Innovate:

Issue 19 2024

CONNECTING FOR IMPACT

Transdisciplinary research for a positive impact on society

Sustainable water solutions

Minerals beneficiation

Regenerative public spaces

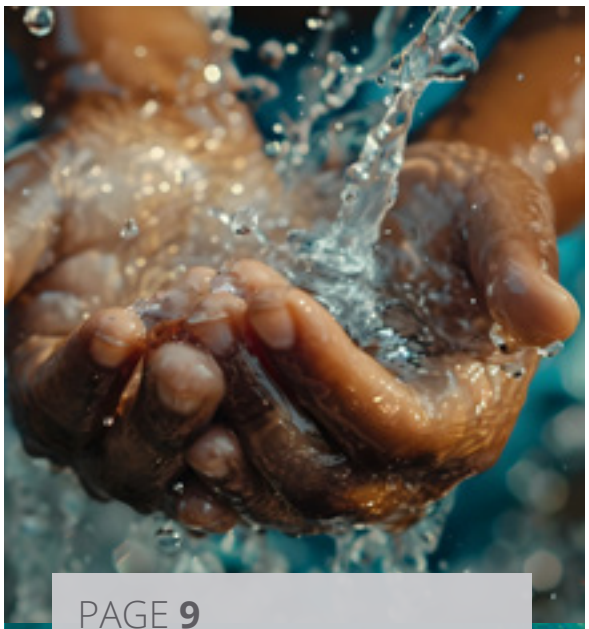
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Make today matter

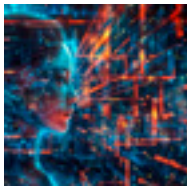
Inside



THE FACULTY'S RESEARCHERS ARE RISING TO THE CHALLENGE OF MAKING A SIGNIFICANT CONTRIBUTION TO SOCIETY AT LARGE. THE FACULTY ENCOURAGES ALL MEMBERS OF THE EBIT GENERATION TO EMBRACE INDEPENDENT THINKING AND A HUMAN-CENTRED PERSPECTIVE OF TECHNOLOGY TO CHANGE THE WORLD.





PAGE 108 ■ T&L FOCUS

PAGE 133 ■ FACULTY NEWS

Innovate:

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Innovate is an annual publication of the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology.

Editorial note: *As a South African publication,* Innovate *uses the term "faculty" to refer to an academic structure within a university, used generally to denote a faculty such as the Faculty of Engineering, Built Environment and Information Technology. It does not denote academic staff members, in the sense that "faculty" is used in some other countries.*

ON THE COVER

CONNECTING FOR IMPACT

The research and academic activities in the various departments of the Faculty of Engineering, Built Environment and Information Technology are expanding their impact by collaborating with partners in industry and with researchers across various disciplines. Their outputs impact tomorrow beyond the traditional disciplines of engineering, the built environment and information technology.

PUBLISHER

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Connecting for impact

Making a positive societal impact is at the heart of the research, teaching and learning, and community engagement endeavours of the Faculty of Engineering, Built Environment and Information Technology (EBIT). By collaborating with partners in industry and with researchers across various disciplines, we are able to expand the impact of our initiatives.

As the only faculty at a South African higher education institution to house a unique combination of schools related to engineering, the built environment, information technology and technology management, EBIT is in the ideal position to pursue research that provides solutions to the societal challenges that face South Africa and the world in general.

Across its four schools, the Faculty focuses on six research areas that contribute significantly to addressing these societal challenges. These comprise the following:

- Smart cities and transportation
- Big Data Science, Information and Communication Technology, and Technology and Innovation Management
- Water and Environmental Engineering
- Energy
- Minerals and Materials Beneficiation
- The Fourth Industrial Revolution

Its academic endeavour is focused on preparing students for the world of work when they graduate. Through innovative teaching and learning initiatives, we enable our students to visualise future challenges and devise creative solutions that exemplify the value of a degree in engineering, built environment and information technology from the University of Pretoria.

In this edition of *Innovate*, you will once again find a selection of exciting contributions to the Faculty's research and educational activities, which illustrate the impact of its research, and its teaching and learning activities. They demonstrate, through their social, economic and environmental impacts, how the Faculty's outcomes continue to improve people's quality of life, and the performance of industries.

Embedded in these articles is the contributors' commitment to maintaining the Faculty's research-intensive, transdisciplinary focus, which is aimed at developing holistic, cross-cutting solutions that transcend traditional disciplinary boundaries.

In its endeavour to impact on global challenges, several articles display the researchers' commitment to finding solutions to problems related to South Africa's water quality, with the objective of improving the quality of life of all the country's

citizens by improving their health and wellbeing. Another important focus in the research presented in this edition is the efficient utilisation of our energy resources. Particular emphasis is placed on the potential of green hydrogen as a sustainable energy source. We also explore various ways of increasing minerals beneficiation to enhance the country's mineral resources.

These articles reflect the Faculty's cutting-edge research, which makes a difference to society through its impact.

Happy reading!

Prof James Maina
Editor

EBIT IS DEDICATED TO MAKING A POSITIVE SOCIETAL IMPACT THROUGH RESEARCH AND POSTGRADUATE EDUCATION WITH A PARTICULAR EMPHASIS ON TRANSDISCIPLINARITY.

MESSAGE FROM THE DEAN

Prof Wynand JvdM Steyn
Dean: Engineering, Built Environment and IT

The strategic vision of the Faculty of Engineering, Built Environment and Information Technology is to develop critical mass and synergies that can contribute to solving the global challenges that form part of the United Nations' Sustainable Development Goals (SDGs). This is the impetus behind our research, and our teaching and learning initiatives, while our community engagement endeavours enable students to use their knowledge and skills to achieve societal impact.

Innovating our tomorrow

Our research is focused on heeding the global call to action to end poverty, protect the environment, address climate change, and ensure peace and prosperity for all people. It concentrates on initiatives to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation, while making cities and human settlements inclusive, safe, resilient and sustainable, and ensuring access to affordable, reliable, sustainable and modern energy for all, and sustainable consumption and production patterns, including those related to minerals beneficiation.

In addition, it does not disregard those sustainability objectives related to alleviating poverty and hunger, promoting good health and wellbeing, quality education, gender equality, clean water and sanitation, decent work and economic growth, and reduced inequalities.

In support of this, our teaching and learning activities are focused on preparing students for the world of work. Through innovative approaches, we enable our students to visualise future challenges and devise creative solutions by embracing the latest technological advancements, such as extended reality, machine learning and Artificial Intelligence (AI).

The process of ensuring that our students enter the industry as work-ready graduates entails taking cognisance of the fact that the industry our students will enter upon graduation is changing by the day. We therefore do not limit ourselves to preparing strategies and approaches for the world of work as it is today. Instead, we prepare our students for what the world of work will look like once they have completed their studies and are called on to find solutions to future global challenges. In the case of students who will be enrolling in their first year of study in 2025, our challenge is to prepare them for the probabilities, possibilities and potential opportunities of 2030.

This is in alignment with the principle of Strategic Foresight and the concept of exploring alternative futures by visualising diverse combinations of identified trends and uncertainties.

This means that we need to anticipate what the future employer in a future industry – or perhaps even in an industry that does not yet exist – will expect of graduates in engineering, the built environment and information technology. It also means that we need to keep abreast of future economic trends, as well as trends in the labour market, in industry and in higher education, in terms of the skills our students will need to prepare them for an unknown future.

We plan to achieve this by maintaining a delicate balance between the subject content students need to master to qualify them for a particular profession and the non-negotiable qualities they need to acquire during their studies. This includes qualities such as time management skills, analytical thinking, problem-solving abilities, the application of scientific knowledge, professional and technical communication skills, teamwork and independent learning.

In the process, students are taught to link discipline-based knowledge with knowledge that can be obtained through collaboration with specialists in other disciplines. This will allow them to apply the principle of transdisciplinarity to devise solutions that will ensure a sustainable future.

The visualisation of potential future scenarios will ensure that the Faculty's research agenda, and its teaching and learning strategies, continue to contribute to the wellbeing of our communities, our cities, our country and the world. By focusing on strengthening our students' agility and adaptability, and applying their knowledge and skills to challenges that are becoming increasingly pertinent to the survival of the planet, they will ensure the University's continued responsiveness and impact on society.

Even if our focus on the future requires us to divert our course, or adapt our methodologies and strategies to meet new challenges, we will continue to embrace the core values of innovation and excellence in education, research and practice to ensure that we remain at the frontier of knowledge. We will do this by continuing to instil in our students an awareness of the non-negotiable attributes that will ensure our continued societal impact.

In this way, we will continue to shape individuals who can make a difference with their qualifications in engineering, the built environment and information technology as agile and responsive citizens of the human race.

Message from the Deputy Dean:
Research and Postgraduate Education

Prof James Maina

The Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria (UP) is dedicated to making a positive societal impact through research and postgraduate education. It aligns with UP's vision to be a leading, research-intensive university in Africa, recognised internationally for its quality, relevance and impact, and for developing people, creating knowledge and making a difference locally and globally.

Our four schools – Engineering, Built Environment, Information Technology, and the Graduate School for Technology Management (GSTM) – are mindful of the National Development Plan (NDP)'s objectives of social and economic development and transformation as we turn threats into opportunities and introduce innovations, disruptive ideas, and technologies to society.

Our research is concentrated on six research focus areas that can bridge the gap between addressing our current realities and aspiring to a better future:

- **Smart Cities and Transportation:** This research area ensures that urban settlements are resilient and connected. We achieve this by co-creating innovative solutions with our partners and collaborators in both the public and private sectors, aiming to develop healthy and sustainable urban systems.
- **Big Data Science, Information and Communication Technology (ICT), and Technology Innovation Management:** Our research in this area employs innovative approaches to unlock the vast knowledge hidden within big data sets. This enables us to respond effectively to future challenges and drive technological advancements.
- **Water and Environmental Engineering:** This research is dedicated to ensuring the sustainability of our environment and reducing human reliance on non-renewable resources. We aim to develop solutions that promote environmental stewardship and sustainable resource management.
- **Energy:** Our focus here is on developing efficient energy systems, promoting the use of renewable energy, and enhancing the efficient utilisation of energy resources. We place particular emphasis on the potential of green hydrogen as a sustainable energy source.
- **Minerals and Materials Beneficiation:** This area aims to enhance the impact of science and engineering on the South African minerals value chain. Our research specifically addresses the needs of the South African mining and manufacturing sectors, seeking to add value and drive innovation.
- **The Fourth-Industrial Revolution:** This area focuses on computer engineering, computer science, electronic engineering, systems engineering, bioengineering, signal processing, power electronics, control systems, optics, electromagnetism, micro-electronics, nanotechnology, additive manufacturing, condition monitoring, and Artificial Intelligence, and creates an integrated environment for innovation.

In our teaching endeavours, we highlight the importance of postgraduate education. We are committed to investing our time and effort into nurturing postgraduate students.

A postgraduate qualification equips our graduates with the skills to identify practical problems in industry and develop unique, knowledge-based solutions to South Africa's social and economic challenges.

This enables our postgraduates to respond effectively to national and global priorities, bringing our innovative solutions into the realm of everyday life.

Message from the Deputy Dean: **Teaching and Learning**

Prof Alta van der Merwe

Preparing students for the world of work when they graduate is one of the Faculty's important priorities. Through innovative teaching and learning initiatives, it enables its students to visualise future challenges and devise creative solutions that exemplify the value of a degree in engineering, built environment and information technology from the University of Pretoria.

The Faculty embraces the latest technological advancements to the benefit of its students.

This is done by considering trends such as the increased automation of systems, the incorporation of machine learning tools in the workplace and the implementation of Artificial Intelligence (AI) to improve processes and enhance efficiency. This includes the challenges related to Generative AI and its impact on teaching and learning.

It recognises innovative methods implemented by its teaching staff to enhance student success and improve the throughput rate.

Its annual Teaching and Learning Awards encourage its teaching staff to devise new ways of overcoming challenges in the presentation and evaluation of module content.

The winner for 2024, Dr Werner Badenhorst from the Department of Electrical, Electronic and Computer Engineering, focused on the challenge of evaluating individual participation in groupwork projects by dividing the students' practical project into four different phases taught in class, which were evaluated individually in four separate demonstration phases.

Excellent performance by students is recognised annually by the inclusion of the top students in each year of study in the Dean's Merit List.

These students are invited to a special event, hosted by the Dean, where they are inspired by the words of a leader in industry.

In 2024, the keynote address was delivered by François Eijgelshoven, co-founder and CEO of iSprout – a company helping young South African professionals achieve international career success.

Students' academic journey starts with the Orientation Week programme for first-year students.

A revamped, innovative, immersive programme was presented for the Faculty's engineering students in 2024. It not only gave them an idea of what they could expect once classes started, but also launched their careers as future engineers by exposing them to the graduate attributes of the Engineering Council of South Africa (ECSA).

Their future success received a boost by introducing them to the Faculty's student success coaches, who are there to provide ongoing assistance with study and examination skills, time management and other co-curricular issues.

This ensures that interventions are initiated before students are at risk of failing due to emotional or academic challenges.

The Faculty is also preparing for an intensive revision of the first-year engineering curriculum, which will be launched in 2026, with initial changes starting in 2025.

This is based on international collaboration and trends regarding the transformation of engineering education. It will bring the Faculty's curriculum in line with global practices.

These initiatives are aimed at ensuring that our students will make a meaningful impact on the world once they graduate.

This reinforces the University's reputation as an institution that is recognised internationally for its quality, relevance and impact.

Faculty welcomes new **Vice-Chancellor and Principal**

The Faculty of Engineering, Built Environment and Information Technology (EBIT) joins the University of Pretoria (UP) in welcoming the new Vice-Chancellor and Principal, Prof Francis Petersen, who assumed duty on 1 October 2024.

Prof Petersen is a dynamic leader with an outstanding record of academic excellence and institutional advancement. With extensive experience in both higher education and industry, he is well positioned to guide UP into an exciting new era of innovation and growth. His academic background includes degrees in Chemical and Metallurgical Engineering, a PhD in Engineering, and executive management training. These are qualifications that equip him to drive UP's strategic vision forward, according to Ben Kruger, Chairperson of the University Council.

PROF PETERSEN PLANS TO FOCUS ON THREE ESSENTIAL PILLARS TO ACHIEVE THE UNIVERSITY'S VISION FOR THE FUTURE: EXECUTION, SUPPORT AND ENABLEMENT.

His leadership journey includes key roles at leading universities and influential positions in industry, highlighting his deep commitment to academic and professional development. During his tenure as Vice-Chancellor at the University of the Free State, Prof Petersen championed inclusivity, research and community engagement, laying the foundation for sustainable progress.

In addition to his academic accomplishments, Prof Petersen has made significant contributions to industry and science councils, demonstrating his ability to bridge the gap between academia and real-world challenges. His strategic leadership at Anglo American Platinum Limited and Mintek has shaped industry practices, and promoted research and development in mining, minerals and environmental engineering.

Commenting on his appointment, Prof Petersen stated: "I am deeply honoured to join the University of Pretoria as its new Vice-Chancellor and Principal. I am committed to advancing the University's mission of academic excellence, research innovation and societal impact. I look forward to working closely with the university community to realise our shared vision."

During a special event to welcome Prof Petersen as the new Vice-Chancellor and Principal, he acknowledged the important role UP plays both locally and globally, while also outlining a path towards continuous improvement and enhanced academic excellence. "The University of Pretoria is an excellent academic institution, adding so much to our country, the continent and the globe."

He acknowledged that, like any organisation, UP has areas of strength and opportunities for improvement. He emphasised that the key to progress lies in consistent reflection and the pursuit of excellence. "In both of these cases, we will assess and reflect, and will enhance and improve. Continuous improvement should be the basis of our approach," he noted.

Central to Prof Petersen's vision is the Academic Project, which he describes as the heart of the University's mission. This project encompasses teaching and learning, research and innovation, and societal engagement. It is a collective effort, involving all 6 085 staff members at UP. "All our staff must be part of delivering an effective and quality Academic Project," he stated.

To achieve this, Prof Petersen highlighted three essential pillars: execution, support and enablement. Execution will be driven by UP's faculties. Support will come from all staff members. Enablement will be provided by the executive and senior management teams.

Beyond the academic mission, he stressed the importance of people. "The University of Pretoria is her people – we must focus on our staff and students. We must care about staff and students. We must create an environment where our staff feel valued," he said, emphasising a commitment to fostering a caring and inclusive culture across the institution.

While the University is set to embark on the development of a new strategic plan, Prof Petersen shared key strategic perspectives that will guide the future direction of UP:

- Enhancing a people-centric approach to university operations and culture, which he calls "human centredness"
- Actively working to elevate UP's global standing and influence
- Positioning UP as a global intellectual leader on African matters, for Africa and the world
- Leveraging technology in all aspects of the University's work
- Increasing UP's contributions to societal development and community engagement

In closing, he humbly underscored his role in this ambitious journey. "Although I am the Vice-Chancellor and Principal, and leader of UP, and I will play that role to the best of my ability, my key focus will be to assist and enable our staff so that we can collectively build an even better UP for the future."

With this clear and inclusive vision, UP's new Vice-Chancellor and Principal has set the stage for a future defined by academic excellence, digital innovation, global leadership and a deep commitment to both staff and students.

His leadership promises to steer the University to new heights and strengthen its foundational values of care, collaboration and societal impact, while exploring new opportunities in teaching, research and community service.

EBIT in a nutshell

29
undergraduate degree programmes

140
postgraduate degree programmes

14 specialised academic departments

QS-RATED SUBJECTS

- MECHANICAL AND AERONAUTICAL ENGINEERING
- COMPUTER SCIENCE AND INFORMATION SYSTEMS
- CHEMICAL ENGINEERING
- MINERAL AND MINING ENGINEERING
- ELECTRICAL AND ELECTRONIC ENGINEERING
- MATERIALS SCIENCE

4 **SCHOOLS**

- School of Engineering
- School for the Built Environment
- School of Information Technology
- Graduate School of Technology Management

Innovating our tomorrow
www.up.ac.za/ebit

72%
Academic staff members with a doctorate

100
NRF-rated researchers

17
Externally funded research chairs

13
Research centres, units and institutes

EBIT FACILITIES

EBIT boasts over **90 laboratorie**s across three of the University's campuses, including:

- UP's state-of-the-art **Engineering 4.0 Complex**
- Africa's first **Virtual Reality Centre for Mine Design**
- **Immersive Technology Laboratory** accessible for all UP students
- **Boukunde Living Laboratory** for architecture and the built environment

BRACE FOR IMPACT

EBIT embraces the concept of interactive immersive technology to provide students with a deep experience of reality. Through virtual reality tools, we immerse students in the learning experience to expose them to the work they will be doing when they enter industry in a fail-safe environment.
This allows students to make the mindshift towards a future in which their unique talents and experiences will further the development and growth of sustainable communities. The Faculty of Engineering, Built Environment and IT offers study and research opportunities across these fields – placing us in a position to conduct exceptional multidisciplinary research to address relevant challenges in society.

Invention to **prevent water loss** has the potential to benefit thousands of local residents

The outcome of research conducted in the University of Pretoria's Department of Civil Engineering has the potential to prevent the loss of almost 40% of the country's household water. A South African patent has been granted to the geotechnical research team of Prof SW Jacobsz for a method of passive leak detection that makes use of fibre optic cables. This method measures both ground strain and temperature along a pipeline to detect leaks, and is ready for commercialisation by a willing investor.

POTENTIAL TO PREVENT THE LOSS OF ALMOST

40%

OF THE COUNTRY'S HOUSEHOLD WATER

In the City of Tshwane alone, an estimated 35% of the potable water distributed by the municipality is lost due to leakages in the ageing distribution system. This amounts to approximately 75 million m^3 per annum. In towns like Makanda (formerly Grahamstown), which has older infrastructure, the percentage loss is substantially greater. In a water-scarce country with a growing population and growing urbanisation, such losses cannot be afforded. A similar situation is prevalent in practically all arid countries around the world.

Perhaps the most significant problem with water lost from the distribution system, according to Prof Jacobsz, is that the presence and location of leaks are not easily detected before a very large volume of water has been lost. "Remedial action is therefore not taken soon enough." Many water leaks do not appear at the surface, resulting in detection difficulties and considerable water loss.

"Fibre optic instrumentation has been developed over the past 25 years to measure temperature and strain at a high resolution in optical fibres," explains Prof Jacobsz. "Continuous strain and/or temperature readings can be taken along the length of a conventional communication-grade fibre optic cable extending to 50 km or more." A major advantage of such systems is that fibre optic cables are cheap and completely inert, and are therefore not affected by electrical interference.

Prof Jacobsz and his team have been investigating the use of fibre optic cables as a means of leak detection in pipelines through two research projects funded by the Water Research Commission (WRC). When they first devised the leak detection concept, they hypothesised that a leak could be detected by registering sudden changes in temperature, usually associated with colder water leaking from the pipe into the ground. The leak detection concept involves burying fibre optic cables with new water distribution pipes during installation. A specialised readout unit is then used to monitor the optical fibre for changes in a phenomenon known as Brillouin backscatter. When laser light passes through an optical fibre, various types of back scatter occur due to imperfections in the glass comprising the fibre. Brillouin backscatter is a particular type of backscatter that is sensitive to both temperature and strain changes in the optical fibre. When a water leak occurs, colder water leaking into the ground generally causes the temperature in the ground to drop. Negative water pressures normally also occur in unsaturated soils, i.e. soils that are not completely saturated with water, as most soils in South Africa are.

These are caused by capillary action affecting the soil water. When water leaks into the unsaturated soil, these negative pressures are dissipated, causing considerable stress changes and therefore strain changes in the soil. The leak-induced temperature and strain changes affect fibre optic cables passing through the ground, causing changes in Brillouin backscatter. Detecting changes in Brillouin backscatter is therefore a highly suitable means to detect water leaks in the ground. Not only does it indicate when a leak occurs, but also where the leak occurs, allowing timeous action to be taken to repair the leak. Although similar concepts had already been applied in the oil and gas industry, none of these systems made use of ground strain measurements to detect leaks. Combining both strain and temperature detection results in a more sensitive system than systems operating on only temperature detection.

By installing fibre optic cables with new pipes and linking these to a centrally located readout unit, a regional leakage detection centre can be set up. This will enable the municipality or other pipeline owner to be notified of exactly when and where a leak is located, making it possible to fix it and prevent any further water loss.

