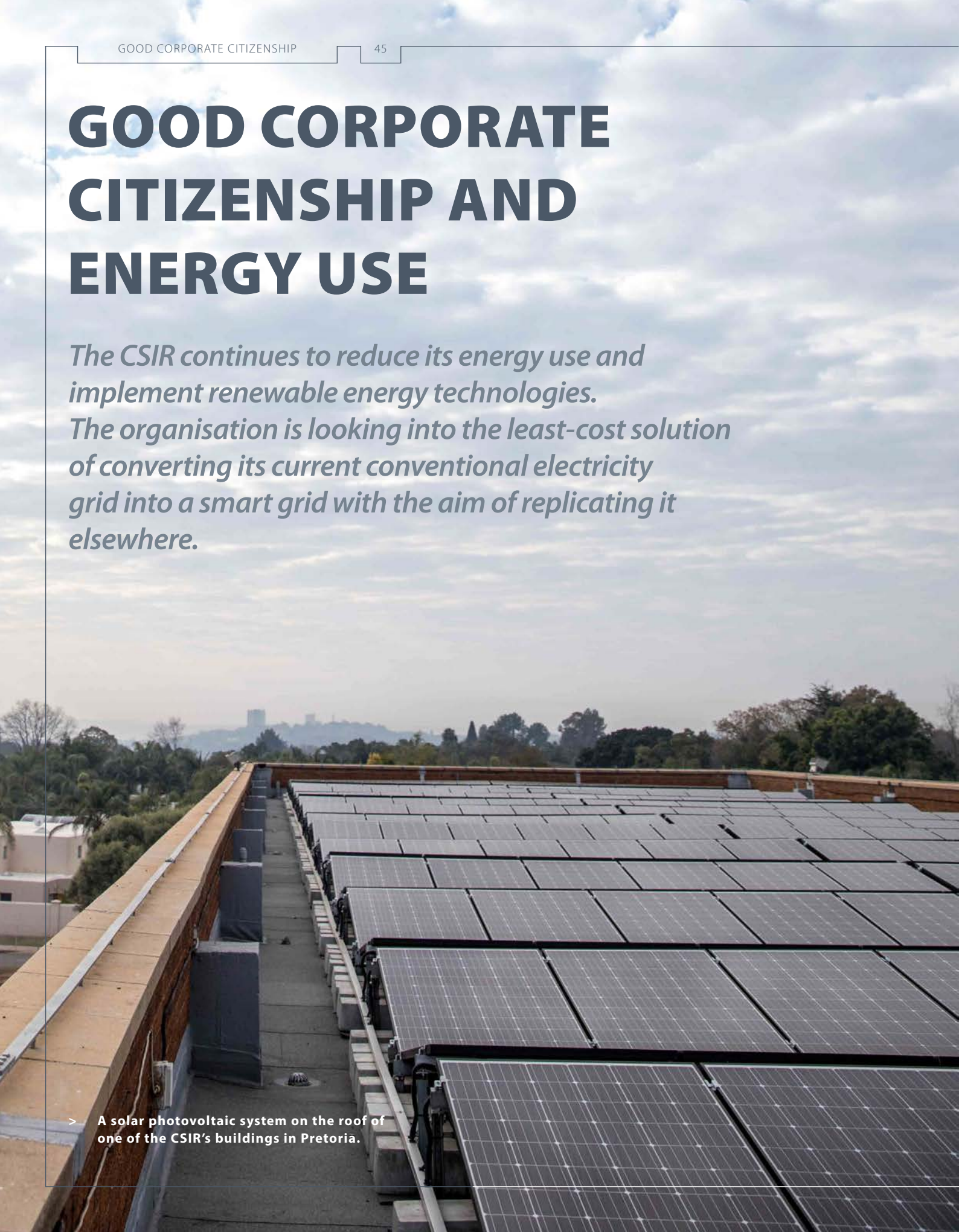
GOOD CORPORATE CITIZENSHIP AND ENERGY USE

The CSIR continues to reduce its energy use and implement renewable energy technologies. The organisation is looking into the least-cost solution of converting its current conventional electricity grid into a smart grid with the aim of replicating it elsewhere.



> **A solar photovoltaic system on the roof of one of the CSIR's buildings in Pretoria.**

The energy use of the CSIR campus in Pretoria is over 30 gigawatt hours per year (GWh/yr) and the organisation wants to reduce its energy usage by 20% to 24 GWh/year by implementing a mixture of energy efficient measures. Current measures include using energy efficient lighting and appliances, as well as electric vehicles and bikes. The CSIR is also working towards producing its own electrical energy using primarily solar photovoltaic, while it is also looking into biogas and wind. The CSIR's Nithin Isaac says, "While we strive to be a good corporate citizen, we also want to understand how a different mix of energy supplies and technologies will shape the future grid."

An on-campus solar photovoltaic system

The CSIR aims to use the power of the sun to produce 13 GWh/yr. The organisation is looking into fitting the majority of CSIR rooftops with solar photovoltaic panels to harness radiation from the sun. The CSIR has some 52 buildings on its Pretoria campus, most of which are suitable for solar installation. The rooftop installations are complemented by ground-mounted plants, using single and dual axis trackers. The single axis tracking system is programmed to follow the course of the sun throughout the day by moving its panels from east to west, while the dual axis tracking system uses sensors to find the optimal position to collect maximum radiation using its ability to track east to west and north to south. The CSIR installed its first solar PV plant system in 2015.

The CSIR's rooftop installations currently generate some 0.4 GWh/yr while the ground-mounted plants generate approximately 1.6 GWh/yr.

Isaac says the CSIR wants to establish how a local blend of energy supply and storage options can best complement the national energy system by providing a cost-effective electricity supplement to the City of Tshwane.

Other renewables

The CSIR has also looked into biogas, a type of biofuel that is naturally produced from the decomposition of organic waste, as an energy source. A biogas plant would use waste generated on the CSIR campus and by the surrounding neighbourhood to produce up to 4 GWh/yr. The process requires environmental impact assessments to determine how the campus' surrounding neighbourhoods and the immediate surroundings would be affected – these assessments continue.

Tests have also been performed to assess wind as a resource and confirmed a relatively low/poor wind resource in Pretoria. The campus energy plans also extend into the possible installation of batteries, fuel cells, electrolysis to generate hydrogen, and hydrogen storage.

ENQUIRIES

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CONTRIBUTING TO SOUTH AFRICA'S FUTURE ENERGY MIX AND THE JUST TRANSITION

Author: *Jarrad G. Wright, CSIR principal engineer*
Co-authors: *Joanne Calitz, Ntombifuthi Ntuli, Ruan Fourie, Mpeli Rampokanyo, Pam Kamera*

In South Africa, energy planning is done centrally, using a long-term energy planning framework. This means that government largely plans the energy systems that individuals and businesses develop and utilise in future. The importance of energy as an enabler for economies to grow is undisputed. Thus, it is critically important to get the long-term plans that inform and guide energy investments right.

The national level electricity component of South Africa's long-term energy planning is known as the Integrated Resource Plan (IRP). This is developed, published and updated by the Department of Energy (DoE), in partnership with system operator, Eskom, and the National Energy Regulator of South Africa.

As part of the IRP update process, the Department of Energy engages in a multistage stakeholder engagement process (including public engagements) to ensure that all affected stakeholders are consulted, including national and local government, business, organised labour and civil society. In 2016/17, the CSIR engaged in the public consultation and submitted comments. As part of the Draft IRP 2018 update process, which builds on the Draft IRP 2016, the CSIR made contributions in the interest of clarity and overall improvement.

A notably different electricity sector plan

The least-cost Draft IRP 2018 scenario (known as IRP1) confirms that variable renewable energy (solar PV and wind), combined with flexibility in the form of natural gas-fired generation capacity (as a proxy for flexibility), is the least-cost combination of new-build options.

These outcomes result in a power system that is 25% renewables-based (mostly solar PV and wind) by 2030 and 70% renewables-based by 2050. The least-cost scenario is approximately R10 billion per year cheaper than the next best scenario and approximately R15 billion per year cheaper than the recommended plan by 2030. By 2040, IRP1 is some R15 billion to R55 billion per year cheaper than all other scenarios and exhibits similar carbon dioxide (CO_2) emissions and water usage to that of other scenarios with stricter carbon limits (IRP6 and IRP7). By 2050, IRP1 is R30 to R60 billion per year cheaper than all other scenarios and also exhibits the least CO_2 emissions and water usage.

> Jarrad Wright

New-build capacity in South Africa should be a combination of variable renewable energy (solar PV and wind) and flexibility (a combination of natural gas capacity, storage and other domestic sources of flexibility).