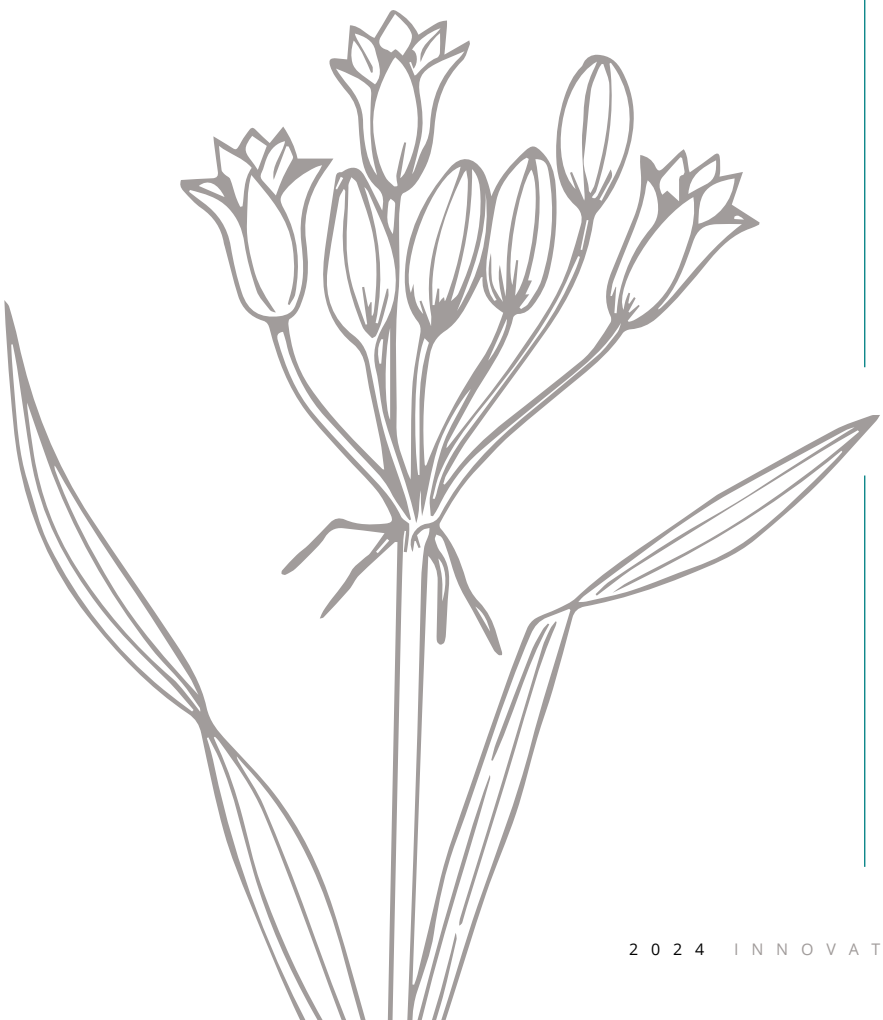
The system can be monitored remotely via the internet. Software can be developed to automatically scan fibre-optic instrumented pipelines for leaks, providing warning messages whenever a leak is detected. This will enable early remedial measures to be taken to repair the pipe to minimise water loss. A significant advantage of this patented leak detection system is that it provides a passive means of leak detection, saving the need to recruit additional service providers to search for leaks.

Leak detection field testing took place on UP's Hillcrest Campus.

PERHAPS THE MOST SIGNIFICANT PROBLEM WITH WATER LOST FROM THE DISTRIBUTION SYSTEM IS THAT THE PRESENCE AND LOCATION OF LEAKS ARE NOT EASILY DETECTED BEFORE A VERY LARGE VOLUME OF WATER HAS BEEN LOST. REMEDIAL ACTION IS THEREFORE NOT TAKEN SOON ENOUGH. MANY WATER LEAKS DO NOT APPEAR AT THE SURFACE, RESULTING IN DETECTION DIFFICULTIES AND CONSIDERABLE WATER LOSS. BY INSTALLING FIBRE OPTIC CABLES WITH NEW PIPES AND LINKING THESE TO A CENTRALLY LOCATED READOUT UNIT, A REGIONAL LEAKAGE DETECTION CENTRE CAN BE SET UP. THIS WILL ENABLE THE MUNICIPALITY OR OTHER PIPELINE OWNER TO BE NOTIFIED OF EXACTLY WHEN AND WHERE A LEAK IS LOCATED, MAKING IT POSSIBLE TO FIX IT AND PREVENT ANY FURTHER WATER LOSS.

Converting water hyacinth carbon biomass to green energy: Global collaboration leads to a sustainable solution

Water, as a precious natural resource, is indispensable for safeguarding human health and ensuring agricultural food production. However, the convergence of climate change, escalating water pollution, unequal resource distribution and the constrained availability of clean water resources has led to over a billion people worldwide having limited access to safe drinking water. To exacerbate the issue, the proliferation of invasive species, often associated with eutrophication, has resulted in a deterioration in the water quality of existing water bodies intended for human consumption.



An invasive species that is particularly problematic in the regard is the water hyacinth. This pervasive aquatic plant has become a formidable challenge in areas of southern Africa and parts of Central and North America. Once this plant takes root in a water body, its eradication becomes an arduous task. Studies in lakes and rivers worldwide have revealed its profound impact on water quality and the loss of biodiversity, while the stagnant water areas under its dense mats create an ideal habitat for disease-carrying vectors such as mosquitoes.

The water hyacinth, *Eichhornia crassipes,* was introduced from Brazil as an ornamental species in South Africa, North America and South East Asia. It does not grow in the soil like other hyacinth species, but invades aquatic ecosystems across the larger geographic area, resulting in unsightly proliferation in natural water bodies. In South Africa, it has been spreading at an alarming rate since 2003.

Its impact is particularly severe in strategically important water bodies such as Hartbeespoort Dam in North West and Roodeplaat Dam east of Pretoria. It is also becoming a problem elsewhere in Africa, most notably Lake Victoria, which straddles Tanzania, Uganda and Kenya. Previous attempts to manage the problem involved harvesting and vermicomposting. These efforts proved unsustainable due to the plant's rapid growth rate.

As an invasive aquatic plant, it spreads rapidly and covers water bodies, such as lakes, ponds, rivers and reservoirs. It serves as a long-term reservoir for critical nutrients such as carbon, phosphate and nitrogen.

These nutrients accumulate within the hyacinth plant and are released into the water body upon the plant's decomposition, primarily during winter. This causes a deterioration in the quality of the water, to the detriment of both human and environmental health. The nutrient release intensifies the occurrence of spring and autumn algal blooms. Even in tidal systems such as estuaries and deltas, water circulates back and forth through the water hyacinth patch, affecting the water quality in the immediate vicinity. In lake systems, the inflow of water carries nutrients into the main water column.

The dense growth prevents sunlight from reaching the water's surface, which inhibits the photosynthesis of the aquatic plants below. This leads to reduced dissolved oxygen levels in the water. This poor water quality negatively affects sources of drinking water, as well as recreational activities. It also leads to changes in the aquatic ecosystem. The loss of biodiversity can have long-term consequences for the overall health of the ecosystem and the services it provides to surrounding communities.

FINDING A SUSTAINABLE SOLUTION

In an attempt to address the global challenges associated with climate change and public health, the World Universities Network Research Development Fund allocated an award to Prof Evans Chirwa, Head of the Water Utilisation Division in the Department of Chemical Engineering and Chairholder of the Rand Water Chair in Water Utilisation at the University of Pretoria. He is the Principal Investigator and Academic Lead in a collaborative, transdisciplinary research project in this area of water utilisation that affects not only Africa and the Global South, but areas of North America, Central America and South East Asia as well.

The project is being conducted in collaboration with a multidisciplinary team of 14 researchers from the University of Pretoria (South Africa), the Technological Institute of Monterrey (Mexico), the University of Leeds (United Kingdom), Makerere University (Uganda) and the University of Technology Sydney (Australia). The team comprises chemical and electronic engineers, biologists, microbiologists and geneticists. The engineers' role was to develop controls in targeting water hyacinth, while minimising harm to non-target species, and to create efficient, cost-effective, and environmentally safe control and monitoring methods.

The biologists studied the water hyacinth's life cycle, growth patterns and reproductive behaviour, and identified possible biological controls. They also monitored and mapped invasive species and their impact on the native fauna and flora. The microbiologists' role was to investigate microbial communities associated with water hyacinth, and to explore potential growth inhibition. They also explored microbial-based solutions by introducing beneficial microbes for growth suspension. The geneticists analysed the plant's genetic diversity and factors that contribute to its invasiveness. They also developed genetic modification techniques for less invasive strains, and investigated genetic traits related to herbicide resistance to disease susceptibility.

Prof Chirwa explains that following a multidisciplinary approach offers numerous advantages across the studied regions. "It provides a comprehensive understanding by offering a holistic view to enhance strategy effectiveness, considering the unique challenges in each region." It also enables the researchers to devise holistic solutions, which encompass ecological, social and economic factors, ensuring a comprehensive approach. "Interdisciplinary teamwork furthermore fosters innovative approaches, which would otherwise have been missed."

The proposed solutions are locally relevant, as they are tailored to specific conditions in South Africa, North America and South East Asia. "The resultant sharing of knowledge promotes long-term cooperation and capacity building across these regions," says Prof Chirwa. "The rigorous testing of control methods in controlled environments is essential to prevent unintended consequences and environmental harm." It is envisaged that the engagement of local communities, government agencies and stakeholders will ensure the sustainable management of the water hyacinth.

Describing the importance of the project, Prof Chirwa explains that it addresses one of the most persistent and pressing problems in regions characterised by warm climates. Since aquatic invasive species have the proclivity to spread rapidly, they render water bodies unnavigable. Water hyacinth obstructs water supply intakes and irrigation systems, which poses significant challenges. The prevailing solutions have predominantly relied on the mechanical clearing of hyacinth, which, in the long run, has proven to be ineffective.

He explains that, by examining the ecological impact and potential benefits of the hyacinth colonies in the study areas in Africa, North America and South America, the researchers hoped to develop sustainable interventions for recalcitrant invasive species that affect water quality. These interventions sought to consider the complex dynamics of this invasive species in water bodies in these regions. Through a volarisation process, biodiesel or biogas would be produced from harvested hyacinth to contribute to the community or regional energy budget.

Prof Chirwa believes that the aims of the study would be achieved through the generation of new insights and expertise in the design and implementation of a passive ecological intervention in runaway eutrophication by managing both micro- and macrophytes in the water body. This problem disproportionately affects the Global South. Electronic sensors were used to track nutrient levels, as well as hyacinth coverage and rebound rates. The project would therefore provide both a technological and an ecological solution to the water hyacinth problem and, by extension, an elimination procedure for the effects of hyper-eutrophication in water bodies. In addition, a patentable biomass-energy reclamation unit would be developed that could utilise water hyacinth as feedstock.

The central focus of the study was on disrupting the nutrient cycle as a potential long-term solution to eliminate water hyacinth in major water bodies in the tropics and subtropics. The proposed approach encompassed a combination of biochemical processes to inhibit hyacinth growth, and mechanical harvesting methods to expedite the removal of biomass in the short term, with conversion of the harvested hyacinths into energy.

In conjunction with the evaluation of nutrient cycling, the research would assess the impact of hyacinths on parameters such as dissolved oxygen and turbidity within the ecosystem. Specific objectives included identifying invasive species pathways, evaluating past control strategies, proposing innovative approaches, assessing the positive impacts of certain invasive species, and considering naturalisation processes.

PHASE 1

The first phase of the project entailed a comprehensive literature review to understand the origins of the problem. In addition to studying the biology of the water hyacinth, the process of nutrient recycling and the potential of water hyacinth as an energy source, the researchers at Makerere University examined elimination efforts under way in Africa's largest water body, Lake Victoria. This was followed by engagement with local communities. Researchers at the University of Pretoria (UP) investigated prior hyacinth control works, while researchers at the Technological Institute of Monterrey explored nutrient cycles and their impact on or from hyacinth. Researchers from the University of Leeds focused on biological factors that affect the growth of aquatic macrophytes.

Laboratory experiments were conducted to understand the biochemical and ecological factors that influence invasion. This phase involved the design of a water hyacinth volarisation unit in UP's Department of Chemical Engineering. This would give rise to the design, testing and implementation of a hyacinth volarisation strategy to convert water hyacinth carbon biomass into green energy. It therefore comprehensively evaluated the ecological impacts and potential benefits of water hyacinth colonies in the proposed study areas by including inhibition and starvation measures (nutrient cycle disruption) and massive harvesting schemes for green energy production.

PHASE 2

The second phase involved the development and installation of experimental units for hyacinth growth, which took place in UP's laboratories. It included the development of monitoring tools for nutrient cycling in the laboratories of the Technological Institute of Monterrey. The evaluation of metabolic factors that affect water hyacinth growth was a collaborative effort between UP's researchers and those from the University of Leeds.

The findings in the first two phases were consolidated, identifying parameters that could be adjusted for hyacinth control. The water hyacinth volarisation unit that was developed in the Department of Chemical Engineering for the digestion or co-digestion of harvested water hyacinth to produce biodiesel or biogas was then tested on the hyacinth colonies at Roodeplaat Dam. The final phase of the research could therefore focus on interpreting the data from the volarisation unit to make recommendations for a full-scale unit. This included the development of a toolkit to manage and control water hyacinth proliferation in lakes and reservoirs, with contributions from all partners in consultation with local communities.

The processes and approaches that were explored in the project signified a departure from conventional strategies by developing processes that disrupt the metabolic pathways and nutrient cycles that underpin the formation and perpetuation of hyacinth colonies. This entailed a comprehensive understanding of the biochemistry of the hyacinth plant and the strategic targeting of nutrients responsible for triggering hyacinth blooms. To this end, engineered processes were tested and piloted for harvesting and processing hyacinth biomass to generate biodiesel or biogas. This presented a sustainable and environmentally friendly solution to an increasingly complex problem.

THE WAY FORWARD

Following the successful completion of the project, the researchers from the University of Pretoria, the Technological Institute of Monterrey and the University of Leeds joined researchers from the University of Venda and the Technical University of Malaysia to participate in further collaborative opportunities.

This includes the submission of co-authored articles to international journals such as *Freshwater Biology, Water Environment Research* and *Water Science and Technology*.

An application for funding from the Water4All European Partnership, co-funded by the European Union, has resulted in a collaborative project with the University of Manchester (UK) for a period of two years.

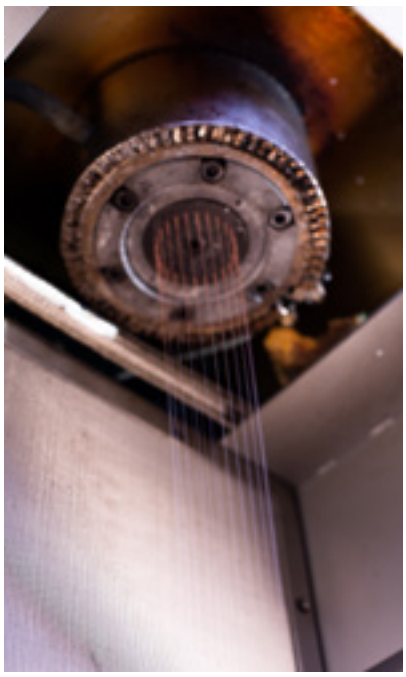
Similar applications have been submitted to the WaterNet regional network of universities, and research and training institutes that specialise in water. The University of Pretoria's researchers in the Department of Chemical Engineering's Water Utilisation Division are also furthering their research as part of the Africa University Twinning Programme of the National Research Foundation (NRF)'s Research, Innovation, Impact, Support and Advancement (RISA) division.

It is furthermore envisaged that the water hyacinth volarisation unit, developed in the Department of Chemical Engineering for the digestion or co-digestion of harvested water hyacinth to produce biodiesel or biogas, will lead to the development of a patentable biomass-energy reclamation unit to utilise water hyacinth as feedstock. It is anticipated that the digester that is being tested at Roodeplaat Dam will be able to be used on other feedstocks as well. The research and development underlying this innovation is currently being conducted in collaboration with the Makerere University and the University of Technology Sydney. Researchers from these institutions are keen to further explore the potential of water hyacinth with a view to creating granular-activated carbon that can be used as a source of energy for a water desalination system.

What started off as the quest for a solution to a water utilisation problem therefore has the potential to not only address localised problems associated with water security and public health, but to resolve the world's energy security problems by meeting the global need for cleaner energy production.

Innovator finds new applications for long-lasting insecticide treatments

Dr Mthokozisi Sibanda, a former member of the University of Pretoria (UP)'s Institute of Applied Materials (IAM), has gained recognition for an invention that reduces the evaporation of expensive insect repellents. This invention, which emanated from research conducted in the Faculty of Engineering, Built Environment and Information Technology, was subsequently licensed. This led to the development of a spin-off biotechnology company of UP, known as African Applied Chemical (AAC).



This innovation led to the manufacture of an insect-repellent mosquito net and insect-repellent hiking socks. Its latest application is the development of an innovative anti-bedbug mattress cover, which is being marketed as NoBugs Nobites™. The effectiveness of the product has undergone independent evaluation by Clinvet International, a global veterinary contract research organisation.

The evaluation entailed the testing of both untreated textile samples and samples that had been treated with the product. The samples that had been treated with the product were divided into several groups prior to testing, including those that were not washed after treatment, those that were washed 10 times after treatment, and those that were washed 20 times after treatment. All the samples were exposed to the common bedbug, *Cimex lectularius*, for 240 minutes before testing. After initial exposure, the insect was removed from the treated and untreated material, and knock-down (alive, but paralysed) was recorded at various time intervals, ranging from five minutes to four hours.

Five minutes after exposure, the treated nets that had been washed 10 times produced the highest knock-down. After 60 minutes of initial exposure, the samples that had not been washed after application of the product achieved 100% knock-down. The samples that had been washed 20 times after application of the product achieved 100% knock-down after 120 minutes. After 24 hours of initial exposure, the samples that had not been washed after application of the product recorded 85% of dead bedbugs, while the samples that had been washed 20 times after application of the product recorded 72% of dead bedbugs. All remaining bedbugs were still in a knock-down state and never recovered. None of the untreated samples induced more than 10% mortality.

Dr Sibanda describes bedbugs as a persistent nuisance pest of humans. They also opportunistically feed on other mammals, including household pets. "Bedbugs do not remain on the host, but only feed at night. They live in shelters such as bedding when not feeding."

THE INNOVATIVE TECHNOLOGY USED TO MANUFACTURE THIS NEW PRODUCT ALLOWS FOR THE INFUSION OF A PIPERONYL BUTOXIDE ACTIVE THAT DEACTIVATES ANY ABILITY OF THE BEDBUGS TO RESIST INSECTICIDAL ACTION. THE INNOVATIVE NOBUGS NOBITES™ ANTI-BEDBUG MATTRESS COVER IS DESIGNED TO BE EFFECTIVE, EVEN ON INSECTICIDE-RESISTANT BEDBUGS.

Dr Mthokozisi Sibanda exemplifies EBIT's aim to take research out of the laboratory and into the lives of real people.

This has led to insecticide treatment being ineffective and the development of insecticide resistance, as contact with insecticides is limited or chemical control is applied when the bedbugs are not present on the host. The chemical control of bedbug populations should therefore be focused on treating the bedbug's environment to ensure sufficient contact with the insecticide treatment.

Beta cyfluthrin, an active ingredient of the product's formulation, which is infused into the fibre of the mattress cover, is a contact insecticide that is released by the mattress cover over an extended period of time, says Dr Sibanda.

Commenting on the results of the experimental evaluation of the product, Dr Sibanda explains that it is important to note that, in a knock-down state, the bedbugs are in a comatose state and cannot actively feed on their victims. "In real-life conditions of application, the knocked down bedbugs will be continuously exposed to the treated material instead of for only 240 minutes as in the laboratory test, and will all die in less than a day." This result proves that the insecticide-infused mattress covers can be washed at least 20 times before they lose their effectiveness.

He stresses that the innovative technology used to manufacture this product allows for the infusion of a piperonyl butoxide active that deactivates any ability of the bedbugs to resist insecticidal action. "The innovative NoBugs Nobites™ anti-bedbug mattress cover is designed to be effective, even on insecticide-resistant bedbugs."

Contributing to social and economic development through impactful research

The research conducted in the four schools of the Faculty of Engineering, Built Environment and Information Technology (Engineering, Built Environment, Information Technology and the Graduate School of Technology Management) strives to achieve a knowledge-based economy by putting the University of Pretoria at the forefront of knowledge.

EBIT AIMS TO BE A LEADING RESEARCH-INTENSIVE ENTITY; MAKING GROUNDBREAKING DISCOVERIES, WHILE SEEKING AND TRANSMITTING KNOWLEDGE AND NEW UNDERSTANDING IN ITS OWN RIGHT, AND TO THE BENEFIT OF SOCIETY.

The Faculty's research is concentrated on five research focus areas, as well as the Fourth Industrial Revolution, that can bridge the gap between addressing our current realities and aspiring to a better future. The case studies illustrated through the selection of articles contained in the following pages display the Faculty's researchers' commitment to turning threats into opportunities, and introducing society to innovations, and disruptive ideas and technologies.

SMART CITIES AND TRANSPORTATION

Research efforts that serve to revive South Africa's cities and facilitate a better life for its citizens have been inspired by a desire to achieve smart urban and public spaces.

Investigations in the Department of Industrial and Systems Engineering have focused on the electrification of an urban delivery fleet. In the Department of Architecture, researchers are examining how global temperature increases are impacting on urban communities, and how solutions need to be sought to lower exposure to heat stress in our cities and improve the health and wellbeing of our urban residents. The Department of Town and Regional Planning has focused on the regenerative potential of public spaces to support enhanced urban development.

The Department of Construction Management examined South African trends related to the cost and business case of green building. Collaboration between the Department of Engineering and Technology Management, the Department of Civil Engineering and the Department of Architecture, through the York Timbers Chair in Wood Structural Engineering, is contributing to the stimulation of a sustainable mass engineered timber construction industry in South Africa.

BIG DATA SCIENCE, INFORMATION AND COMMUNICATION TECHNOLOGY, AND TECHNOLOGY INNOVATION MANAGEMENT

Research efforts that serve to harness innovation, secure growth and sustainability, and introduce new products have been inspired by a desire to continue to make disruptive advances in technology and innovation management.

Research in the Department of Electrical, Electronic and Computer Engineering is making use of deep learning techniques to support farmers and wildlife managers in the identification of crocodiles from

aerial images. In the Department of Computer Science, researchers are ensuring that African languages are becoming more representative in natural language processing (NLP) models. In other studies in the Department of Computer Science, research by members of the Nature-inspired Computing Optimisation Research Group are creating new techniques, and are extending existing Artificial Intelligence (AI) techniques to bring about innovation in industry, health and wellbeing, lifelong learning and renewable energy. Some of their research projects have contributed to the automated diagnosis of various diseases, including COVID-19, diabetes, heart disease and depression. In the field of technology and innovation management, researchers are examining the future shaping drivers and the role of technology foresight.

WATER AND ENVIRONMENTAL ENGINEERING

Research efforts focused on the management of South Africa's water quality and wastewater treatment have been inspired by a desire to improve the quality of life of all South Africans, and to improve their health and wellbeing.

Researchers in the Department of Civil Engineering are engaged in various studies related to water resources engineering. These topics include the integration of hydropower development into existing water infrastructure, exploring pumped storage scheme opportunities in South Africa, determining the biological stability of water in community reservoirs, and optimising pier structures to prevent the blockage and flooding of bridges and culverts. Another project in the Department of Civil Engineering has led to the invention of a passive leak detection method that makes use of fibre optic cables to prevent water loss.

This has the potential to benefit thousands of local residents. In the Department of Chemical Engineering, researchers in the Environmental Engineering Division are making use of plasma technology for the treatment and purification of wastewater. Postgraduate research in Chemical Engineering is also considering issues such as reducing pollution from industrial effluents, improving water quality in Africa through an innovative solution for industrial wastewater treatment, and eliminating lead contamination in industrial wastewater.

ENERGY

Research efforts on efficient energy systems, renewable energy and the efficient utilisation of energy by end-users have been inspired by the need to provide energy to all the citizens of South Africa to support quality of life.

Researchers in the Department of Mechanical and Aeronautical Engineering are developing a system to generate electricity by using a mobile solar-dish gas turbine hybrid. In the Department of Chemical Engineering, researchers are developing a sustainable solution to the problem of the proliferation of invasive species in the country's water bodies by converting the carbon biomass of the water hyacinth into green energy. In the Department of Materials Science and Metallurgical Engineering, researchers are investigating the possibility of repurposing existing steel pipelines for green hydrogen, as well as the possibility of using alternative methods of steelmaking to achieve lower carbon emissions. Research in the Department of Engineering and Technology Management is considering the decarbonisation of the global economy with green hydrogen, as well as the development of investment planning models for wind and solar fleets, and the commercialisation potential of bio-based chemicals from waste to be used in transport fuel, and as a feedstock for power generation.

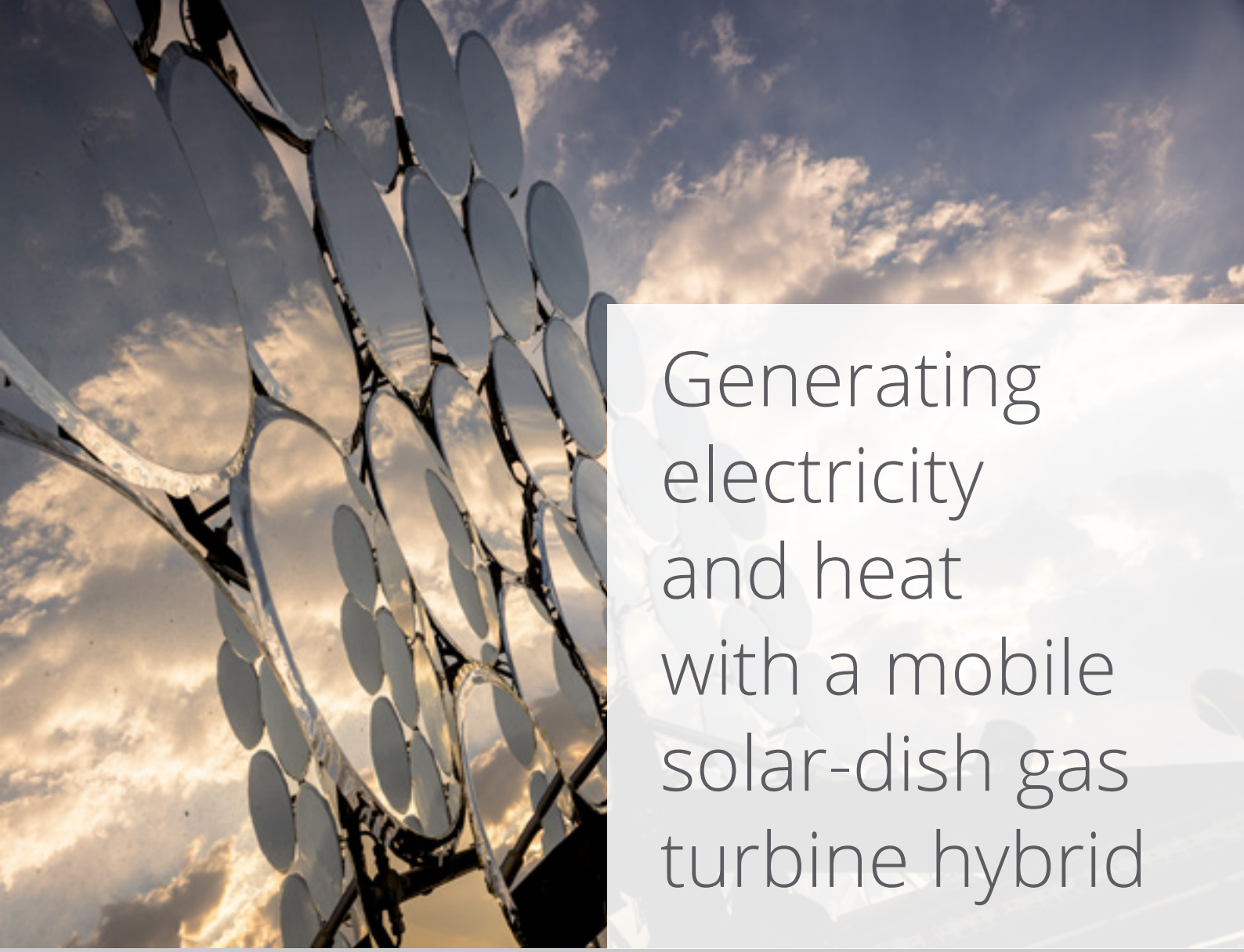
MINERALS AND MATERIALS BENEFICIATION

Research efforts that promote minerals beneficiation have been inspired by a desire to find new ways to source valuable minerals from previously unexploited sources.

Researchers in the Department of Chemical Engineering are investigating the recovery of rare earth elements (REEs) and uranium from mined phosphate ore. In the Department of Materials Science and Metallurgical Engineering, researchers are devising environmentally friendly alternatives to materials produced in the refractory industry. They are also investigating ways of extracting minerals from fine particles to increase minerals beneficiation, developing a system to monitor and track particles in a slurry, and exploring ways to increase beneficiation and improve the purity of platinum and other minerals.

In the Department of Mining Engineering, researchers are finding homegrown solutions for South Africa's unique challenges in the mining industry, with a particular emphasis on mechanisation and automation, and the development of techniques to simulate the rock mass behaviour in South Africa's deep-level gold mines.

RESEARCH IN THE FACULTY IS FOCUSED ON IMPACTING GLOBAL CHALLENGES



Generating electricity and heat with a mobile solar-dish gas turbine hybrid

South Africa receives an average of over 2 500 hours of sunlight a year, placing it among the countries with the most potential for solar electricity and heat generation in the world. Several innovative means of power generation have been developed that tap into the sun's abundant energy using concentrated solar power systems. These systems redirect the sun's rays towards a focal point to enable thermal energy capture.

A research team in the Department of Mechanical and Aeronautical Engineering, led by Prof Willem le Roux, has developed a mobile solar-dish gas turbine hybrid using a micro gas turbine for small-scale power and heat generation. The effectiveness of this method of power and heat generation relates to the turbine's high inlet temperature and low emissions. Mobile energy systems can provide access to electricity and heat where grid access is limited, especially in rural areas. A prototype is therefore being developed for testing and in an operational environment. Once it has been rolled out, it can be transported to rural areas when the need for electricity and heat arises.

Prof Le Roux explains that micro turbines are versatile, as they can operate on various fuels, from diesel to natural gas or liquid petroleum gas (LPG). They can have a low noise output and are relatively vibration-free. The turbine and compressor are usually attached to a single shaft through a single-stage, radial flow application. Micro turbines can also utilise solar thermal energy in a hybrid configuration and its high-temperature exhaust can be used for co-generation. "A solar dish can supplement or replace the heat added by the fuel to further reduce the micro turbine's emissions," he says.

The hybrid gas turbine configuration that was developed has the advantage of being able to generate electricity and heat using concentrated solar energy and LPG as energy sources. Electricity is generated from the output shaft of the micro turbine, while high-

temperature exhaust gases are used for metal melting (or recycling) and water heating purposes.

"Small-scale co-generation concentrated solar power (CSP) plants can be compact," says Prof Le Roux, "and can improve accessibility to heat and power in off-grid rural environments." A hybrid solar-dish Brayton cycle combines heat and power generation, where heat is sourced from combustion, as well as through the focal point (the cavity receiver) of a solar dish, while high-temperature exhaust gases and electricity are acquired from the micro turbine. "A Brayton cycle is a power conversion cycle that uses a gas as the working fluid for compression and heating and, finally, expansion through a turbine to generate power," he explains.

A HYBRID SOLAR-DISH BRAYTON CYCLE COMBINES HEAT AND POWER GENERATION, WHERE HEAT IS SOURCED THROUGH THE FOCAL POINT (THE CAVITY RECEIVER) OF A SOLAR DISH, WHILE EXHAUST GASES AND ELECTRICITY ARE ACQUIRED FROM THE MICRO TURBINE.

The initial testing of such a system was done on the roof of the University of Pretoria's Engineering II Building, using a state-of-the-art solar dish with multiple facets. The solar dish has a 21 m^2 reflective surface area. The dish concentrates the sunlight into an aperture of 0.25 × 0.25 m, upon which a coiled pipe receiver is mounted.

The 42 individual elliptical vacuum-membrane solar-dish facets each have a variable focal length, depending on the membrane depth. Membrane displacement was previously identified as a significant challenge affecting system performance throughout an operating day due to changing environmental conditions, especially ambient temperature. In response to this challenge, the research team implemented a cost-effective focus control system that is characterised by its low power consumption. This was mounted to the 42 facets to maintain the membrane depth to within ±2 mm to achieve a theoretical minimum intercept factor of 90%.

The system's effectiveness was further enhanced by employing a manual alignment method using a laser pointer mounted on a movable guide arm, which enabled the precise alignment of each facet at night. This method allowed for the accurate alignment of the 42 facets, ensuring that the reflected solar radiation would be directed to the receiver aperture.

An initial full-moon validation test demonstrated that these focus control and alignment methods will assist in achieving a higher intercept factor compared to previous setups, with minimal light spillage outside the receiver aperture. This focus control system and alignment calibration can significantly improve the performance and efficiency of small-scale CSP systems by maintaining accurate focal lengths and enhancing solar radiation concentration.

Further on-sun testing is currently ongoing and it is expected that the current solar dish can reduce the fuel consumption of the micro turbine by between 13 and 33%. The setup being tested by the research team makes use of an unrecuperated single-shaft micro gas turbine, which runs on the combustion of LPG and concentrated heat from the solar dish.

The hybrid solar-dish Brayton cycle makes use of the micro turbine's compressor to compress and direct air through the cycle. The solar dish concentrates solar energy onto the cavity receiver to preheat the air. Once heated, the air is mixed with LPG and fed into the combustion chamber for ignition. Expansion of the air occurs after combustion and enables rotation of the micro turbine connected to a generator for electrical power generation. The high-temperature exhaust gases from the micro turbine can be captured to melt and recycle materials, while heating water in a custom-designed pipe-in-pipe heat exchanger. The micro turbine is expected to produce 1 to 3 kW of electrical power, while the whole system is expected to generate 40 to 60 kW of process heat. During the initial testing of this state-of-the-art micro gas turbine with an air bearing, experimental results showed that it can produce up to 1 480 W of electricity when operated at a turbine inlet temperature of 1 088 K. The turbine reached speeds of up to 138 000 rpm.

A mobile system has been developed for demonstrations outside of campus. It comprises a parabolic reflector dish, a cavity receiver, a micro turbine, a heat exchanger, supporting steel structures and a custom-built trailer. The control system can lower the solar dish into a stow position to protect the dish from the elements. Due to geometric constraints and legislation restrictions, the system is disassembled and transported in sections. Subsequently, the system will be erected on a mobile platform (also the trailer) at the demonstration site. Once erected, an automated control system will enable the solar dish to follow the sun's path to ensure optimal usage of the available solar energy.

Key measurable metrics obtained during testing and demonstrations include electrical power generated from the micro turbine, the amount of materials melted for recycling purposes, and the water heating rate.

The research team at the solar-dish gas turbine setup funded by the Renewable Energy Hub and Spokes Programme of the Department of Science and Innovation (DSI) (from left): Dr Dirk van Vuuren, Caitlin Cockcroft, Tlou Mokobodi, Henno de Beer, Prof Willem le Roux, Erwin Marula, Zwivhuya Muofhe and Evan Humphries.

Various temperatures and pressures are also measured to aid in calculating these parameters. Once successfully demonstrated in a rural community, a route-to-market plan will be created for commercialisation purposes, including identifying the target market, reassessing user requirements, cost implications, marketing strategies and mass-production strategies.

A reduction in the cost of micro turbines could help hybrid solar-dish Brayton cycles access more target markets and improve repayment periods. The use of off-the-shelf automotive turbochargers is one way to reduce the cost of micro turbines. Turbochargers have been used extensively in the automotive industry to enhance the performance of an internal combustion engine. This means that their production has already been streamlined, so they are commonly available. While an automotive turbocharger might not be as efficient as a commercial micro turbine in generating shaft power, it is readily available and relatively cheap. "This may be an attractive solution in combination with a solar dish in industries that require large amounts of heat, such as smelters, bakeries, small businesses or apartment blocks," says Prof Le Roux.

Integration of hydropower development into existing water infrastructure

Prof Marco van Dijk and Dr Louis Coetzee

Hydropower is pivotal in the water-energy nexus to facilitate the clean energy transition. As a renewable energy source, hydropower contributes to decarbonising the energy sector, while supporting water management objectives. By integrating hydropower generation into existing water infrastructure, synergies can be leveraged to optimise resource utilisation and enhance system resilience. However, the complex interaction between water availability and energy production necessitates careful planning and adaptive strategies to mitigate risks associated with climate variability and changing demand patterns. Harnessing the potential of hydropower from existing water infrastructure systems therefore provides an opportunity to advance sustainability goals and ensure the viability of clean energy transitions.

South Africa faces a unique challenge in balancing its energy demands with sustainable development and environmental stewardship. The integration of hydropower development with existing water infrastructure represents a fundamental strategy to achieve a just energy transition, ensuring sustainable energy generation, while optimising water resource utilisation. This approach leverages the synergy between the energy and water sectors to address energy security, climate change and socio-economic development.

South Africa's heavy reliance on coal for approximately 80% of its electricity generation contributes significantly to greenhouse gas emissions, making the transition to renewable energy sources a pressing need. At the same time, the country's water-stressed condition, with uneven water resource distribution and frequent droughts, impacts various sectors. The integration of hydropower with existing water infrastructure offers a practical and relevant solution to these challenges.

Hydropower, as a renewable energy source, is a key player in diversifying South Africa's energy mix. It offers reliable, flexible and low-carbon electricity. Small hydropower and pumped storage schemes are particularly relevant in this context. Small hydropower can be integrated into existing water infrastructure by retrofitting non-hydropower dams and weirs, and exploring unconventional hydropower avenues such as conduit hydropower and turbine installations at wastewater treatment works (WWTW) outlets and drinking water systems.

South Africa's extensive water infrastructure, including dams, reservoirs and irrigation systems, presents significant opportunities for hydropower development. Good examples of potential hydropower that could be integrated into existing infrastructure are where excess pressure exists in a pipeline and can be converted into hydro-electric power. As considerable energy consumption is associated with urban water supply systems, which represent approximately 7% of the world's energy demands, a portion can, in some cases, be recovered. Numerous studies have identified possible locations within existing water supply and distribution systems for energy recovery. A study by the Oak Ridge National Laboratory (ORNL) in Tennessee, USA, estimated a total of 1.41 GW of new conduit hydropower potential across the United States.

South Africa has over 4 450 dams (of which 1 269 are classified as large dams with a wall height of 30 m or more). Many of these dams were constructed primarily for water supply, irrigation and flood control. Integrating hydropower into these structures and utilising the existing flows (ecological reserve or irrigation releases) can optimise water resource utilisation, enhance infrastructure value and provide additional revenue streams.

The International Committee on Large Dams has indicated that only 20% of the world's large dams are used for hydro-electric power generation. This provides ample opportunities for hydropower development.

Only 3% of the approximately 80 000 dams in the USA are equipped to generate power. Most are used for flood control, municipal drinking water, navigation, recreation and irrigation. In 2012, an ORNL study estimated that non-powered dams in the USA can generate up to 12 GW of electricity, which is enough to power 4.8 million homes.

An extremely positive development in South Africa is the Department of Water and Sanitation (DWS)'s request for the submission of water use licence applications, where developers can utilise DWS's water infrastructure to retrofit turbines and generate hydro-electricity.

Energy recovery at WWTWs is often overlooked, with a very limited number of WWTW pilot plants having been developed. An article published in *Renewable and Sustainable Energy Reviews* (Bekker et al., 2022), reported on a study to identify and review opportunities at WWTW, which resulted in the compilation of a framework for South Africa to evaluate these opportunities. Electricity generated at WWTW outlets can be directly utilised in the WWTW, offsetting some of the operational costs associated with the water treatment process.

Integrating hydropower with existing water infrastructure aligns with sustainable energy-generation principles. Hydropower projects have low operational emissions and can be designed to minimise environmental impacts. Utilising existing infrastructure reduces the need for new construction, which can be resource-intensive and disruptive to ecosystems. Additionally, small-scale and distributed hydropower projects can bring clean energy to remote and underserved areas, supporting local development.

By generating electricity from water flows that are already being managed for other purposes, hydropower projects can contribute to more efficient water use. This is particularly important in a water-scarce country like South Africa. The integration of hydropower with existing water infrastructure can deliver significant socio-economic benefits. These include job creation, skills development and economic opportunities in rural and marginalised communities. Local hydropower projects can stimulate economic activity, improve energy access and alleviate poverty.

A supportive policy and regulatory framework are essential for integrating hydropower into existing water infrastructure. South Africa's energy and water policies must be aligned to facilitate the development of multipurpose projects. Incentives, such as feed-in tariffs, grants and tax benefits, can encourage investment in hydropower. Advancements in hydropower technology can further enhance the feasibility and efficiency of integrating hydropower into existing water infrastructure.

Innovations such as modular hydropower systems, low-head turbines and advanced control systems can enable more flexible and cost-effective projects. Research and development efforts, such as those conducted by the Hydropower Research Group in the University of Pretoria's Department of Civil Engineering, focus on technologies that are suitable for South Africa's unique environmental and infrastructural conditions.

Integrating hydropower development into existing water infrastructure is a fundamental strategy for South Africa's just energy transition. It offers a sustainable pathway to enhance energy security, reduce greenhouse gas emissions and optimise water resource utilisation. By leveraging existing infrastructure, South Africa can minimise the environmental impacts and maximise socio-economic benefits. This approach requires supportive policies, technological innovations and active community involvement to succeed.

Potential to retrofit the Vaal Dam outlet works and generate a baseload energy of 4.4 MW.

INTEGRATING HYDROPOWER DEVELOPMENT INTO EXISTING WATER INFRASTRUCTURE IS A FUNDAMENTAL STRATEGY FOR SOUTH AFRICA'S JUST ENERGY TRANSITION.

Further reading

Bekker, A., Van Dijk, M. and Niebuhr, C.M. 2022. A review of low head hydropower at wastewater treatment works and development of an evaluation framework for South Africa. Renewable and Sustainable Energy Reviews 159: 112216. Available at: https://doi.org/10.1016/j.rser.2022.112216.

Oak Ridge National Laboratory 2022. An assessment of hydropower potential at national conduits. Report No. ORNL/TM-2022/2431. Available at: https://doi.org/10.2172/1890335.

Oak Ridge National Laboratory 2022. Non-powered dam retrofit exemplary design for hydropower applications. Report No. ORNL/TM-2021/2232. Available at: https://doi.org/10.2172/1869108.

Van Dijk, M., Hansen, C.D., Bekker, A. and Mahamba, N.N. 2022. The South African Hydropower Atlas. WRC Report No 288/3/22. Pretoria: Water Research Commission.

Van Vuuren, S.J., Blersch, C.L. and Van Dijk, M. 2011. Modelling the feasibility of retrofitting hydropower to existing South African dams. Water SA 37(5): 679–692.

Pumped storage scheme opportunities in South Africa

Prof Marco van Dijk and Dr Louis Coetzee

Pumped storage schemes represent a pivotal component in the realm of energy storage and grid stability. South Africa, with its diverse topography and growing energy needs, holds significant potential for the development and expansion of these schemes.

HYDROPOWER, AS A RENEWABLE ENERGY SOURCE, IS A KEY PLAYER IN DIVERSIFYING SOUTH AFRICA'S ENERGY MIX.

South Africa's energy sector relies heavily on coal, which accounts for approximately 80% of its electricity generation. The world is moving towards a more sustainable energy future by evolving the energy market to include more variable renewable generation. This is a way of responding to the increasing energy requirements due to increasing population growth and industrialisation.

South Africa is undergoing a significant transition towards renewable energy sources, driven by the need to reduce carbon emissions and enhance energy security. In this context, pumped storage schemes offer a viable solution to balance supply and demand, integrate renewable energy sources and provide ancillary services to the grid.

South Africa already has four major pumped storage schemes: the Drakensberg, Palmiet, Ingula and Steenbras schemes. These facilities play a crucial role in stabilising the grid by storing excess energy during low-demand periods and releasing it during peak-demand periods.

Despite these existing projects, there remains substantial untapped potential for additional schemes nationwide.