ENQUIRIES

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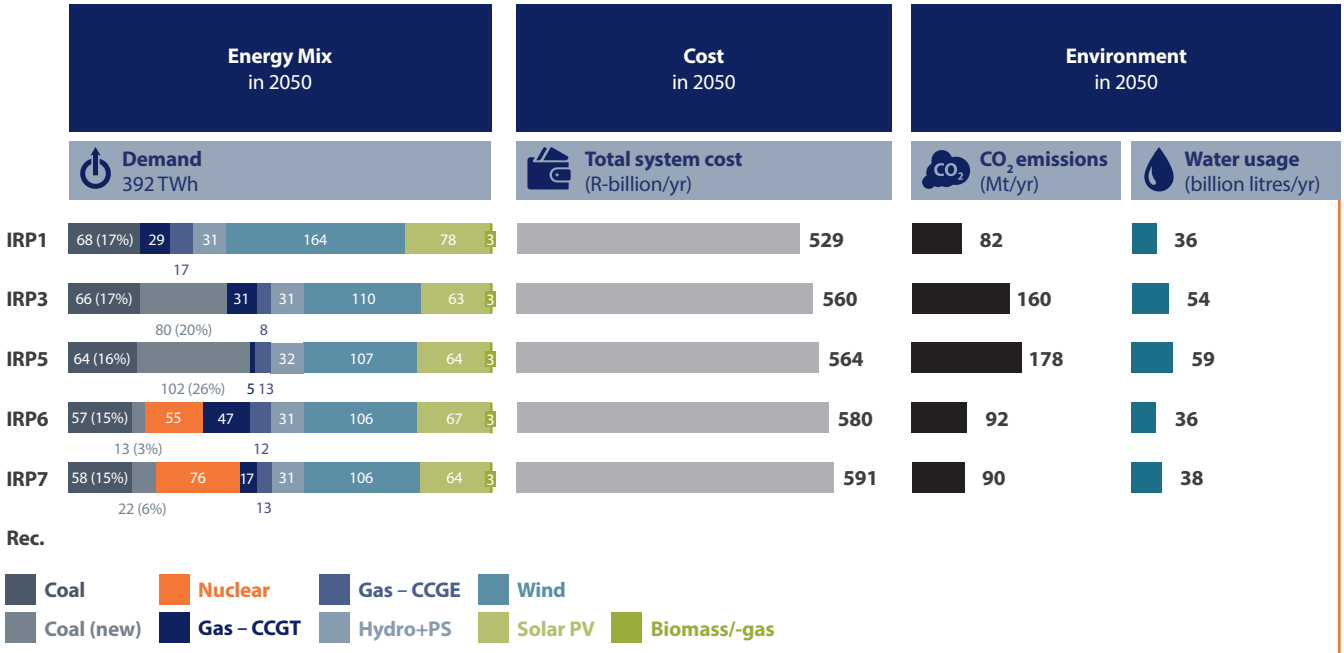
2050 SCENARIOS



Smaller contributions: Nuclear (new), Peaking, Concentrating solar power, demand response and other storage

Source: DoE Draft IRP 2018; Eskom on transmission cost, distribution cost; CSIR analysis; flaticon.com

> **Summary of energy mix scenarios in the latest version of South Africa's electricity plan (Draft IRP 2018)**

CSIR contributions to IRP 2018

The CSIR identified some notable energy planning risks and opportunities and communicated these to the DoE.

These include the reliability of the existing Eskom coal fleet and decommissioning schedule, completion of under-construction coal capacity (Medupi/Kusile), expected cost trajectories of stationary storage and demand-side response opportunities.

When incorporating these into a risk-adjusted scenario, increased levels of new-build solar PV and wind are deployed along with stationary storage technologies. There is also a shift in timing of new-build capacity to as early as 2023. The deployment of stationary storage also results in a notable decreased deployment of flexible natural gas-fired capacity and reduced natural gas-fuel offtake (likely imported). Demand-growth expectations impact only the timing of new-build capacity, while the energy mix remains largely unchanged.

Net employment potential in the power sector (direct, indirect and induced) is estimated to increase towards 2030 if the DoE recommended plan is implemented. This is primarily driven by employment growth for natural gas (approximately 55 000 jobs by 2030), solar PV (approximately 50 000 jobs by 2030) and wind (approximately 60 000 jobs by 2030). This is offset by net reductions of approximately 100 000 jobs by 2030 in employment in the coal sector.

A brief analysis of system services was also conducted, including system stability (with particular focus on system inertia), reactive power and voltage control and variable resource forecasting. No system integration issues are foreseen pre-2030, but an informed and co-ordinated work programme is necessary to prepare for post-2030 increased variable renewable energy penetration levels.

Going forward – what does this all mean?

New-build capacity in South Africa (whenever it is needed), should be a combination of variable renewable energy (solar PV and wind) and flexibility (a combination of natural gas capacity, storage and other domestic sources of flexibility). There is also a distinct need for transparency in all input assumptions, models and outcomes that are comprehensively and consistently published.

All stakeholders need to develop and implement an integrated programme of work on long-term power system integration, system services topics and the broader planning for a just transition in South Africa. Further investigation and leveraging of domestic flexibility sources and storage are required. Particular focus for South Africa should be on the coal sector as the country considers the risks and opportunities of a low-carbon future.

VISION

We are accelerators of socio-economic prosperity in South Africa through leading innovation.

MISSION

Collaboratively innovating and localising technologies while providing knowledge solutions for the inclusive and sustainable advancement of industry and society.

VALUES

Our beliefs, principles and the impact we wish to make to improve the quality of South Africans are **EPIC**.
Excellence **P**eople-centred **I**ntegrity **C**ollaboration

CSIR
our future through science

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