South Africa's varied topography presents numerous opportunities for the development of new pumped storage schemes. Key regions with high potential include the hilly areas of the Eastern Cape and the mountainous regions of KwaZulu-Natal. Existing water infrastructure in the Eastern Cape areas offers several suitable sites for the development of pumped storage schemes.

The potential for wind and solar energy in these areas also makes them ideal for integrating renewable sources with pumped storage schemes. The significant rainfall that occurs in the mountainous regions of KwaZulu-Natal gives rise to multiple sites that could be explored for pumped storage schemes. The proximity of some potential sites to major urban centres has the advantage of reducing transmission losses. Mpumalanga is another key region.

Its numerous coal mines and power stations make it strategically important for South Africa's energy sector. The introduction of pumped storage schemes in this province could facilitate the transition from coal to renewable energy sources.

The Hydropower Research Group in the University of Pretoria's Department of Civil Engineering collaborated with the Geoinformatics division in the University's Department of Geography, Geoinformatics and Meteorology to develop a web-based geographical information systems (GIS) hydro-power atlas for South Africa.

The South African Hydropower Atlas (SAHA) was developed to identify suitable potential sites for various types of hydropower across South Africa and was created using ArcGIS Online. One of the layers provided theoretically identified pumped storage scheme locations.

THE MOST VIABLE SOLUTIONS WOULD BE WHERE EXISTING WATER INFRASTRUCTURE COULD BE UTILISED.

Due to its large capital costs and geographical constraints, hydropower generation needs to consider technical, legislative, environmental, social and economic aspects to make recommendations for the viability of sites prior to the project feasibility phase.

Crucial requirements for a pumped storage scheme include the available head, volumetric flow rate over the turbine, horizontal distance between upper and lower reservoirs, volume capacity of the reservoirs and minimum power capacity that needs to be generated.

The costs for a pumped storage scheme include the civil infrastructure, electromechanical equipment, legislative licensing requirements, environmental mitigation costs, electrical connection and integration into the grid, and ultimately the operations and maintenance costs.

Pumped storage schemes offer several economic and environmental benefits that make them attractive investments. Pumped storage schemes can rapidly respond to fluctuations in energy demand, providing essential services, such as frequency regulation and load balancing. This enhances the reliability of the electricity grid and reduces the risk of blackouts.

By storing excess energy generated from renewable sources like wind and solar, pumped storage schemes can mitigate the intermittency issues associated with these technologies. This facilitates a higher penetration of renewables in the energy mix.

The construction and operation of pumped storage schemes can create jobs and stimulate local economies. Additionally, the long lifespan of these projects ensures sustained economic benefits over several decades.

Compared to fossil fuel-based power generation, pumped storage schemes have a relatively low environmental impact. They produce no direct emissions and can be designed to minimise ecological disruption.

Despite the promising opportunities, there are several challenges and considerations associated with the development of pumped storage schemes in South Africa. These include the high initial investment required and the regulatory requirements. While pumped storage schemes have a lower environmental impact than fossil fuels, they can still affect local ecosystems and communities.

Studies are currently underway to develop a multidisciplinary tool to evaluate the viability of the pumped storage scheme sites, and to prioritise and classify these.

South African Hydropower Atlas – opportunities for pumped storage schemes in southern Africa.

The most viable solutions would be where existing water infrastructure could be utilised. It was exciting news when the Department of Water and Sanitation (DWS) requested the submission of water use licence applications for pumped storage generation using its impoundments. As pumped storage schemes rely on the availability of water, which can be a limiting factor in regions prone to drought, utilising existing dams could provide a sustainable water supply, which is essential for the long-term operation of these schemes.

The future of pumped storage schemes in South Africa looks promising, with several potential projects under consideration. The government's commitment to expanding renewable energy capacity and improving grid stability provides a condusive environment for the growth of pumped storage schemes.

As South Africa ramps up its renewable energy capacity, the role of pumped storage schemes in balancing the grid will become increasingly important. The integration of pumped storage schemes with wind and solar farms can provide a holistic solution to energy storage and grid management.

Innovations in turbine technology, materials science and energy management systems can further enhance the efficiency and reduce the costs of pumped storage schemes. In a continental-scale assessment of micro-pumped hydro energy storage using agricultural reservoirs (Gilmore et al., 2023), research suggests that Australia's agricultural water reservoirs could be an innovative energy storage solution for variable renewables. From Australia's 1.7 million farm dams, 30 295 promising pumped hydro sites were identified in dam-to-dam and dam-to-river reservoir configurations. This highlights the fact that the application could be implemented on smaller installations as well.

As global efforts to combat climate change intensify, the role of energy storage in reducing greenhouse gas emissions will gain prominence. Pumped storage schemes, with their low carbon footprint, will be integral to South Africa's climate strategy. Pumped storage schemes therefore hold significant promise for South Africa's energy future. By providing grid stability, enabling renewable energy integration, and offering economic and environmental benefits, these projects can play a crucial role in the country's energy transition.

Further reading

Gilmore, N., Britz, T., Maartensson, E., Orbegoso-Jordan, C., Schroder, S. and Malerba, M. 2023. Continental-scale assessment of micro-pumped hydro energy storage using agricultural reservoirs. Applied Energy 349: 121715. Available at: https://doi.org/10.1016/j.apenergy.2023.121715.

Determining the biological stability of water in community reservoirs

Researchers in the University of Pretoria's Department of Biochemistry, Genetics and Microbiology recently collaborated with researchers in the Department of Civil Engineering's water resources engineering focus area to monitor and characterise the biological stability of water in reservoirs that store drinking water for distribution to the community.

This was one of several projects related to water quality to tackle the global challenge of sustainable water management and the availability of clean water for future generations. It was supported by the South African Water Research Commission, and led by Prof Fanus Venter of the Department of Biochemistry, Genetics and Microbiology.

Dr Ione Loots, a member of the research team, explains that community reservoirs form an integral part of the water distribution network. They can be regarded as storage reservoirs that maintain the balance between supply and demand in a distribution system. However, as the water in these reservoirs ages, the quality of the water can become questionable. Bacterial regrowth can take place, which impacts the quality of the water distributed for human consumption.

"Stagnation within these reservoirs could occur due to long residence times, sub-optimal flow dynamics and intermittent water demand," says Dr Loots. Stagnation is often associated with disinfectant decay, which results in an increase in bacteria. Prof Venter explains: "These conditions often occur during the warmer summer months or during periods of water restrictions, when a rapid deterioration in microbial quality could put entire communities at risk."

Water utilities use various treatment strategies to ensure that the water distributed to reservoirs will not pose a significant health risk to consumers. Water leaving a treatment plant is typically of a high quality, but conditions within the distribution system can cause the quality of the water to deteriorate. Maintaining the biological stability of drinking water is one of the major challenges facing water utilities and local authorities in their endeavours to supply safe drinking water to communities.

Most water utilities in South Africa use the heterotrophic plate count (HPC) method to monitor the general microbial quality of treated drinking water and to assess the biostability within the distribution network. Other methods include flow cytometry and adenosine triphosphate (ATP) measurements. The research conducted, however, demonstrated flow cytometry to be superior to HPC to monitor the quality of drinking water. Flow cytometry has been shown to be fast, accurate and reproducible, and can even be automated. It is therefore a very promising method for the direct assessment of changes in drinking water networks' microbial quality.

The major difficulty encountered by researchers when implementing a direct assessment approach, such as flow cytometry, within the water distribution environment, is that there are no clear guidelines as to what constitutes a significant or relevant change in the microbial community. Flow cytometry counts are found to vary between different systems (chlorinated and chloraminated) and deviations or abnormal changes can only be detected once a proper baseline for the various cell count values has been established for each system.

PHASE 1

In the first phase, the value of flow cytometry was investigated as a process indicator when managing water distribution networks. The objective was to provide the necessary foundation to develop a strategy for the drinking water industry to incorporate flow cytometry and community profiling into its processes when monitoring and managing the biostability of drinking water during distribution, as this is a more sensitive and faster approach compared to the currently used HPC method.

To investigate the value of flow cytometry as a process indicator when managing water distribution networks, multiple trial runs were conducted to determine the best concentration and volumes of stains used to obtain the various cell count concentrations, as well as the selection of successive subpopulations of cells to be used for the flow cytometry analysis. The controls to be included were confirmed and a final procedure established, which was used throughout the study.

The flow cytometry results confirmed the presence of a large quantity of bacteria in the samples analysed. They revealed flow cytometry to be a reliable process indicator that could provide additional information at each sample point. However, the results were site-specific. Flow cytometry can also rapidly detect significant changes or clear trends linked to these bacterial communities.

To test this in the field, researchers collected samples from a large distribution network at six different sampling locations on a bi-weekly basis over a period of eight months. For reticulation samples (point of use), they collected water from different residential locations in the network. The analyses included culturing, an approach that industry has used for many years, which was compared with more recent tools such as flow cytometry and community profiling based on next-generation sequencing. The results clearly demonstrated that newer technologies have developed to such a level that they can now easily be incorporated into microbial drinking water quality studies. The costs associated with sequencing-based techniques have decreased to a level where they can be considered for more routine use.

PHASE 2

In the second phase, researchers sought to understand how the flow regimes and microbial ecology of community reservoirs could assist in the development of guidelines for the operation of these systems. It entailed characterising the microbial samples obtained in the first phase of the project using flow cytometry to compare them to the bacteria isolated using the HPC method.

Permission was obtained from two of the local municipalities in Gauteng to include one of their community reservoirs in the study. The first reservoir was situated in an area known to experience water quality problems. Water leaving the purification plant was typically of an acceptable quality, but by the time it reached the consumer, the water quality had deteriorated. This reservoir was sampled over several months to determine the interplay between the reservoir's design and its flow patterns on the microbial quality of the water in the reservoir.

The research team collected measurements such as flow, temperature and water levels within the reservoir as input to create a model of the flow patterns within the reservoir using computational fluid dynamics (CFD). This information was used to identify possible stagnation zones in the reservoir. This data served as input for the location of sampling points within the reservoir. To ensure that sufficient biological material was collected, all the samples were concentrated with membrane filtration. This was followed by DNA extraction from each sample, which was used for gene profiling and metagenomic studies.

Sampling was also done at the second community reservoir to determine the effect of residence time on the microbial water community in the reservoir. This reservoir received treated drinking water from a large water treatment works facility. After the reservoir had been filled, the inlet to the reservoir was closed and not refilled until the level of the reservoir had dropped to 35%. This was done to allow for the longest possible residence time in the system. Sampling was conducted over a week-long period, and samples were processed and analysed.

The gene profiling results showed that the bacterial diversity in the reservoirs was high in all the samples. The bacterial communities in the samples were rather unique and the abundance of specific species varied. Different parameters could be responsible for the differences in the bacterial diversity across the various sampling points. "When one looks at each sampling location," Prof Venter explains, "one would expect the bacterial community present to be fairly consistent."

However, a temporal influence played a role in the variation in the observed diversity. "No dominant bacterial community was observed in any of the samples in which the flow cytometry count deviated from the norm."

The first reservoir was also analysed to determine the impact of the autotrophic bacteria on the biological stability in the distribution system, and to establish the functional role of these bacteria in the ecosystem. An assessment of this reservoir's design showed that, depending on the fill-draw cycle, regions of stagnation could be predicted.

The researchers found that a late fill-draw cycle could have a larger stagnation zone directly opposite the inlet on the other side of the reservoir. "The microbial population based on gene profiling looked very similar at all points and different depths throughout the reservoir, indicating the presence of a homogenous bacterial community," says Prof Venter. "The microbial functionality of the bacteria present in the reservoir, which was found to remain constant, revealed microbial stability and functional redundancy." The second reservoir's bacterial community also appeared to be similar, regardless of the time of day the samples were taken. This implied that retention time (tested for up to three days) did not influence the composition of the bacterial community. The dominant bacteria that were seen at all the sample points are common in many drinking water systems.

Prof Venter explains that the vast amount of information collected when applying molecular approaches provides a detailed view of the microbial community. When compared with samples taken at other time or sampling points, this data could be used to investigate the interactions and dynamics within other distribution systems or reservoirs. Combined with other water quality parameters, this information provides a better understanding of the microbial ecology of such systems.

Upon conclusion of this research, the researchers found the main challenge to be the interpretation and integration of various sets of information and their application when managing large networks. They recommended that the implementation of these analyses for routine purposes within the industry should only be considered after a careful cost-benefit analysis. The main cost associated with these analyses is not necessarily linked to their direct costs or the infrastructure that is required, but is often related to the human resources component. This type of data interpretation requires a highly skilled team of scientists with a detailed understanding of the system, its associated microbiology and bioinformatic analyses.

The research team concluded that these findings and recommendations can contribute to ongoing efforts to optimise reservoir performance and guide operational decisions for the enhanced efficiency of overall reservoir function.

The optimisation of pier structures to prevent the blockage and flooding of bridges and culverts

Severe weather events in urban areas of South Africa can have serious consequences. Among other challenges is the flooding that results from the accumulation of debris such as tree stumps, branches and plastic bags at the entrance of culverts or bridges. This often results in the failure of the river crossing structure, erosion of the culvert and destruction of the surrounding infrastructure.

EFFECTIVELY SETTING UP PIERS TO RETAIN DEBRIS CAN PREVENT FLOODING AT THE CULVERT, WHICH LEADS TO LESS INFRASTRUCTURE BEING DESTROYED.

Several methods have been used globally with varying degrees of success to prevent the accumulation of debris. One of these is the placement of piers upstream from a culvert to retain different types of debris. The pier shape and pier placement influence the amounts of debris that accumulate and the height of the backwater rise. Research in the Department of Civil Engineering's water resources engineering focus area evaluated the optimisation of debris retention piers to address the issue of debris accumulation at culvert inlets.

Effectively setting up piers to retain debris can prevent flooding at the culvert, which leads to less infrastructure being destroyed. Piers furthermore retain debris in a way that requires less maintenance at culvert inlets, compared with other debris-retaining structures such as debris deflectors or debris racks.

The main design elements in a pier-retention structure are the spacing, height and shape of the piers, and the passage of the debris. The height of the pier is directly linked to the greatest height rise in backwater since the debris should not be pushed over the pier. Various configurations of piers in a channel have been tested at hydraulic structures in selected areas of the USA and Europe (Wallerstein et al., 1997). This has included piers installed perpendicular to the flow path, piers installed diagonally across the channel, and 60° V-shaped configurations with the apex pointing downstream and upstream. These researchers found that the configuration with the apex pointing downstream performed the best, since it had the smallest backwater effect, while still passing the design discharge.

Other researchers found that the shape of a pier significantly influences the stream's flow characteristics. It not only affects the profile of the water surface, dictating how the water behaves in its vicinity, but also influences the velocity of the surrounding water, thereby affecting the stream's flow dynamics. The accumulation of debris at the pier is also determined by its shape. These factors highlight the importance of considering pier shape when assessing the impact of a pier on water behaviour and debris accumulation.

The purpose of an undergraduate research study by Thea Giliomee from the Department of Civil Engineering was to determine the most effective pier shape, and to evaluate the angle of the V-shaped pier configuration with the apex pointing downstream in retaining debris that would otherwise accumulate at the culvert, as well as the backwater effect when debris accumulates at piers. Giliomee explains that the most effective pier configuration will allow the most debris to flow through the culvert

and further downstream, and will have the least amount of debris accumulating at the culvert.

She says that previous studies have explored various pier shapes, but have not specifically examined the angle of the V-shaped pier configuration in terms of its effectiveness in debris retention and its impact on the backwater. Her research therefore entailed performing physical model tests in a hydraulic channel to assess the different pier shapes and angles of a V-shaped pier configuration. She used a circular, square and downward teardrop-shaped pier in three pier configuration angles: 90°, 60° and 30°.

The configuration of the physical model in the hydraulic channel produced no disturbance to the channel flow other than that caused by the piers and the culverts. She used fasteners to secure the piers, and tested the three different pier shapes installed at the three different configuration angles. A constant flow rate was maintained for all the tests.

The flow was deliberately set to be subcritical and deep enough to minimise the influence of the meniscus effect on flow depth measurements. Giliomee also chose a low flow velocity, since this would result in the highest blocking probability during uncongested flow.

As mixed debris, such as tree stumps, branches and plastic bags, is often transported downstream during serious urban rainfall events, she released different types of debris upstream of the piers and culvert at a constant rate over a period of two minutes. The debris mixture was made up of small, medium and large wooden sticks and plastic bags, scaled down to represent the typical debris found in South African urban streams. Tests were carried out three times for each pier shape and configuration as a certain level of unpredictability is associated with debris retention.

The water level was measured at four locations: 4.15 m upstream of the culvert, 0.15 m upstream of the pier structure, just upstream of the pier closest to the culvert, and just upstream of the culvert. The amount of debris retained at the piers and culvert, respectively, as well as the amount of debris that passed through the culvert and flowed further downstream, was measured after each test.

All the tested pier structures were found to be efficient in preventing significant blockage of the culvert, although in varying degrees.

The downward teardrop-shaped pier proved to be most effective in retaining debris, and caused the least backwater effects compared to the circular or square piers. No clear distinction could be made between the angle of the V-shaped pier configurations in terms of their ability to retain debris. However, the 30° configuration had the smallest rise in backwater.

A V-shaped debris retention pier with an angle of 30° would therefore offer a viable and effective solution to the problem of debris retention at culverts during storm events.

References

De Cicco, P.N., Paris, E., Solari, L. and Ruiz-Villanueva, V. 2020. Bridge pier shape influence on wood accumulation. Journal of Flood Risk Management 13(2):16.

Johnson, K.R. and Ting, F.C.K. 2003. Measurements of water surface profile and velocity field. Journal of Engineering Mechanics 129(5):12.

Wallerstein, N., Thorne, C.R. and Abt, S.R. 1997. Debris control at hydraulic structures in selected areas of the USA and Europe. US Army Research Development and Standardization Group. London.

ALL THE TESTED PIER STRUCTURES WERE FOUND TO BE EFFICIENT IN PREVENTING SIGNIFICANT BLOCKAGE OF THE CULVERT.

Plasma technology proves its success for water purification

The Department of Chemical Engineering's Plasma Technology Laboratory, established in 2020 with the support of the Royal Society via the Future Leader African Independent Research (FLAIR) Fellowship, is conducting groundbreaking work in terms of water purification and the removal of contaminants from wastewater.

The research conducted in this laboratory is supervised by Dr Samuel Iwarere and Prof Michael Daramola. It makes use of laboratory-scale plasma units for water and wastewater treatment and a pilot-scale plasma unit. Dr Iwarere explains that the plasma unit has various research applications in addition to the treatment of water, including hydrogen fuel cell research, and the sterilisation of food, disinfection of wounds and cancer treatment.

Two recent studies have made use of plasma technology to determine its efficacy in the removal of residual pharmaceuticals from wastewater, while a mobile solar-powered water purification unit has been tested and is ready to be piloted in a local community within the Tshwane Metropolitan Municipality. This unit makes use of advanced oxidation processes to remove organic and inorganic material, as well as microorganisms from water through the combination of reaction oxygen species such as hydroxyl radicals.

REMOVAL OF RECALCITRANT CONTAMINANTS FROM WASTEWATER

The increased production and consumption of pharmaceuticals such as analgesics and antibiotics over the past two decades has led to an increase in contaminants in wastewater that are difficult to remove using a conventional treatment approach. The residual pharmaceuticals in wastewater are due to the fact that the entire prescribed dosage of these products is not absorbed in the body, leaving the remaining portion to be excreted as waste.

Dr Samuel Iwarere demonstrates the functioning of a simulated laboratory for the development of solar-powered plasma technology to treat contaminated water in rural communities. It includes a solar panel on the roof of the outdoor laboratory.

Although they are detected in very low concentrations, these emerging contaminants have become a source of concern to both the scientific community and the public due to their persistence in the environment. They pose risks to both aquatic life and human health.

Prolonged exposure to some persistent antibiotics has been linked to developmental abnormalities, reduced reproductive success, disruptions in the balance of microbial ecosystems in aquatic environments and antibiotic resistance.

Two studies have been conducted on residual pharmaceuticals. The first one investigated the removal of the analgesic Tramadol™ in deionised water and final wastewater effluent using a novel continuous flow dielectric barrier discharge reactor, while the second examined the degradation of the antibiotic Cefixime™ with an atmospheric air dielectric barrier discharge.

These studies formed part of the doctoral research of Samuel Babalola, under the supervision of Dr Iwarere and Prof Daramola.

Babalola describes Tramadol™ as an opioid that is widely used to treat moderate to severe pain. Only about 70% of the prescribed dosage is metabolised by the human body. It has been classified as an extremely recalcitrant water micropollutant, rendering its elimination through conventional wastewater treatment systems very challenging. Cefixime™, on the other hand, is an antibiotic that has been included in some lists of emerging contaminants that are being monitored by regulatory agencies in water and wastewater. Its absorption in the human body is also incomplete, causing it to end up in wastewater.

As emerging technologies like advanced oxidation processes continue to gain interest in the degradation of refractory organic pollutants, plasma generated in electrical discharges is being investigated as a possible degradation method for antibiotics since it leaves fewer toxic by-products. Plasma formation occurs by introducing energy into the gaseous phase, initiating inelastic conditions that lead to ionisation and dissociation processes. The most fascinating aspect of plasma, according to Babalola, is its capacity to establish a dynamic environment where photons, electrons, positive ions, reactive species (excited molecules and atoms) and radicals can co-exist simultaneously. "As a collective entity, plasma demonstrates macroscopic neutrality and exhibits synergistic behaviour."

Advanced oxidation is an innovative method that encompasses the generation of highly potent reactive species such as ozone and hydroxyl radicals, which can potentially oxidise toxic pharmaceutical compounds into harmless by-products.

Hydroxyl radicals have the advantage of not only being strong oxidisers. They are also non-selective towards various types of micropollutants.

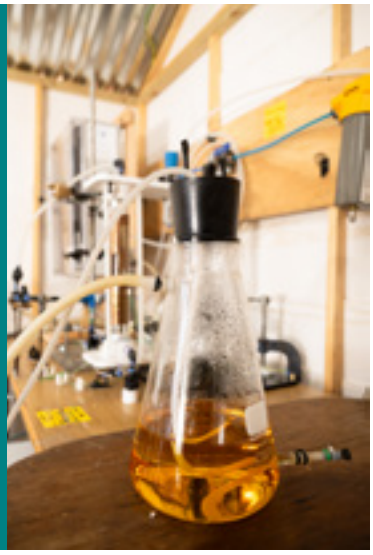
Among emerging advanced oxidation processes, non-thermal plasma technology has garnered significant interest due to its simplicity, versatility, high energy efficiency, environmental suitability and minimal reliance on additional chemical reagents. This treatment capitalises on the synergy of reactive species, molecules, ultraviolet light and shock waves.

Within non-thermal plasma configurations, the dielectric barrier discharge stands out for its operation at low or atmospheric pressure conditions and near-ambient temperatures. This configuration offers distinct advantages, such as low energy consumption, thereby contributing to a cost-effective treatment solution. It provides a novel means by which molecular species can be generated at relatively low temperatures and with high energy efficiency. It has been shown to significantly degrade non-biodegradable pharmaceutical pollutants, which prompted its use in the two case studies.

Typically, studies on Tramadol™ removal have been conducted in batch mode, where the generated reactive species have adequate mass transfer in the solution and contact with the pollutant. While this mode yields rapid and energy-efficient degradation, its drawback lies in its limited throughput, curtailing potential applicability beyond the laboratory scale. The conductivity of the solution can also influence the rate of reactive species generated in certain advanced oxidation processes. It was therefore decided to use a continuous flow method of contaminant removal in this study.

In addition to examining the performance of flow-through volume dielectric barrier discharge reactors in the degradation of Tramadol™, the study probed the divergences in pollutant removal between synthetic water and final wastewater effluent. It also performed a simple toxicity investigation with *Escherichia coli.* The reactor was initially optimised for applied voltage and the initial concentration of the pollutant. Increasing the voltage led to a direct increase in the concentration of the reactive species, which, in turn, improved the degradation of Tramadol™. After 60 minutes of treatment, the degradation efficiency of Tramadol™ was 93% in the deionised water and only 27% in the final wastewater effluent. Meanwhile, an increase in the concentration of the pollutant was a setback to the conversion process as the available molecules quickly scavenged the reactive species and inhibited further degradation.

THIS PROJECT HAS LED TO THE SIGNIFICANT DEGRADATION OF NON-BIODEGRADABLE PHARMACEUTICAL POLLUTANTS IN WASTEWATER.



The second study achieved a complete degradation of Cefixime™ using non-thermal plasma technology after eight minutes of treatment at 6 kV and 20 kHz using a high-voltage alternating current power supply unit. The degradation of the pollutant was influenced by the solution flow rate, applied voltage and solution characteristics. Five degradation by-products were identified and a possible degradation pathway for the pollutant proposed. Radical scavenger experiments were also set up to understand the specific chemical species that facilitated Cefixime™ degradation.

In an attempt to understand the controlling effect of active radicals, this study explored the degradation of pollutants in the presence of radical scavengers. The results showed that radical scavengers could impede or enhance the degradation of a pollutant, depending on the active residual chemical species. The feed gas composition also had a remarkable effect on the treatment process during plasma treatment.

Previous studies on Cefixime™ degradation using non-thermal plasma were conducted in a batch reactor and in a small volume. The present study is the first to examine the removal of Cefixime™ using a continuous-flow dielectric barrier discharge plasma system generated by natural atmospheric air. The intrinsic advantage of running a plasma experiment with natural air lies in its reduced costs, which boosts its potential for commercial deployment.

An underexplored area in plasma water treatment and advanced oxidation processes entails the investigation of the technology's performance in the presence of low-cost metal ion catalysts and radical scavengers. After optimising the factors that affect the degradation of the pollutant, the study sought to investigate the reactive species that facilitates this process. The intermediate products identified during the degradation process with the key reactive species provided a hint on the possible removal mechanism for Cefixime™. The study also investigated the influence of a catalytic metal ion, as well as its effect in enhancing the degradation of Cefixime™ in the presence of various hydroxyl radical scavengers. Considering the interrelationship between hydroxyl radicals and hydrogen peroxide, the concentration of hydrogen peroxide was monitored in the synthetic solutions containing hydroxyl radical scavengers and the metal ion catalyst.

Overall, the main results from this study suggest a method for significantly increasing the efficiency of a dielectric barrier discharge plasma technology in handling persistent micropollutants like Cefixime™, while potentially reducing the cost of treatment.

MOBILE SOLAR-POWERED WATER PURIFICATION UNIT

Since 2022, members of the Plasma Technology Laboratory have been developing an easily operated, small-scale solar-powered plasma ozonation system for the purification of water that works without chemicals. The Water Research Commission (WRC) provided funding for its development. It involves the combination of plasma technology and renewable energy options to provide clean drinking water to rural, off-grid communities.

Since many villages in South Africa and the rest of Africa do not have clean running water or access to electricity, the addition of a solar energy unit to the prototype's design is very important. The villagers very often need to get their water from rivers and other contaminated sources that are not fit for human consumption. They then need to boil their drinking water to purify it. This is not energy-efficient, and does not remove all the contaminants, such as manganese, as can be done through plasma technology.

However, the unit needs a constant supply of power. This led to the idea of a unit that makes use of renewable solar-powered batteries. The laboratory-scale purification unit has already been successfully tested. It includes a plasma reactor in which water is cleaned to drinking standards as a result of the electric current that is sent through it at a high voltage, with tanks storing untreated and clean water separately. The current laboratory prototype could provide 120 ℓ of water every four hours in off-grid situations. This is enough to serve the purposes of at least eight rural households.

Ongoing work in this area includes research into the inactivation of antibiotic-resistant bacteria and antibiotic-resistance genes in wastewater streams, and the rapid susceptibility of Carbapenem-resistant *Pseudomonas aeruginosa* and its resistance gene to non-thermal plasma treatment in a batch reactor.

Dr Iwarere hopes that the Laboratory's research will ultimately help people in many countries in sub-Saharan Africa who struggle with access to clean, drinkable water. "Many lives are lost through water-related diseases. Our vision is to see a healthy and productive Africa, and to address some of the United Nations' Sustainable Development Goals (SDGs), as well as the targets of the African Union's Agenda 2063."

WHAT IS PLASMA TECHNOLOGY?

Plasma technology is used in plasma television sets, plasma etchings, water purification systems and high-temperature laser cutting. Plasma is one of the four fundamental states of ordinary matter (along with solids, gases and liquids). It makes up 99% of the visible universe and is electrically conductive because it contains charged particles such as ions and/or electrons. Plasma is generated and put in motion by sending a strong electromagnetic current through a neutral gas.

Protecting Tanzania's agricultural security during the extraction of valuable elements

Researchers in the Environmental Engineering Division of the University of Pretoria (UP)'s Department of Chemical Engineering have been involved in collaborative research to investigate the extraction of rare earth elements (REEs) and uranium from the phosphate ore mined at the Minjingu Mines in northern Tanzania. The research team, upon evaluation of their findings, sought to ensure that the recovery of these valuable elements from the phosphate ore did not impact on the country's production of phosphate fertilizer as a source of income and commodity that guaranteed agricultural and food security.

PHOSPHATE ORE IS AMONG THE 5TH MOST MINED MATERIAL ON EARTH.

This research project involved 21 researchers from Austria, Croatia, the Czech Republic, Egypt, France, Germany, India, Morocco, Poland, Serbia, South Africa and Tanzania. The South African researchers were Prof Hendrik Brink and Hilda Kyomuhimbo from UP's Department of Chemical Engineering, Prof Liezel van der Merwe from UP's Department of Chemistry, and Prof Wayne Truter from the University of the Free State's Faculty of Natural and Agricultural Sciences.

The phosphate ore from Minjingu Mines is Tanzania's sole domestic source of phosphorus. The ore contains medium to high concentrations (20–35%) of naturally occurring phosphorus pentoxide. Relevant concentrations of uranium and REEs have also been found to occur in the ore. These are important elements for energy applications, especially in the context of the just energy transition. Currently, neither uranium nor REEs are recovered from the phosphate ore. They either end up in mine tailings or are spread across agricultural soils with fertilizer products.

According to Prof Brink, this research provides the first systematic overview of Minjingu phosphate ore processing in Tanzania. It places the uranium and REE concentrations found in the different ore layers, tailings and fertilizer products in context by comparing them to concentrations of uranium and REE in phosphate ore globally.

The phosphate ore that is used to produce mineral fertilizers can show elevated concentrations of heavy metals. Cadmium, in particular, has been identified as having a potential health risk. Radiotoxic uranium, as well as REEs, can also be found in relevant concentrations in phosphate ores worldwide. Although the concentrations of uranium and REEs in phosphate ore can be considered moderate at best, the overall quantities of both these minerals that could theoretically be recovered are impressive, given that approximately 220 million metric tons of phosphate ore is mined globally per year.

Phosphate ore is among the fifth most mined material on earth. REEs recovered from phosphate ore in Morocco alone are estimated to cover 7–15% of global demand. By way of example, the USA could cover its entire demand if REEs were recovered during phosphate processing in Florida. Researchers furthermore estimated that uranium recovered during phosphate fertilizer production could have theoretically provided some 10–15% of the world's commercial uranium requirements in 2018.

Currently, neither REEs nor uranium are industrially recovered during phosphate fertilizer production. During the 1980s and 1990s, uranium was recovered on an industrial scale using a wet phosphoric acid process to achieve an intermediate liquid product in

phosphate fertilizer production in Florida, USA, before decreasing uranium prices made this practice uneconomic. Although phosphate can probably not be recovered from all the fertilizer plants around the world, recovery operations at phosphate mines that show elevated uranium concentrations could show promising results. This could also contribute to lowering the concentration of uranium in fertilizers sold commercially and spread across agricultural soils.

Prof Brink explains that the Minjingu phosphate ore deposit in northern Tanzania is known for its relatively high concentration of naturally occurring uranium. It was, in fact, the increased radiation levels that led to the discovery by a South African mining company in 1956 of a deposit at the edge of Lake Manyara. The Minjingu phosphate ore shows natural uranium levels that would qualify the deposit as very low-grade uranium ore under the definition of the World Nuclear Association (WNA). It has even been pointed out that Minjingu's uranium concentration is higher than that of the commercial uranium mines in Namibia. However, since fertilizer is more important for Tanzania's economy than uranium, the ore is mined for its elevated phosphorus pentoxide content and not for its elevated uranium content.

It is worth noting that the potential recovery of uranium at the Minjingu fertilizer plant will ideally result in a cleaner fertilizer product, and will reduce the environmental pollution that presently occurs at *in-situ* leach and open-pit uranium mining in Tanzania. Due to ongoing uranium exploration and mining operations, Tanzania already has a regulatory framework for uranium production in place that could ease the way for by-product uranium recovery.

Research into the viability of extracting these elements from the phosphate ore needs to consider the following questions: What are realistic average uranium concentrations? What are realistic uranium recovery rates? Will the final fertilizer products still work as effectively without the uranium content? Are other valuable minerals, such as REEs, present in sufficient concentrations that could be co-extracted and sold as well?

The research entailed the analysis of 10 distinct Minjingu phosphate ore layers (the surface layer, a hard rock layer, three soft rock phosphate layers and five semi hard rock phosphate layers), four mine tailings, and five intermediate and final mineral fertilizer products from the Minjingu mine and processing plant for their REE and uranium contents.

The samples that were obtained from the phosphate ore were crushed, powdered, dried and sieved, and a portion of each typical sample sent to Morocco's National Centre for Energy and Nuclear Science and Technology for inductively coupled plasma mass spectrometry (ICP-MS) analysis. Two tailing samples and two surrounding soil samples were also prepared and analysed.

The results of these tests provided valuable information on the REE and uranium concentrations in the phosphate ore, as well as the uranium concentration in the phosphate fertilizers. Considerable differences were observed in the REE concentration between the different rock layers from which the samples were taken. Prof Brink explains that it is not unusual for different rock layers to show varying concentrations of elements. At Minjingu, however, only the three soft phosphate rock layers are presently mined and processed. Future plans to also mine the hard phosphate rock layers can provide higher concentrations of phosphorus pentoxide than are presently being mined in the soft phosphate rock layers alone. However, even the highest concentrations of REEs found in the deepest soft rock layer are not exceptionally high compared to REE concentrations found in major phosphate rock deposits in countries like Russia and Brazil. The concentrations found in the presently mined Minjingu phosphate ore layers do not therefore encourage the commercial recovery of REEs.

The average REE concentration in the mine tailings is even lower than in the phosphate ore, and does not encourage REE extraction either. These findings reveal that REE recovery will most likely not be economically viable. In alignment with this, the researchers strongly encouraged the development of techno-economic solutions for more comprehensive utilisation of the Minjingu ore.

In terms of the uranium concentration, however, the presence of this element in the Minjingu phosphate ore was found to be higher than that found in sites studied in countries like Australia, Egypt, New Zealand and Syria.

A source of concern among the scientific community relates to the uranium build-up in agricultural soils due to the extended use of phosphate rock and phosphate fertilizer. Since the metal is radiotoxic, it can endanger soil fertility, leach into groundwater and be taken up by crops. At present, there is no legal limit for uranium in mineral fertilizers, although some organisations, such as the Soil Protection Commission of the German Federal Government Agency, suggest determining a legal limit.

Prof Brink explains that uranium recovery could be considered during the processing of Minjingu phosphate ore due to the relatively high-occurring concentrations that could make recovery economically profitable. These elevated concentrations were, however, not found to pose a significant risk to users.

THE PHOSPHATE ORE FROM MINJINGU MINES IS TANZANIA'S SOLE DOMESTIC SOURCE OF PHOSPHORUS. THE ORE CONTAINS MEDIUM TO HIGH CONCENTRATIONS OF NATURALLY OCCURRING PHOSPHORUS PENTOXIDE. RELEVANT CONCENTRATIONS OF URANIUM AND RARE EARTH ELEMENTS HAVE ALSO BEEN FOUND TO OCCUR IN THE ORE. THESE ARE IMPORTANT ELEMENTS FOR ENERGY APPLICATIONS, ESPECIALLY IN THE CONTEXT OF THE JUST ENERGY TRANSITION.

Minjingu currently uses a dry beneficiation process to extract the phosphate from the ore. This differs from the wet phosphoric acid process that is used globally to process phosphate ore, whereby uranium that occurs naturally in the phosphate ore transfers to liquid phosphoric acid, where it can be recovered using industrially proven solvent extraction processes. It is, however, unlikely that the Minjingu phosphate ore will ever be processed using a wet beneficiation process as such processes require significant amounts of water, in addition to sulphuric and other acids. Such processes have a much higher overall environmental footprint than the current dry beneficiation process (without uranium recovery) that is used in Tanzania. However, Minjingu's phosphate ore may benefit from alternative dry processing methods, such as the electrostatic separation or other innovative dry concentration processes. As the Minjingu plant is located in an area with high levels of solar radiation, the introduction of solar thermal calcination may be a long-term proposition for the mine.

Theoretically, the uranium could be directly leached from the phosphate ore after primary sieving and sorting before calcination or from the fertilizer powder after calcination. Researchers in India and Finland have proposed the bioleaching of a lower-grade uranium apatite, while researchers in other countries have proposed the direct leaching of REEs and uranium from phosphate ore in Egypt. Such an approach has also been proposed for phosphate ores from Mexico with the explicit aim of reducing the dissipation of radiotoxic uranium. However, the direct leaching of uranium from phosphates is presently not economically viable. This will most likely also be the case at the Minjingu fertilizer plant, given the relatively small size of the operation, and the still fairly low uranium prices worldwide.

It is essential to realise that Minjingu's phosphate rock and its fertilizer products substantially increase crop yield in Tanzania. The domestically produced Minjingu fertilizer products are an affordable source of domestically produced fertilizer that works well on the country's acidic soils, decreasing the dependency on the international fertilizer market. If uranium is to be recovered from Minjingu's phosphate ore during mineral fertilizer production, it is paramount that the quality of the final fertilizer product is not compromised.

The researchers thus concluded that Minjingu's phosphate fertilizer products are important for the development of food security in Tanzania, and it is crucial that the final fertilizer products work as effectively as they do now. Despite this, they suggest looking into ways of making the production of Minjingu fertilizer more sustainable, such as solar calcination or reducing dust and uranium recovery, without affecting the quality of the final fertilizer products.

Further reading

Haneklaus, N.H. et al. 2024. Rare earth elements and uranium in Minjingu phosphate fertilizer products: Plant food for thought. Resources, Conservation and Recycling 207 (107694). Available at: https://www.sciencedirect.com/science/article/pii/S092134492400288X.

Postgraduate research in environmental engineering

A very active field of postgraduate research in the Department of Chemical Engineering is that of water utilisation and environmental engineering. The programmes in this field are formulated to provide human capacity for industry and the public sector, and to raise awareness about the finite nature of the assimilative capacity of the environment. They consider issues relating to clean coal technologies such as carbon capture, storage and utilisation, and clean energy production.

REDUCING POLLUTION FROM INDUSTRIAL EFFLUENTS

PhD student **Hilda Dinah Kyomuhimbo** has been awarded the Schlumberger Foundation Faculty for the Future Award for her doctoral research under the supervision of Prof Hendrik Brink. Her research focuses on using biological methods for wastewater treatment to control pollution.

The goal of her research is to utilise the laccase enzyme, which is commonly found in nature, and which is known for its ability to degrade a variety of organic pollutants. However, enzymes often have poor stability under severe conditions like high temperatures and when harsh chemicals are used, limiting their industrial and commercial applications.

Her research aims to improve the stability and reusability of laccase by immobilising it on readily available and biodegradable polymers to treat industrial effluents, particularly from the textile, dye and pharmaceutical industries. It also aims to enhance laccase efficiency by incorporating the biocatalyst with nanoparticles, which will increase the enzyme's specificity, and thereby widen the range of pollutants that can be degraded. The biocatalyst (containing laccase, nanoparticles and polymers) is in the form of beads that can be used in various settings such as industries and wastewater treatment plants.

IMPROVING WATER QUALITY IN AFRICA

PhD student **Ruth Kasavo** has been awarded the Excellence in Africa (EXAF) 100 PhDs for Africa fellowship of the Federal Polytechnic of Lausanne (EPFL) in Switzerland for her doctoral research under the supervision of Prof Hendrik Brink. Her research focuses on developing an innovative solution for industrial wastewater treatment using advanced materials.

It entails creating nanocomposites by fusing polymers with magnetic nanoparticles, supported by biochar. These materials will undergo testing in a continuous flow system to replicate real-world industrial scenarios. The objective is to improve the efficiency and sustainability of wastewater treatment processes by harnessing the distinct attributes of these nanocomposites.

Her research offers a scalable and efficient technique for treating industrial wastewater. The increasing presence of pollutants is a major global concern. Many researchers have found that adsorption using different materials, such as carbon nanotubes, graphene, metal oxides and polymer composites, is effective in the removal of pollutants from water and wastewater.

She is therefore investigating the viability of using magnetic nanoparticles and polymer nanocomposites to remove pollutants from wastewater.

ELIMINATING LEAD CONTAMINATION IN INDUSTRIAL WASTEWATER

Nokuthula Nchabeleng is completing the research for her master's degree, and is planning to continue with her PhD work in 2025, under the supervision of Prof Hendrik Brink. Lead contamination in water poses severe environmental and health risks due to its toxicity and persistence. Lead ions, which are commonly found in industrial wastewater, can have detrimental effects on human health, including neurological damage and kidney dysfunction. The effective removal of lead from aqueous solutions is crucial for environmental protection and public health.

Her research investigates the removal of lead ions from aqueous solutions using reclaimed mine water sludge, a waste by-product from a water reclamation plant, as an adsorbent. Her study aims to optimise the adsorption process through batch experiments and includes kinetic and isothermal studies to evaluate the time and temperature behaviour of the adsorption system.

After conducting batch studies to determine the optimal conditions for lead removal, focusing on parameters such as pH, initial lead concentration and adsorbent dosage, she found reclaimed mine water sludge to be highly effective in lead remediation.

A new era for materials science and metallurgical engineering

South Africa is not only blessed with the world's largest deposits of platinum, chromium, vanadium and manganese. It also has extensive reserves of gold, iron, lead, zinc, copper, nickel, coal and diamonds. The minerals industry contributes 50% of South Africa's exports and is one of the largest employers in the country. Metallurgical engineers play a key role in the production of minerals and metals, and help to process metals into final products with added value. In this way, the maximum income is generated in local and international markets. Components made from metals and other materials are designed to perform optimally in all aspects of modern life.

The University of Pretoria's Department of Materials Science and Metallurgical Engineering is unique in South Africa as it is the only department entirely dedicated to metallurgical engineering. It provides aspiring metallurgical engineers with a comprehensive education in minerals and metals, covering a wide range of topics.

It has been ranked as the best metallurgical engineering department at a South African university for several consecutive years by the Minerals Education Trust Fund (METF). It was also ranked 36th in the world for minerals and mining engineering in the latest QS rankings. This acknowledges the Department's valuable impact on the field, both in terms of knowledge advancement and producing skilled professionals. Its commitment to providing advanced education and state-of-the-art facilities ensures that its graduates are well prepared to meet the challenges of the modern world.

The University of Pretoria has become a centre for metallurgical research, focusing on issues relevant to South Africa's mining industry, including mineral processing, metal extraction and alloy development. The Department focuses on six key areas related to the processing, refinement and application of minerals and metals: minerals processing, pyrometallurgy, hydrometallurgy, physical metallurgy, welding engineering and corrosion engineering.

RANKED #1

TOP METALLURGICAL ENGINEERING DEPARTMENT AT A SOUTH AFRICAN UNIVERSITY BY THE METF

TOP 36

IN THE WORLD FOR MINERAL AND MINING ENGINEERING

QS World University Ranking by Subject

Sophisticated research equipment is available in the Department, as well as in the Industrial Metals and Minerals Research Institute (IMMRI), established in the Department in 2001. Industry-sponsored research chairs enable the Department to carry out innovative research with global relevance. These include the Anglo American Chair in Pyrometallurgy, established in 2011, and the South African Institute of Welding Centre for Welding Engineering, established in 2011.

The Department receives generous financial support from leading mining and metallurgical companies and has healthy interactions with partners such as African Rainbow Minerals, Anglo American, Anglo American-Kumba Iron Ore, ArcelorMittal SA, BHP Billiton, Columbus Stainless, the Council for Scientific and Industrial Research (CSIR), Exxaro, Glencore, Metso South Africa, Mintek, Multotec, Sasol, Sibanye Stillwater, the South African Institute of Welding, Tenova-Bateman and Weir Minerals.

COLLABORATION FOR IMPACT

The Department understands the importance of maintaining close working relationships with local industry. Students in metallurgical engineering are often awarded bursaries by local companies, which can lead to employment after graduation. In addition, collaboration with industry partners enhances the relevance of its research programme, which enables the Department to serve as a technical resource for industry, providing information and expertise. This can only be achieved with a robust team of academic staff members.

The Department produces outstanding alumni who hold executive positions in industry. These alumni play a vital role in driving changes and maintaining the high quality of graduates over the years. The Department maintains close relationships with its alumni through, for example, its Advisory Board. This board helps align the Department with industry changes and trends, and supports the implementation of desired improvements within the Department.

The latest development in the Department, which included the establishment of a high-tech Virtual Conference Centre to enhance online collaboration sponsored by African Rainbow Minerals (ARM), was the large-scale refurbishment of the Department's facilities in the Mineral Sciences Building.

Phillip Tobias, Chief Executive Officer of African Rainbow Minerals (ARM) (left) and Prof Sunil Maharaj, UP's Vice-Principal for Research, Innovation and Postgraduate Education, officially open the UP-ARM Virtual Conference Centre.

Refurbished facilities

The Department has occupied the Mineral Sciences Building since 1987 when the old Physics Building was completely renovated to accommodate the Department of Materials Science and Metallurgical Engineering and the Department of Mining Engineering in the Faculty of Engineering, Built Environment and Information Technology, and the Department of Geology in the Faculty of Natural and Agricultural Sciences. The Mineral Sciences Building harbours a hub of collaboration between these three departments, providing space for transdisciplinary research.

In 2023, the Department's facilities were renovated to provide students with world-class learning environments. These facilities include the new ARM Virtual Conference Centre, as well as refurbished laboratories, offices for staff members, three classrooms and computer laboratories for postgraduate students.

Virtual Conference Centre

The new ARM Virtual Conference Centre, which was officially launched on 18 October 2024, is a state-of-the-art facility aimed at enhancing collaboration between academia and industry. It will empower staff and students to connect and engage virtually with local and international institutions of higher learning, academic communities, research organisations and industry leaders.

By fostering collaboration, the virtual centre will enrich students' educational experiences and facilitate the rapid exchange of information and data, ensuring the timely delivery of high-quality results. It serves as a collaborative space for various departments within the faculties of Engineering, Built Environment and Information Technology, and Natural and Agricultural Sciences, enabling high-tech meetings, workshops and seminars that enhance engagement among staff, students and industry partners.

Key departments, including Geology, Mining Engineering, Materials Science and Metallurgical Engineering, and Mechanical Engineering, which together host over 150 postgraduate students, will greatly benefit from this facility.

By providing access to cutting-edge technology, the UP-ARM Virtual Conference Centre aims to modernise academic research and industry applications, enabling more effective collaboration between students, staff members and industry leaders.

This centre will be instrumental in bridging the digital divide in our universities, nurturing the next generation of leaders and thinkers equipped to thrive in the digital age.

Laboratories

The refurbishments included updating the Department's existing laboratories, such as those dedicated to Pyrometallurgy, Hydrometallurgy, Advanced Materials Characterisation, Physical Metallurgy, Minerals Processing, Flotation, Welding and the laboratories of the Industrial Metals and Minerals Research Institute (IMMRI).

The Department utilises a range of sophisticated analytical and simulation equipment, including a deformation dilatometer, a thermomechanical simulator, scanning electron microscopes with electron backscatter diffraction (EBSD) facilities, X-ray diffraction (XRD), high-temperature XRD, a texture analyser and residual stress analyser. New equipment and capabilities are added to the Department's research facilities as technology advances.

These include the following:

- A CORTEST Slow Strain Rate Testing (SSRT) facility to evaluate slow strain rates in a chamber to simulate corrosive field environments
- An MTS electromechanical test system (with a digital image correlation system) for the mechanical evaluation of embrittlement
- A PLX plastometry machine that extracts metal stress-strain curves from indentation test data
- A LECO-C and moisture analyser

RESEARCH

The Department's research programme is focused on industrial problems faced by the metallurgical industry in South Africa and the rest of the world. A selection of research projects focused on promoting minerals beneficiation, particularly new ways of sourcing valuable minerals from previously unexploited sources, is presented in the following pages.

This includes research to devise environmentally friendly alternatives to materials produced in the refractory industry; an investigation of ways to extract minerals from fine particles to increase minerals beneficiation; developing a system to monitor and track particles in a slurry; and exploring ways to increase beneficiation and improve the purity of platinum and other minerals.

Phillip Tobias, CEO of African Rainbow Minerals, experiments with extended reality during the official opening of the UP-ARM Virtual Conference Centre.

Repurposing existing steel pipelines for green hydrogen

Since the approval of government's Hydrogen South Africa Strategy (HySA) in 2007 and the publication of the Hydrogen Society Roadmap for South Africa by the Department of Science and Innovation (DSI) in 2021, research across diverse sectors and by various organisations has been focused on devising plans to secure a clean, affordable and sustainable energy future for South Africa. The Department of Materials Science and Metallurgical Engineering at the University of Pretoria is no exception.

THE DEPARTMENT HAS A WELL-EQUIPPED LABORATORY WITH STATE-OF-THE-ART EQUIPMENT AND ELECTROCHEMICAL INSTRUMENTS, A DIFFUSIBLE HYDROGEN ANALYSER, AND SLOW STRAIN RATE AND CONSTANT LOAD TESTERS THAT ARE SPECIFICALLY USED TO PERFORM THE NECESSARY TESTS FOR HYDROGEN EMBRITTLEMENT STUDIES.

The effective implementation of the Hydrogen Society Roadmap will mean that hydrogen can become an important source of energy and a catalyser to enable the decarbonisation of crucial carbon-intensive sectors of our economy, like heavy-duty transport and other energy-intensive industries. This can lead to the development of a green power sector and a domestic manufacturing sector for hydrogen products and fuel cell components, and the creation of an export market for South Africa's green hydrogen.

Prof Roelf Mostert, an Associate Professor in the Department of Materials Science and Metallurgical Engineering, considers green hydrogen to be the most environmentally friendly means of providing energy to fulfil society's needs. It does not produce any greenhouse gas (GHG) emissions, and releases only water vapour into the atmosphere.

CHALLENGES TO EMBRACING HYDROGEN

The metals and mining industry can play an important role in the decarbonisation of the heavy-duty transport sector, in particular. This is essential to achieve just and inclusive net-zero carbon economic growth for societal wellbeing by 2050 in terms of government's National Development Plan (NDP). According to the global Hydrogen Review Report of 2021, the transport sector accounts for 20% of global GHG emissions, and 25% of final energy demand, mostly due to the use of oil products. While the use of hydrogen in the transport sector has historically remained below 0.01%, hydrogen and hydrogen-based fuels offer opportunities to reduce emissions, particularly in heavy-duty trucks, shipping and aviation.

In South Africa, the transport sector is responsible for 10.8% of the country's GHG emissions, with road transport accounting for 91.2%. The Department of Transport's Green Transport Strategy of 2018 advocates the adoption of electric vehicles (powered by batteries and fuel cells) to reduce emissions in the transport sector. By 2021, there were over 300 battery electric vehicles in South Africa, while the use of hydrogen fuel cells has been demonstrated in mining locomotives and forklifts, among others.

The mining company Anglo American has set up a pilot plant at its Mogalakwena Platinum Mine in Limpopo, where it is testing fuel cell mining trucks. This forms part of the company's Sustainable Mining Plan. According to this plan, it targets a 30% reduction in GHG emissions by 2030. It also aims to be carbon neutral across all its operations by 2040. The challenge to using hydrogen fuel cell trucks to transport ore on a mine lies in the fact that the hydrogen must be transported to the mine and stored there at a very high pressure, usually via steel pipelines. "This is where materials science and metallurgical research comes in," states Prof Mostert.

The Hydrogen Society Roadmap identified a number of catalytic projects that will launch the development of a hydrogen society in South Africa.

THE EFFECTIVE IMPLEMENTATION OF THE HYDROGEN SOCIETY ROADMAP WILL MEAN THAT HYDROGEN CAN BECOME AN IMPORTANT SOURCE OF ENERGY AND A CATALYSER TO ENABLE THE DECARBONISATION OF CRUCIAL CARBON-INTENSIVE SECTORS OF OUR ECONOMY.

The first such project is the Platinum Valley initiative (dubbed South Africa's Hydrogen Valley), which entails the development of green hydrogen hubs in Johannesburg, Durban/Richards Bay and Mogalakwena/Limpopo. These hubs have been identified based on their potential for a high concentration of future hydrogen demand, their capacity to produce hydrogen and their potential contribution to a just energy transition.

Another catalytic project that Prof Mostert believes has immense potential is the Boegoebaai project in the Northern Cape, just south of Namibia. Managed by Sasol Limited, it is located in the Namakwa Special Economic Zone (SEZ).

Since it is located in an area with a lot of wind and sunshine, the facility could also support a 30 GW solar and wind farm (six times South Africa's current renewable energy capacity) and 5 GW of electrolysis.

Prof Mostert explains that pipelines are a central element in the plans to transport hydrogen to ports such as Richards Bay. The question that arises, however, is to what extent the transportation of hydrogen under high pressure will affect the integrity of the steel pipelines. Research being conducted in the Department is focusing on quantifying how the hydrogen atom will degrade the steel through processes like hydrogen-assisted cracking, and accelerate metal fatigue.

STRUCTURAL INTEGRITY

During the 5th International Conference on Structural Integrity, held in Madeira, Portugal, in August 2023, Prof Mostert presented the results of two of the Department's projects.

The first paper examined criteria for the onset of the degradation of structural integrity due to the high-temperature hydrogen attack of carbon-manganese steel. Samples of a pressure vessel of carbon-manganese steel were exposed to 46 bar pure hydrogen at 550 °C in an autoclave for various exposure periods. Some samples were instrumented with a high-temperature strain gauge to track the accelerated expansion strain and evaluate the extent of embrittlement. The results demonstrated that severe degradation of the tensile ductility occurred after experiencing expansion strains much smaller than anticipated, especially for samples in the plate through-thickness orientation.

The second paper examined the role of hydrogen in the corrosion-induced reduction of plane-stress fracture toughness and strain-induced intergranular cracking of AA2024, an aeronautical aluminium alloy. It specifically investigated the role of diffusible hydrogen in the embrittlement of AA2024 after short-term exposure in the standard exfoliation corrosion test solution. Significant degradation was observed in the effective slow strain rate toughness after short-term exposure of the AA2024-T3 specimens to the exfoliation corrosion solution. Post-exposure heat treatments appeared to restore the plane-stress fracture toughness to its original values. The formation of secondary and primary intergranular cracks in the plastic zone of the compact tension samples was also studied.

However, the presence of these cracks was not altered by heat treatment. The study furthermore made use of thermal desorption mass spectroscopy to evaluate the extent of hydrogen absorption due to the corrosive exposure, and the effect of the subsequent heat treatment in removing it.

The conference revealed that research on hydrogen's influences on structural integrity has seen an exponential increase over the past two years. This has, for the most part, been fuelled by the necessity to diversify energy sources and societal pressure to cope with climate change. Research into metal behaviour in the presence of hydrogen has become the focus of a growing number of scientists due to its importance in hydrogen storage and transportation.

During the conference, Prof Mostert recognised the need to scale up the Department's research on this topic. He acknowledged that South Africa's hydrogen economy could receive a major boost if some of the country's existing liquified natural gas (LNG) pipelines could be repurposed to transport hydrogen. He notes, in particular, the major gas supply pipeline that runs from Mozambique to Secunda, which has the potential to be repurposed to transport hydrogen.

Referring specifically to the catalytic projects that are envisaged in the Platinum Valley's green hydrogen hubs and the Boegoebaai facility in the Northern Cape, he explains that their viability could be increased if local researchers would prioritise research into hydrogen steel interactions, with a specific emphasis on repurposing existing pressure vessels and pipelines. "Hydrogen fuel cells are not suitable for large-scale industrial applications," he says, "so the storage and transportation of the gas under high pressure via a pipeline into storage vessels is central to the success of the venture."

CURRENT RESEARCH

Several postgraduate researchers in the Department are currently investigating various aspects related to this topic. This is currently the only research group in South Africa to be examining this aspect of the hydrogen economy, which can play an important role in accelerating the implementation of the Hydrogen Society Roadmap due to the costs involved in laying new pipelines for hydrogen transportation and storage.

Some of the potential solutions being examined in the Department include the following:

- Covering the inside of the pipeline with a glass platelet-reinforced coating to delay the permeation of the hydrogen into the steel. If this proves successful, the pipelines' inspection intervals could be substantially delayed.
- Determining the critical hydrogen levels in the steel to prevent embrittlement and corrosion. Tests are being conducted to determine how much of the hydrogen actually penetrates the steel and what levels would cause damage.
- Changing the stress profile of the surface of the steel pipeline to delay the penetration of hydrogen.
- Modifying the surface of the steel by means of laser beams to delay the penetration of hydrogen.

The Department has a well-equipped laboratory with state-of-the-art equipment and electrochemical instruments, a diffusible hydrogen analyser, and slow strain rate and constant load testers that are specifically used to perform the necessary tests for hydrogen embrittlement studies. This research can mean the difference between success and failure when it comes to embracing South Africa's hydrogen economy for a more just and carbon-neutral society.

Does green steel hold promise for reduced carbon emissions?

Iron and steel are integral to society. However, about 10% of global carbon dioxide (CO_2) emissions comes from traditional steelmaking. Prof Charles Siyasiya in the Department of Materials Science and Metallurgical Engineering is particularly concerned about the contribution of steel to the global carbon footprint. An important focus of his research is decarbonisation in steel production, and whether "green" steel holds promise for reduced carbon emissions.

He explains that steel makes up an important component of our daily lives, and will continue to do so. It is used in construction, oil refineries, hospitals, kitchenware, gymnasiums, mining, wind turbines and battery-powered vehicles, and even in coffin handling, to mention a few. Its popularity relates to the fact that it is abundant, versatile, can be recycled without sacrificing its properties, and is relatively cheap to produce.

For the past 150 years, steel has been one of four materials with the most significant global consumption, making up an estimated 2 billion tons per annum. The other materials are cement, plastic and ammonia (as compounds for fertilizers). Until the 1970s, affluent civilizations emerged without advanced computers. This was made possible because of the availability of these four major materials. These materials account for 20% of the global CO_2 emissions, of which 50% comes from steelmaking. If these emissions are allowed to continue at their current rate, global warming will be exacerbated.

The production of a steel coil, weighing 30 tons, emits 60 tons of CO_2. This translates into 33 400 m^3 of carbon emissions per 30 ton coil of steel. Steel is traditionally produced using coal, which decomposes into carbon monoxide and reacts with iron ore to produce iron. This accounts for 95% of global steel production. While the amount of energy used per ton and the corresponding CO_2 emissions of traditional steel have decreased by more than 60% over the past 40 years, progress has stalled, and each ton of steel produced accounts for 2 tons of CO_2. "It is clear that we have reached the limit of efforts to reverse the carbon-intensive effects of traditional steelmaking," he says.

Prof Charles Siyasiya in the Scanning Electron Microcope (SEM) Laboratory of the Department's Industrial Minerals and Metals Research Institute (IMMRI) where he performs steel research.

An alternative route that Prof Siyasiya believes we should be embracing entails the use of hydrogen to reduce iron ore into iron. "Dramatically curbing traditional steelmaking and replacing it with green steel will make a tangible contribution towards curbing increases in global temperature. This is a more sustainable process, he explains, as it emits water vapour as a by-product. However, green steel currently accounts for only 5% of global production.

ADVANCES IN STEELMAKING

Several advances have been made in iron and steelmaking over the years, from the ancient smelters of the Iron Age to the blast furnace that was invented in China in about 200 BC and introduced to Europe in the 12th century. Since then, the fundamental principles have remained the same, except for improved efficiency and CO_2 emissions. A modern blast furnace produces up to 15 000 tons of crude steel a day. The invention of the Bessemer process in 1856 revolutionised steel production and ushered in the industrial revolution of the 1800s. Until the 1950s, energy consumption and CO_2 emissions were not a cause for concern due to the low level of steel production. In 1952, the basic oxygen furnace replaced the Bessemer process.

However, in the last 60 years, the focus has been on reducing the energy consumption per ton of steel and making steel stronger and tougher to reduce the mass of its components, while increasing the payload in pursuit of improved CO_2 emissions to curb climate change. Despite recent improvements, iron and steelmaking remains one of the world's most energy- and carbon-intensive industries.

Work done under Prof Siyasiya's supervision has focused on alloy design, thermomechanical processing and the heat treatment of steel to curb CO_2 emissions. Steel shaping currently contributes 20% of CO_2 emissions in the steelmaking chain (300 kg per ton of steel). This excludes the impact of the mass of steel components and consumables like work rolls.

Three research projects, in particular, conducted by Prof Siyasiya have illustrated the limitations of metallurgical improvements in curbing CO_2 emissions.

Two of the projects were focused on the alloy design of rolls for hot strip mills, while the other focused on steel design and the thermomechanical processing of structural steels.

In the first two projects, he demonstrated that, through alloy design and heat treatment, it is possible to improve the wear rate of high-speed steel rolls by 20%, and by replacing indefinite chilled double-pour cast iron rolls with graphitic high-speed steel rolls, the rolls can last three times longer, reducing CO_2 emissions per ton of steel.

In the last project, he showed how replacing niobium with vanadium by optimising the coiling process can lead to less CO_2 emission per ton of steel. Vanadium is sourced locally and, therefore, has a lower carbon footprint. Vanadium steels require lower slab reheat temperatures and lower mill loads as they are softer. Hence, they bring about more mill stability and less cobble. Therefore, less recycling of defective steel strips is needed, resulting in lower CO_2 emissions per ton of steel. However, all these achievements are not impactful enough to curb CO_2 emissions in steel production because the major culprit is the iron ore reduction process, which is inherently carbon intensive.

THE VIABILITY OF GREEN STEEL

Evaluating the future of steel production, Prof Siyasiya considers whether transitioning from traditional steelmaking processes to green steel is a viable alternative. It appears to be a promising alternative. Where steel currently contributes 10% of global CO_2 emissions, the production of green steel will lead to a 90% reduction in CO_2 emissions from steelmaking, aligning with a 1.5 °C increase in global energy projection by 2050 instead of an increase of 3 °C or more.

However, this comes at a price in terms of energy input, which implies that more energy is required in the production process. This energy must be in the form of clean, renewable energy if the required reduction in carbon emissions is to be achieved. The question that arises is therefore whether we currently have sufficient capacity to sustain the steelmaking industry.

Future research contains several innovation opportunities, and needs to focus on optimising South Africa's hydrogen energy industry chain, as well as repurposing existing hydrogen storage and transportation systems in a cost-effective manner.

However, the transition to near-zero carbon emissions from green steelmaking comes with its own challenges.

He explains that the production of green steel requires hydrogen produced from water using clean and renewable energy from solar or wind turbines. "This would call for massive investments in solar and wind energy." On top of that, green steelmaking still makes use of some carbon, albeit only a fraction of that used in traditional steelmaking.

He explains that, for green steel, carbon is required to lower the melting point of iron, reduce the risk of iron fines catching fire by oxidation and to act as an alloying element. "There are also challenges around the production, storage and transportation of green hydrogen." Another challenge is what to do with existing steelmaking infrastructure and machinery, and whether this can be repurposed.

While green steel has its challenges, these must be viewed as opportunities for innovation, which can only be achieved with the involvement of all stakeholders, including researchers, government and non-governmental bodies, and industry.

Devising environmentally friendly alternatives to taphole clay

Research at the Department of Materials Science and Metallurgical Engineering's Centre for Pyrometallurgy focuses, among other areas, on finding environmentally friendly alternatives to materials produced in the refractory industry.

The research of Izak Cameron (above) focused on finding environmentally friendly alternatives to taphole clay.

One such material is taphole clay, which is used to form a semi-permanent seal in a smelting vessel until it is opened to tap the molten liquid from the smelter or furnace. While sealing the furnace, taphole clay must withstand the hydrostatic pressure from inside the furnace, resist chemical interactions between the clay and the charge, maintain a secure seal, protect and preserve the tap hole and its surrounding area, and ensure that no gases escape through the tap hole, as this could disrupt operation.

Three processes are associated with taphole clay use: ramming, tapping and protection. Closing the tap hole is performed through a ramming process, during which taphole clay is pushed into the tap hole using a mud gun. Opening the tap hole is done through mechanical drilling, ideally with minimal oxygen lancing, followed by tapping, during which the molten charge (e.g. metal and slag) is removed from the furnace. Taphole clay also serves a protective role by shielding the taphole blocks that line the tap hole from flowing liquids.

Taphole clay is a composite carbonaceous monolithic refractory material consisting of aggregates (> 1 mm), a matrix (45 µm to 1 mm), ultra fines (< 45 µm), additives and binders. Typical aggregate used in taphole clays include sintered or fused alumina, calcined bauxite, andalusite, sintered andalusite, calcined kaolinite clay, fused silica, silicon carbide and zirconia-mullite (AZS). Common matrix constituents and additives include filler materials (bauxite, fired andalusite, calcined kaolinite clay), metakaolin, bentonite clay, coal, coke, silicon carbide, zirconia, ferrosilicon nitride, aluminium and silicon.

PhD student Izak Cameron explains that high-temperature coal tar (CTht) and high-temperature coal tar pitch (CTPht) have been used as binders in taphole clays for over 50 years. The binder is used on its own or in conjunction with a temperature-curing resin. The introduction of phenolic resin to the binder system started when stricter holding, drilling and tapping times had to be achieved during furnace operations. However, the use of conventional CTht and CTPht as binders in taphole clays has been under scrutiny for some time as they contain polycyclic aromatic hydrocarbons (PAHs), which are carcinogenic, mutagenic and harmful to reproduction. The health impacts of these binders on individuals working in the taphole area are therefore severe, necessitating legislation to limit exposure to PAHs.

Cameron, under the supervision of Prof Andrie Garbers-Craig and Dr Shatish Ramjee as co-supervisor, identified the need to find an alternative to the binders that are currently used in taphole clay. This aligns with the global desire to reduce the pitch content in binders due to health and environmental concerns associated with prolonged exposure to PAHs. He began his PhD research by determining the critical properties that a binder for taphole

clay should have. He commented: "Since coal tar is very versatile, the challenge is to find the right alternative for the right application, as not all alternatives are universally suitable."

Characterisation of the binders was conducted using analytical techniques to describe the molecular composition and toxicity (Fourier-transform infrared spectroscopy and gas chromatography-mass spectroscopy, both targeted and untargeted), thermal behaviour (thermogravimetric analysis and differential scanning calorimetry) and rheological properties (flow behaviour, including the influence of temperature on flow behaviour). The most suitable alternative non-toxic binders were then identified and evaluated in taphole clay. This evaluation included examining changes in clay plasticity as it ages in air (workability ageing), the extrusion pressure of the mud gun as the clay ages in air, and the strength development profile to simulate the green strength development of the taphole clay. The associated mass change of the clay was also studied to investigate volatilisation behaviour at lower temperatures. Additionally, strength at higher temperatures under a reducing atmosphere was assessed to understand the effect of temperature on clay properties. This test was conducted at 800 °C, as this is the lowest temperature at which the strength of the clay develops solely due to carbon network formation. Strength is most crucial at this temperature, as solid oxide-phase sintering, which further enhances strength, only begins above 1 000 °C.

The selected alternative binders originated from various sources, including coal-based sources (a coal tar pitch-merisol oil blend and a low-PAH synthetic coal tar pitch), petroleum-based sources (a crude waxy oil, a distilled version of the crude waxy oil, and a phenolic-based mesophase-forming pitch), wood and plant-based sources (a beechwood tar and a pinewood tar, both by-products from the Kraft process, and a vegetable tar derived from processed vegetable discards) and a glycerine-resole resin mixture. Analytical techniques, similar to those used in the characterisation of the conventional binder (CTht), were used to rank the alternative binders, with the coal tar reference binder (CTht) produced from destructive coal distillation during coke-making serving as the benchmark.

The results indicated that the binders had molecular structures that were either cyclic aromatic hydrocarbons (aromatic benzene), chain hydrocarbons (aliphatic) or a combination of both. Precautionary measures for exposure to carcinogens in organic binders should address the 16 PAH species defined by the US Environmental Protection Agency (16-EPA-PAH) and eight PAH species defined by the European Union (EU), as both regulatory bodies classify these compounds as hazardous.

A comparative descriptor known as the benzene equivalent (BE) is used to calculate the toxicity of a substance based on the concentrations of the 16 EPA-PAH compounds. The total 16-EPA-PAH content of the evaluated binders ranged from 431 ppm to 19.9 mass%, while the BE values ranged from 0.03 to 1.92, with the coal-based binders (including the reference CTht binder) having the highest toxicity values. The wood-based and glycerine-based binders had 16-EPA-PAH and BE values of zero.

A liquid binder used in a taphole clay should volatilise over a wide temperature range to ensure the establishment of a fine pore size distribution within the clay matrix, which, in turn, enhances the strength and corrosion resistance of the clay. The carbon yield after firing is also important for high-temperature strength development. For these reasons, the ranking of binders first considered the average mass loss, followed by the temperature range over which the mass loss occurred. Thermal analysis indicated an average mass loss for the binders ranging from 0.21 to 1.79 g/°C, with the glycerine-based binder having the highest average mass loss over the narrowest volatilisation temperature range and a low carbon yield. In contrast, the coal-based binders had the lowest average mass losses over wider temperature ranges, with higher carbon yields.

The rheological requirements of a binder system for taphole clay focus on allowing continuous flow of the clay into the tap hole, with minimal variability in extrusion pressure and the ability to maintain a low extrusion pressure. The results indicated that the reference binder (CTht) had Newtonian behaviour and exhibited good thermal stability between 30 °C and 150 °C. The glycerine-resole resin mixture showed similar thermal stability to the reference binder, while the pinewood tar and vegetable tar binders were disqualified as potential binder replacements for CTht due to their limited rheological thermal stability.

The overall ranking of the binders, based on molecular structure (toxicity), thermal properties and rheology, indicated that the glycerine-resole resin mixture, the beechwood tar and the crude waxy oil were the most suitable replacements for CTht in taphole clay. The behaviour of these top three selected non-toxic alternative binders was subsequently evaluated in a taphole clay formulation. Both non-standardised tests (workability and extrusion pressure ageing, hardenability, strength development) and standardised tests (volatile organic compounds, cold crushing strength, apparent porosity, carbon yield) were used to describe the behaviour of the taphole clay and the changes resulting from the binder substitutions.

During pilot-scale manufacturing, mixing procedures revealed that beechwood tar was unsuitable for use in taphole clay, as it failed to form a mouldable clay mass upon mixing. Consequently, only crude waxy oil and the glycerine-resole resin mixture were selected for evaluation in taphole clay. Taphole clay with a glycerine-resole resin binder had the lowest decay in plasticity (7%) and the smallest increase in extrusion pressure (17.5%) during ageing. Thermal ageing results indicated that the glycerine-resole resin binder had the lowest hardenability. Strength development tests showed insufficient strength development for the crude waxy oil-containing clay, as it could not retain its shape after firing. In contrast, the clay with the glycerine-resole resin binder achieved compressive strength values (2.4 MPa), comparable to the reference CTht clay sample (3.1 MPa), and demonstrated a lower release of volatile organic compounds. These evaluations confirmed that the glycerine-resole mixture was the most suitable replacement for CTht in taphole clay.

Prof Garbers-Craig believes this research has provided much-needed information that is currently lacking in the literature. Industry has already expressed interest in alternatives to coal tar as a taphole clay binder to ensure safer and healthier options. Many of the potential alternative binders are by-products from other industries, making them more sustainable and cost-effective options that support a circular economy.

Since it is inevitable that coal tar will be replaced in taphole clays, the next step will be to test these alternatives on a pilot scale and optimise them on an industrial scale. This ultimately illustrates how industry and academia can work together to achieve a more sustainable and healthier future for both the people and the planet.

Prof Andrie Garbers-Craig

Extracting minerals from fine particles to increase mineral beneficiation

With the important role that the mining industry plays in South Africa's economy, it is essential that as much of the mineral ore as possible is extracted and processed. This includes the recovery of valuable minerals from smaller pieces of ore, known as fine particle beneficiation. As the high-grade ore that is relatively easy to extract becomes depleted, it is becoming increasingly necessary to develop techniques to extract the finer ore that is left behind. In this way, the full potential of our country's mineral resources can be maximised.

The liberation of finely disseminated ores, the generation of fines due to ore breakage characteristics, and the recovery of valuables from fine tailings streams are among the key challenges faced in the process of fine particle beneficiation. As particle size decreases, conventional gravity separation methods become less effective, while alternatives such as centrifugal separators prove costly alternatives. Innovative solutions are therefore required to overcome these challenges.

A PROMISING SOLUTION

According to Wynand Roux, a lecturer in the Department of Materials Science and Metallurgical Engineering, the REFLUX™ classifier[1] has emerged as a promising system to treat high tonnages of fine materials, especially in the coal and chrome industry. The apparatus was designed by Prof Kevin Galvin of the University of Newcastle in Australia, and is marketed by the multinational company FLSmidth & Co, based in Denmark. It offers potential benefits across various fine ore applications. However, operators need to optimise its design and operating parameters to unlock its full potential in specific applications. With the financial support of Anglo American, the Department was able to construct a lab-scale apparatus using 3D printing and other techniques.

The REFLUX™ classifier is an advanced fine-particle, gravity-based separator, which offers significant advantages in terms of capacity, adaptability and efficiency. However, like most gravity separation methods, its separation mechanisms are complex due to the many variables that affect the process's hydrodynamics. This includes the particle properties (size, density and shape), operating conditions and design variables. It incorporates a laminar high-shear rate mechanism to separate fine particles based on the difference in their density or particle size. It is typically used for coal, chrome and iron ore.

As a liquid fluidised bed separator that is combined with a laminar settler, it was developed specifically for the beneficiation of fine ore. "It makes use of an interesting concept called the Boycott effect," explains Roux, "that significantly increases the throughput rate compared to alternative techniques." Other advantages include its enhanced separation efficiency, compact design and low operating costs.

According to the company's description of its product, it combines a conventional fluidised bed separator with a set of parallel inclined plates that form lamella channels. The feed slurry enters the system below the lamella plates via internal feed chambers. As the fluidised bed builds up in the mixing chamber, material with a density higher than the bed will sink, whereas material with a density lower than the bed will float. As a higher-density bed of settling solids forms,

1 *https://www.flsmidth.com/en-gb/products/centrifugation-and-classification/reflux-classifier*

Dr Wynand Roux extracts minerals from fine particles in the Department's Mineral Processing Laboratory.

jets of incoming fluidisation water keep the material in suspension at the bottom of the mixing chamber. Two pressure probes in the mixing chamber's lower/middle section are used to calculate the fluidised bed's density.

The system uses the relative density of the fluidised bed between the two probes to determine the discharge rate of the high-density solids via a single central underflow valve. The underflow contains high-density particles, which are generally coarser than the feed. At the same time, the course and fine low-density particles that may have been trapped in the dense fluidised bed rise due to their density differential, and eventually migrate to the lamella section of the classifier. The low-density and fine particles tend to overflow from the lamellas in their first pass, along with most of the process water and any slimes.

Fine heavy particles in suspension below the lamella section form an autogenous dense medium, which aids the separation of the slightly denser and larger particles within the vessel, enabling them to rise and be displaced to overflow. The internal launders at the top of the classifier direct the overflow slurry into a single discharge "overflow" collector. The lamella channels enhance the settling rate of any misplaced fine, high-density particles, which slide down the plates and slowly recirculate into the autogenous zone of the mixing chamber.

THE RESEARCHER IDENTIFIED NUMERICAL MODELLING AS A POWERFUL APPROACH TO EVALUATE THE SYSTEM'S DESIGN PARAMETERS WITHOUT THE NEED FOR EXTENSIVE PHYSICAL PROTOTYPING. VARIOUS NUMERICAL METHODS CAN SIMULATE MULTIPHASE FLOWS WITH GRANULAR COMPONENTS, AMONG WHICH DEM AND CFD ARE PROMINENT. AS CFD DISCRETISES THE FLUID DOMAIN INTO A MESH AND SOLVES GOVERNING EQUATIONS AT EACH GRID POINT, THIS METHOD WAS CHOSEN TO SIMULATE FLUID BEHAVIOUR AND TEST THE APPLICABILITY OF THE CLASSIFIER IN SPECIFIC INDUSTRY APPLICATIONS.

OPTIMISING THE SYSTEM'S OPERATING PARAMETERS

Roux explains that various fine ore applications can benefit from treatment with a system such as the REFLUX™ classifier. However, laboratory and pilot-scale testing on many of these ores show poor efficiencies and recoveries. He is of the opinion that a better understanding of the design, operation and mechanisms of the classifier will determine if and how it can fit into different applications. He therefore embarked on a series of laboratory experiments to test its suitability for industry application, particularly by Anglo American.

Operating on the principle of a fluidised bed with stacked lamella channels, the classifier diverts suspended particles from the fluidised bed overflow directly into these channels. Here, particles experience enhanced settling rates due to an increased effective settling area and reduced settling distance before returning to the fluidised bed via gravity. This mechanism minimises the bypass of fine, high-density particles to the overflow, thereby boosting throughput significantly.

The aim of his study was to gain insight into how the classifier's variables affect the separation of particles in a lab-scale fluidised bed separator based on the design of the REFLUX™ classifier using multiphase modelling to investigate how the ratio between the horizontal cross-sectional area of the incline channels and fluidised bed (the area ratio) affects separation. Altering this ratio modifies the velocity within the lamella channels without affecting fluidised bed velocity, which potentially leads to efficiency improvements. "The fluidised bed needs a fluidisation velocity at least high enough to maintain a fluidised bed, while the lamella section needs a velocity that can transport the light fraction to the overflow," he explains.

Roux identified numerical modelling as a powerful approach to evaluate the system's design parameters without the need for extensive physical prototyping. "Various numerical methods can simulate multiphase flows with granular components, among which discrete element modelling (DEM) and computational fluid dynamics (CFD) are prominent." As CFD discretises the fluid domain into a mesh and solves governing equations at each grid point, this method was chosen to simulate fluid behaviour and test the applicability of the classifier in specific industry applications.

He explains that, for effective validation, the model needs to accurately predict both the suspension density within the fluidised bed and the position where solids settle in the lamella channel. This was achieved with the CFD simulations.

All simulations were conducted in 2D to balance computational efficiency and accuracy following recommendations from prior research on two- and three-dimensional computation studies of liquid-solid fluidisation conducted by researchers from the North China Electric Power University and the China University of Petroleum in Beijing, China, and the University of Edinburgh, UK. Two sets of simulations were executed. The first was aimed at model verification using experimental data obtained from research on the influence of inclined plates on the expansion behaviour of particulate suspensions in a liquid fluidised bed conducted by researchers from the University of Newcastle and the University of Sydney in Australia. The second explored the area ratio of a specially designed inclined fluidised bed.

Roux subsequently evaluated three geometries, with two, three and four channels, respectively, tested on ilmenite and silica particles with average sizes of 150 µm, and densities of 2 650 and 4 600 kg/m^3, respectively. Silica and ilmenite were chosen as an ideal case, as it is easier to simulate than other more complex ores. In all three cases, the ilmenite volume fraction at the bottom of the bed was similar. However, the settling distance of the ilmenite in the channel was greater with a smaller area ratio, and smaller with a larger area ratio, which aligned with the expected changes in liquid velocity as the area ratio varied.

The inlet liquid velocities were adjusted to equalise the channel velocity across the three geometries. The settling distance of the ilmenite in the channel became nearly identical for all three cases because of the similar velocities in the channels. In the lower part of the inclined fluidised bed, higher ilmenite volumetric fractions were obtained with lower inlet velocities. Smaller volumetric fractions were obtained with lower inlet velocities. Increased velocities in the fluidised bed section led to more ilmenite entering the channels, which then settled quickly due to the reduced velocity in the channels. The simulation suggested that the optimised inlet velocity can enhance particle segregation and reduce undesired settling of the ilmenite in the channels.

Based on the simulations performed, Roux considers it clear, at this time, that the area ratio has a significant effect on the segregation inside the inclined fluidised bed. This can be a very important variable that might improve the separation efficiencies for applications that have been difficult to treat in the conventional REFLUX™ classifier.

Developing a system to monitor and track particles in a slurry

Minerals and materials beneficiation is an important research area in the Faculty of Engineering, Built Environment and Information Technology. It is, however, not only researchers in the departments of Materials Science and Metallurgical Engineering, and Mining Engineering that are devising more efficient ways to extract minerals and/or improve current understandings of extractive processes.

TRANSDISCIPLINARY RESEARCH FACILITATES BROADER IMPACT

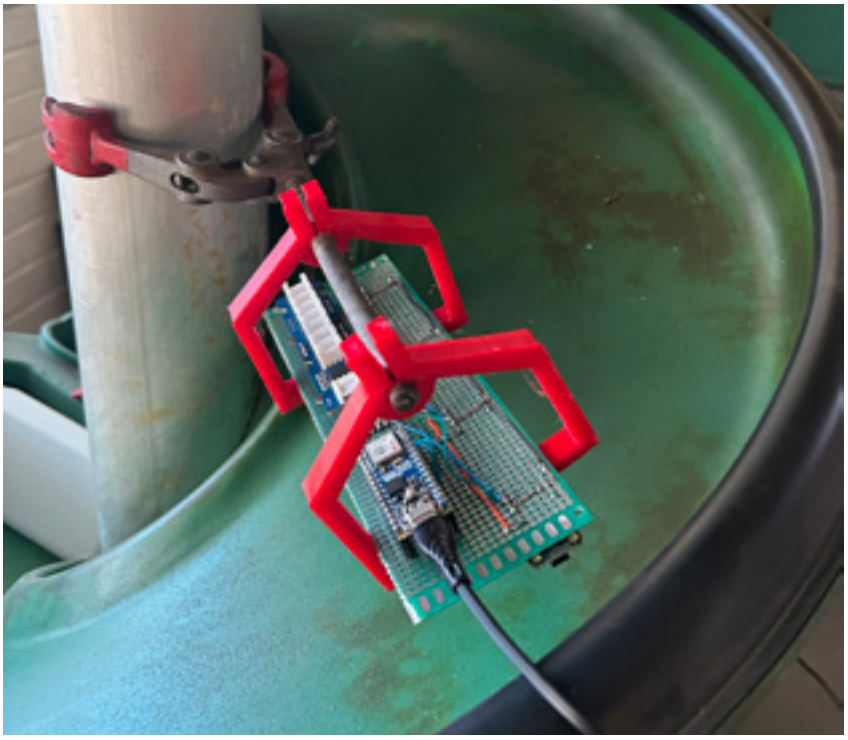
THIS PROJECT WOULD NOT HAVE BEEN POSSIBLE WITHOUT THE COLLABORATION BETWEEN THE TWO ACADEMIC DEPARTMENTS.

Transdisciplinary research in the Department of Electrical, Electronic and Computer Engineering, and the Department of Materials Science and Metallurgical Engineering has developed novel methods to monitor and track mineral particles in mineral slurries (a mixture of fine mineral particles and water, which is non-transparent).

A spiral concentrator is an example of gravity-separating equipment used widely in the minerals processing industry to separate high- and low-density minerals. Up to 8 000 tons of material can be processed per hour in a spiral plant, which translates to around 2 000 spirals operating simultaneously. Even small improvements in the recovery efficiency of these plants would result in higher revenue and a reduction in environmental impact.

Currently, the operations in spiral concentrator plants can only be visually inspected to determine their operational efficiencies. Such inspections are of relatively limited value due to the inability to measure what is happening inside each spiral concentrator. While various theories and models exist to describe the movements of different density particles in spiral concentrators, these theories are limited by a lack of measurements of these particle movements.

The aim of this research project was thus to determine whether a system could be designed to monitor and track a tracer particle with properties comparable to those of real mineral particles in an opaque slurry on the surface of the spiral concentrator.



Under the supervision of Prof Natasia Naudé, Xander Wehmeyer, a student in Materials Science and Metallurgical Engineering, examined the possibility of manufacturing tracer particles for *in-situ* particle trajectory tracking in three dimensions for his final-year research project.

He explains the context of this work. "Mineral processing entails treating crude ore and mineral products to separate valuable products from waste." Many attempts have been made to theoretically describe the behaviour of particles inside equipment such as spiral concentrators, he says. "However, these theories cannot be validated as one cannot measure what is happening inside the slurry and the equipment."

The aim of Wehmeyer's project was to manufacture detectable tracer particles that match the physical properties of the mineral particles in a spiral concentrator. Tracking these tracer particles would serve to validate empirical theories on the performance of spiral concentrators. This can only be achieved using in-process tracer particles of different shapes, sizes and densities that are detectable within the slurry.

The second part of this research, tracking these tracer particles, led to collaboration with Surica Naudé, a Computer Engineering student, who was conducting her final-year project under the supervision of Prof Warren du Plessis. She developed a particle-tracking system to determine the movement of the tracer particles manufactured by Wehmeyer in a slurry. Her focus was on developing an algorithm to be able to trace the detectable particles within a slurry.

Wehmeyer manufactured magnetic tracers that contained magnetite, silica and resin, and rare earth elements in the solid component of the tracer. The first test was to determine what ratio of resin to solids (silica and magnetite) would result in tracers with little or no segregation, good magnetic properties and high tensile strength for different density classes. The second set of tests was to determine the influence of different ratios of silica to magnetite on the densities of the tracers. It was concluded that detectable tracers, which are representative of real mineral particles with different sizes, shapes and densities, could be manufactured. The novelty of the tracers that he developed lies in the fact that he was able to manufacture tracers that are smaller than 1 mm and have an extremely low cost. By comparison, existing tracers are both significantly larger than mineral particles (with fixed shapes), leading to inaccurate measurements, and are far too costly to allow large-scale use.

Explaining her interest in conducting research on the same dilemma in the mining industry, Naudé says she was fascinated by the idea of overcoming the challenge experienced with spiral concentrators. If the movement of particles in slurry could be determined, changes could be made to the process to achieve a higher efficiency rate. "A higher efficiency rate will lead to better recovery of the valuable particles in the slurry," she says. "This will lead to increased profit margins, while having less of an impact on the environment." The drawbacks of visual inspections on the spiral concentrator operations can be addressed by introducing a traceable particle and a suitable tracking system. "The development of such a system could even lead to an automated inspection process," she says.

Her research therefore continued with the magnetic tracer particles that had been introduced by Wehmeyer in his research, using magnetic field sensors to determine the position and velocity of the tracer particles. She believed that the particle position and velocity could be calculated from the measured magnetic field strength captured by magnetometers.

She admits that the system she planned had certain design challenges. It required magnetometers to detect the measured magnetic field strength of the environment and relate that to the movement of a magnetic tracer particle. She explains that a complex relationship exists between the position of the magnetic tracer particle and the measurements, as the tracer would also detect other magnetic disturbances. "The challenge therefore lay in removing the effects of any other magnetic materials from the measured magnetic field strength, and relating it to the particle's position and velocity."

One of the biggest challenges was in relating magnetic field strength to distance, while still maintaining accuracy in the results. Naudé therefore focused on tracking the movement of a particle inside the slurry using a magnetic particle, along with several magnetometers. "When the magnetic particle moves past the magnetometers," she explains, "a disturbance is detected relative to the earth's magnetic field strength. This disturbance can be used to determine the relative position of the particle in the slurry."

The development of this system therefore involved a combination of hardware and software to determine the path travelled by a particle and its velocity, while computing the slurry's velocity. The hardware Naudé developed integrated different devices to detect the magnetic particle moving in a slurry. She also implemented a mapping algorithm to relate the magnetic field strength of a particle to distance and velocity. This enabled her to determine the three-dimensional parameters of the particle in a slurry. The calculation of the surface velocity measured the dense optical flow of the moving surface and related it to its velocity. Visualisation showcased the movement of the slurry using a system of lines. She conducted several tests to determine the reliability of the system by capturing results in real-world field conditions.

The results showed that the path travelled by a particle and its velocity was successfully estimated.

Prof Warren du Plessis (left), Prof Natasia Naudé (centre) and Surica Naudé made use of a spiral concentrator to track particles in a slurry.

This system created a good foundation to detect particles in a spiral concentration plant. Future research can focus on detecting even smaller particles, as well as capturing more measurement samples between the respective sensor arrays to improve the fidelity of the measurements. This approach also has the potential to be developed into a system that can be used by industrial spiral concentrator plants.

Naudé states that this project would not have been possible without the collaboration between the two academic departments. The development of the magnetic particle by Wehmeyer in the Department of Materials Science and Metallurgical Engineering enabled the implementation of her project.

An outcome of her research was that she was able to develop a novel system that makes use of magnetic particle tracking (MPT) to track tracer particles in a slurry for the first time. This novel system of MPT is also inexpensive to manufacture, and relatively easy to install and recover.

Laboratory studies seek to increase beneficiation and improve the purity of platinum and other minerals

South Africa is the world's largest producer of platinum, holding approximately 70% of the world's platinum reserves. Research conducted by Mfesane Tshazi, a member of the Department of Materials Science and Metallurgical Engineering, is responding to some of the challenges experienced in the flotation industry, while focusing on the most efficient way of extracting valuable minerals and removing impurities from platinum and other mineral-bearing ore.

His research relates to the separation and beneficiation of minerals using froth flotation in laboratory batch scale cells. Batch flotation tests have contributed considerably to industrial process development and troubleshooting in the mining industry. Tshazi explains that engineers use findings from these tests, coupled with appropriate scale-up factors, to design flotation equipment and construct process flowsheets. A major limitation of batch testing, however, is the poor correlations between data gathered in the laboratory and that obtained at plant-level. This discrepancy can be attributed to equipment configuration differences between laboratory setups and full-scale plants, as well as operational parameters.

"Despite these issues," says Tshazi, "research continues to investigate ways in which batch test results may more accurately predict plant-level outcomes, while accounting for factors such as particle size distributions or reagent concentrations." Correlations between laboratory-scale experiments and plant-scale implementations can become more reliable and provide greater confidence when scaling up new processes or troubleshooting existing processes within an industrial setting. Technologies that offer a higher level of reproducibility and that accurately correlate data to the industrial scale will allow for the automation of processes.

Froth flotation, as a method to concentrate valuable minerals, forms part of the process of extracting platinum from the ore. Laboratory flotation cells are commonly used to perform and establish processing procedures. Tshazi's research specifically examined the performance differences between two common laboratory flotation cells (the Denver and the Leeds) when separating minerals from waste or broken ore of different particle size fractions. In addition to examining the effect of particle size, he also analysed hydrodynamic parameters, such as air flow rate and impeller speed, during operation to understand the contributions of these parameters in achieving optimal performance. He hypothesised that the recovery of minerals by flotation depends on the type of laboratory flotation cell used.

When the froth flotation technique was established in 1906 as a method to treat fine minerals below the particle size limit of gravitation beneficiation processes, it revolutionised the metallurgical industry. The process was initially developed to beneficiate sulfide minerals, explains Tshazi. "Froth flotation is an important metallurgical operation that allows for the separation of valuable minerals from waste ore." Research and modifications have enabled its application to several types of minerals, from simple materials like coal to low-grade complex ores. Non-metallurgical applications, such as water treatment processes, have also benefitted from flotation techniques.

Many of the crucial fundamental parameters of froth flotation are determined from laboratory tests conducted using laboratory flotation machines. Tshazi explains that a laboratory flotation test provides a

quick snapshot of performance that can be expected at a pilot scale, and further at the industrial scale, based on a small sample (approximately 2 kg of ore). Bench-scale experiments and ongoing research are used to collect useful data that helps to better understand the many factors that influence a froth flotation process. Testing in a laboratory forms an integral part of designing froth flotation processes and improving operational performance and efficiency.

The batch flotation procedure involves filling cells with slurry (solids and water), which is mixed and suspended by an impeller (a driven rotor that continuously converts torque energy into fluid flow). In a typical mechanical laboratory cell, the hollow impeller shaft pipe acts as a channel to transport air into the cell. As air reaches the rotating impeller, it is sheared into small bubbles. Appropriate reagent suites are added to the pulp.

The air bubbles collide with particles in the pulp and become attached to the hydrophobic mineral particles. Other minerals remain in the pulp. Stable aggregates of a bubble and hydrophobic mineral move upwards into the froth layer due to buoyancy forces, where they are removed into the concentrate tray. The concentrates are generally removed at regular intervals to evaluate the process kinetics. Hydrophilic materials that remain in the pulp are removed as tailings.

The concentrated valuable minerals from flotation are typically subjected to downstream extraction steps, such as dewatering, followed by pyrometallurgical and/or hydrometallurgical processing. Chemistry plays a significant role in this process as flotation reagents modify the surface properties of particles and bubbles, enhancing separation efficiency. Hydrodynamics must also be considered when designing a successful flotation system.

Mfesane Tshazi performs research in the Department's Flotation Laboratory.

This comprises air and slurry flows, particle suspension, bubble dispersion and energy dissipation or turbulence intensity, which can affect particle behaviour, depending on particle size distributions within the flotation cell. Operational variables, such as mineralogy, particle size and pulp density, must be optimised to ensure maximum recoveries.

Although most minerals are hydrophilic (can be wetted in water), for flotation, the minerals need to be rendered hydrophobic (able to repel water) for concentration purposes. This process generally relies on the use of chemicals to ensure selective separation between the pieces of ore and valuable minerals. Many mineral industries report overall flotation recoveries of between 80 and 90%. The selection of an appropriate technique for the concentration of an ore to achieve adequate mineral separation depends on several factors, including ore properties (size, liberation, shape, specific gravity and colour), electrical properties, magnetism, radioactivity, surface composition and texture.

Froth flotation is a complex process with many influencing factors and interdependent interactions. A change in a single variable can typically impact other variables. There could be as many as 100 interdependent variables. Tshazi focused on particle size and agitation as the primary variables in his study, while other variables were kept constant.

His intention was to limit complexity and avoid bias during the interpretation. He chose a non-conventional route by using a single mineral – quartz – for the test work comparison. His selection of quartz for the laboratory experiment was based on it being a strongly hydrophilic mineral, which requires chemical activation. This ensured consistent mineralogy, resulting in uniform hydrophobicity. Any observed variations in flotation performance could be attributed to differences in impeller design, which significantly affects the hydrodynamics and flotation behaviour of both coarse and fine particles.

The testing conditions were carefully optimised and refined by calibrating the impeller's rotational speeds. This was done to ensure that the cells were operating at the same level of performance.

Similar performance was obtained at 1 200 rpm for the Denver cell and 1 400 rpm for the Leeds cell. The difference in operating speeds required to obtain similar results may be attributed to the different impeller designs, which influence the manner of air bubble creation in the cells and mineral recovery. With the optimised conditions in place, the focus shifted to comparing the effect of particle size and assessing the hydrodynamic conditions of these cells.

Tshazi compared the performance between the two different laboratory flotation cells (the Denver and the Leeds), using four varying particle size ranges: fine (-25 µm), intermediate (+25–45 µm), medium (+45–75 µm) and coarse (+75–106 µm).

The test work also showed that particle size has a significant influence on mineral recovery. Finer particles require more reagents and longer flotation times for optimal recovery. Process efficiency can therefore be improved by understanding how best to optimise particle size distribution. The Denver cell was found to perform better than the Leeds cell for this particular application as the Leeds cell required a higher impeller speed to yield similar recoveries. The laboratory Denver cell appeared to effectively handle all size fractions. The impact of cell design, particularly impeller efficiency, therefore becomes more pronounced at smaller particle sizes. The Denver cell ultimately reported higher recovery rates across all test ranges with faster kinetic rates.

In addition to evaluating kinetic performance across various particle size fractions, the flotation cells were assessed using several metrics, including dimensionless numbers (such as Power and Reynolds numbers), chemical tracer tests and critical speed evaluations, ranging from 1 000 to 1 500 rpm.

Dimensionless numbers are calculated by considering operational variables like impeller rotational speed, volumetric airflow, pulp density and dynamic viscosity, as well as geometric variables such as impeller diameter. These numbers provide a useful tool to analyse the flow characteristics of fluids (hydrodynamics) within a cell.

When comparing the Reynolds and Power numbers for the Denver and Leeds impellers, the Denver impeller showed a remarkable ability to overcome the resistance posed by solid particles. This is evidenced by its Power number rapidly approaching the fully turbulent regime, a characteristic not observed in the Leeds impeller under the same experimental conditions. These findings suggest that the Denver cell produced consistent fluid fields, while consuming power more efficiently.

The experiments revealed that the Denver and Leeds cells must be operated at different rotational speeds (1 200 rpm and 1 400 rpm, respectively) to achieve similar performance. This difference is supported by the higher Power number values required by the Leeds impeller, which dissipated significantly more power just to create flow.

In contrast, the Denver impeller, operating under fully turbulent conditions, efficiently converted torque into flow, enhancing bubble dispersion, particle dispersion and particle-bubble interactions.

A chemical tracer (NaOH) was used to assess the mixing efficiency of the impellers, evaluating their ability to pump or circulate substances. The data from these tests indicated that both impellers experienced minor flow rate improvements as impeller speed increased.

However, operating at higher impeller speeds did not significantly enhance fluid pumping or circulation, suggesting similar capabilities in this regard.

The critical impeller speed, or 1-s criterion, is the minimum speed at which all solids are suspended from the tank's bottom. This was used to assess the suspension status of the +45 to 75 µm-sized fraction at various solids concentrations.

The critical impeller speed was achieved at 600 rpm for the Denver cell, while the Leeds cell required double this speed. These results indicate that the Leeds cell is more adversely affected by air and requires higher rotational speeds to achieve complete suspension. Additionally, the Denver cell was less affected by increasing solids content, making it more energy-efficient for suspending the same mass of solids. Therefore, the Denver cell is a better choice for applications requiring higher solids content due to its superior efficiency and lower energy requirements.

The Denver flotation cell demonstrated superior performance compared to the Leeds cell, achieving higher recovery rates with lower power consumption.

This efficiency is attributed to the effective design of its impeller and stator, which allowed it to overcome the resistance of the slurry and operate at optimal levels, surpassing the capabilities of the Leeds cell. The inferior performance of the Leeds cell is attributed to several factors, including its design and air input mechanism.

The superior performance of the Denver flotation cell can be attributed to its more versatile hydrodynamic characteristics, making it better suited to handle a broader range of particle sizes. This also makes it the ideal choice for benchmarking laboratory tests.

Finding homegrown solutions for South Africa's unique challenges in the mining industry

Despite South Africa's prevailing electricity shortages, logistical problems and low commodity prices, the mining industry remains a key contributor to economic prosperity. The Department of Mining Engineering focuses on conducting world-class research to meet the unique challenges of the South African mining industry.

Prof Francois Malan, Head of the Department of Mining Engineering, remarks that this is not the first time that the South African mining industry has had to survive exceptionally difficult periods. "With ingenuity, and a bit of luck, we always seem to pull through." In the 1960s, for instance, the gold price was artificially low due to the actions of the London Gold Pool to defend the price of US$35 per ounce. Many of South Africa's marginal gold mining operations had to close. The strong mining units survived, however, and did exceptionally well during the gold boom that followed in the 1970s.

South Africa is currently ranked first in the world for chromium, manganese and Platinum Group Metals (PGM) reserves; fourth for gold reserves; and sixth for coal reserves. These commodities will always be in demand and the South African industry needs to develop economically viable mines. Part of building this resilience, explains Prof Malan, is to ensure that we conduct the necessary research to improve our productivity and lower our production costs. In its 1995 report, the Leon Commission of Inquiry into safety in the mining industry stated:

> *...as no other region of economic significance has similar geometry, no mining industry outside South Africa pursues the solution to this problem.... The solution must therefore be found in South Africa.*

Now, almost three decades later, the solution still lies in conducting world-class research to solve South Africa's mining challenges. This is accompanied by a need to establish and maintain research groups to

contribute to the generation of new knowledge. With the demise of the historically important mining research centres in South Africa (the Chamber of Mines Research Organisation and the Council for Scientific and Industrial Research (CSIR) Miningtek), the Department of Mining Engineering has become a key player to rebuild and grow the country's mining research capacity and find solutions to its problems. The Department's research therefore endeavours to increase the productivity and safety of the country's mines. "The focus must be on homegrown solutions for South Africa's unique challenges," explains Prof Malan.

The Department has four key research areas: mechanisation and automation, management and leadership, rock engineering and extended reality technology.

MECHANISATION AND AUTOMATION

The Department's longstanding association with the South African Mining, Extraction, Research, Development and Innovation (SAMERDI) initiative has given rise to several projects in the Mechanised Mining Systems programme.

This collaborative venture with the CSIR, the University of the Witwatersrand and the University of Johannesburg is coordinated by the Mandela Mining Precinct (MMP).

The Department's involvement in this initiative received a boost in 2021 when the MMP announced that it had selected UP to host its new Research Activity in Mechanised Mining Systems (RAMMS). This is managed as a multidisciplinary research initiative between the Department of Mining Engineering and the Department of Mechanical and Aeronautical Engineering. Such initiatives will stimulate the increase in research activities in the mining industry even further.

Research thrusts that are pursued in this research initiative include the cutting and drilling of hard rock, the productivity and maintenance optimisation of mining equipment, and the utilisation, performance and condition monitoring of mechanised mining equipment.

Prof Malan explains that many of South Africa's ore bodies have a tabular, flat dipping nature. This geometry is found in the coal, gold, platinum, chrome and manganese mines. This makes the mechanisation of hard-rock mines with a small mining height very difficult, and exacerbates the seismic problem in deep gold mines. Finding solutions to these challenges underpins many of the Department's research projects. The aspect of layout and pillar design in the platinum, chrome and manganese mines is another active research area.

MANAGEMENT AND LEADERSHIP

The research projects in leadership relevant to mining range from acceptance of technology by leaders of the safety and risk leadership that is required to navigate the impact of the Fourth Industrial Revolution on South African mining companies.

Doctoral research conducted by Dr Manie Kriel, CEO of VBKOM engineering consultants, for example, proposed a new integrated dispensation model to unlock the value-adding potential of the junior mining sector in South Africa. Comparing the situation in South Africa to an international case study, he showed that a well-established and well-supported junior mining sector holds the key to creating 50 000 additional direct mining jobs and 350 000 secondary jobs. These jobs can contribute substantially in additional taxes to the state, which can benefit the country in terms of the maintenance and building of national infrastructure.

ROCK ENGINEERING

A key aspect of research in rock engineering is the development of new design criteria and layouts for hard rock mines to ensure their sustainability. Improved formulae and methods for designing hard rock pillars are being investigated. Close collaboration has been established with leaders in the mining industry like Northam Platinum, Impala Platinum and Harmony Gold.

Through the support of Harmony Gold in the form of a Research Chair in Rock Engineering, the Department is recognised as a leader in this field. The Research Chair investigates techniques to simulate the rock mass behaviour

in South African deep-level gold mines. It is the only research programme currently conducted in South Africa to develop the rock engineering tools to improve safety in and the profitability of the deep tabular gold mining industry. Important aspects related to this research include locally developed numerical modelling software, enhanced design criteria to improve layouts, better tools to study which pillars and remnants can be mined safely, and better simulation of closure rates for enhanced support design in seismic conditions.

A numerical investigation of asymmetrical pillar contact stress and a weak internal layer, for example, revealed that contrasts in material properties can play a vital role in determining the design strength of pillars. The development of a particular numerical technique using a crack strain density plot provided a useful device to compare the damage patterns that arise in different cases.

The study focused on determining the primitive stress field in shallow depth mine workings that are established below a variable surface topography. This highlighted several significant problems related to the specific assumptions that are made concerning the geological processes that have occurred in the formation of the current surface features. As a solution, a specific prior "paleo" stress state was assumed. This made it possible to calculate the perturbations that are induced when the current surface topography is represented by an explicit mesh tessellation within an elastic region that is sufficiently extensive.

The main difficulty that arises in this situation is the appropriate choice of the assumed initial stress state that can significantly affect the calculated stress perturbations. The need to represent the extended surface is present, as well as several numerical difficulties that have not yet been fully resolved. In particular, it is not possible to use existing lumping techniques on non-planar surfaces. It may also become necessary to introduce local element shape function enhancements when calculating near-surface stress values.

EXTENDED REALITY TECHNOLOGY

Extended reality (XR) technology is a new research focus in the Department. It gained momentum with the establishment of the Exxaro Chair in XR Technology. Although formally housed in the Department of Information Science, the interdisciplinary research in this field will benefit more than just the mining industry. It has three main focus areas: developing the proof-of-concept application of XR systems within the Exxaro Group, using Exxaro's test sites to evaluate the effectivity of XR interventions, and establishing the viability of these interventions within the mining industry. The intended outcome is to improve productivity through the use of this technology.

XR technology has been identified as a mature and innovative tool since the economic upheaval of COVID-19 forced companies to invest in emerging technologies to aid recovery. Research in this area by master's student Sihle Buthelezi revealed that early adopters are seeing significant benefits in learning, training, immersive data visualisation and remote assistance. In South Africa, the mining industry is increasingly interested in using extended reality to optimise and innovate operations.

Citing the Minerals Council of South Africa's July 2021 report, which highlighted the potential of extended reality to achieve zero-harm production and to modernise the industry, he discovered that the extent of extended reality adoption in mining remains unclear due to limited information on its usage.

His study addressed this gap by distributing an online survey to assess awareness, knowledge and current uses of extended reality in South Africa's mining sector. The results indicated that virtual and augmented reality had the highest levels of awareness and usage, primarily for learning and training. Mixed reality had the lowest awareness and knowledge levels. In terms of applications, visualisation and remote assistance had the least use cases. These findings highlight that the South African mining industry is deficient in its understanding and use of XR technologies. Without better awareness and application, the South African mining industry risks missing out on the full benefits of extended reality.

CROSS-DISCIPLINARY RESEARCH

The Department furthermore engages in cross-disciplinary research, which is facilitated by its Mining Resilience Research Centre (MRRC). Its activities are aimed at revitalising mining research, development and innovation in South Africa to ensure the sustainability of the industry. Through research initiatives such as these, the Department is enthusiastic about developing the next generation of mining engineering researchers to benefit the South African mining industry.

National recognition for Department's mining research

The Department of Mining Engineering's expertise in rock engineering has once again received national recognition. During the annual awards ceremony of the South African National Institute of Rock Engineering (SANIRE), which was held in Johannesburg on 28 September 2024, the University's team walked away with three important prizes, including the highest accolade that the Institute awards. Its top researchers also earned a gold medal from the South African Institute of Mining and Metallurgy (SAIMM).

SANIRE AWARDS

Napier Award

Prof Francois Malan, Head of the Department of Mining Engineering, was awarded the Institute's Napier Award. This is the most prestigious prize to be awarded by SANIRE. It was instituted to honour the outstanding contribution to rock engineering made by Prof John Napier (an extraordinary professor in the Department of Mining Engineering) over many decades. This award is typically made every four years in recognition of distinguished contributions to the field of rock engineering. The requirements for the award include the performance of world-class research in rock mechanics over a period of many years, research that has contributed significantly to the development of aspects such as new design criteria, analysis methods, design methodologies or new technology, and extensive publication in local and international journals.

Salamon Award

Prof Francois Malan and **Prof John Napier** were the joint recipients of SANIRE's Salamon Award. This prize is awarded to the South African authors of the best technical paper published in 2024. Preference is given to papers published in accredited, refereed journals. Prof Napier received this award in 2012, while Prof Malan has received it on three previous occasions as a joint winner: in 2012, in 2017 and in 2018.

Ortlepp Award

Divine Ile, a master's degree graduate, who received her degree *cum laude* at the University's winter graduation ceremony in May 2024, received SANIRE's Ortlepp Award. This prize is awarded to the best technical paper to be published by a "young" South African (under 35 years) in 2024. Preference is given to papers published in accredited, refereed journals.

Student Award

Karabo Mamaregane, a final-year student in the Department of Mining Engineering, was recognised as the top university student in Rock Engineering. This award is given to students who receive the top marks in the final-year Rock Mechanics module at the University of Pretoria and the University of the Witwatersrand.

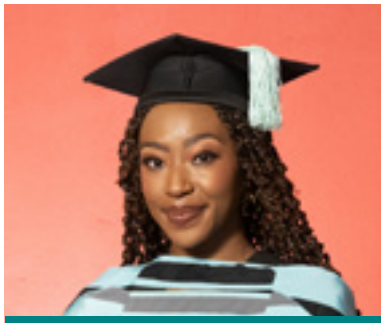
SAIMM AWARD

Gold medal

The Department's top researchers, **Prof John Napier** and **Prof Francois Malan**, also received a gold medal from the South African Institute of Mining and Metallurgy at the Institute's annual general meeting, which was held in Johannesburg on 22 August 2024. They received this award for their paper titled "Numerical simulation of large-scale pillar layouts", published in the May 2023 issue of *SAIMM Journal*. This medal is awarded for papers that are of a world-class standard and are judged to be publications that will become key reference works in the mining field in the future.

Prof Francois Malan

Prof John Napier



Divine Ile

Karabo Mamaregane

Electrifying an urban delivery fleet

THE TRANSPORTATION SECTOR IS RESPONSIBLE FOR AS MUCH AS

16.2%

OF GREENHOUSE GAS PRODUCTION GLOBALLY

The transportation sector is one of the primary sources of CO_2 emissions and is responsible for as much as 16.2% of greenhouse gas production globally. In addition to the environmental and social obligation of lowering CO_2 emissions, a lower carbon footprint can lead to increased investment opportunities as investors progressively recognise environmental, social and governance issues when allocating their resources.

Collaborative research conducted by researchers in the Department of Industrial and Systems Engineering's Centre for Transport Development and the Institute for Mobility in KU Leuven in Belgium's Centre for Industrial Management evaluated the viability of using electric vehicles for distribution fleets to mitigate the effect of fuel-driven vehicles on the global carbon footprint.

In an effort to reduce their impact on the environment, many transportation companies are already using electric vehicles. This observed increase in electrified fleets worldwide can also be attributed to the advantage of reducing a company's long-term life cycle costs. According to Prof Johan Joubert of KU Leuven, formerly associated with UP's Department of Industrial and Systems Engineering, electric vehicles are generally more expensive than fuel-driven ones. However, they are accompanied by long-term savings on fuel consumption and maintenance.

Many contextual variables can influence the decision to electrify the logistics fleet, for example, the availability of electric truck variants in a particular market, a reliable (clean) electricity supply, and the distances and cargo types of the fleet concerned. Companies are cautioned to undertake thorough research before embarking on an ambitious fleet renewal process.

The researchers therefore examined a case study of a large South African

pharmaceutical company that was planning to convert its urban distribution and delivery vehicles into an electric fleet. The researchers modelled the performance of each delivery vehicle on an existing road network. Each vehicle's emissions characteristics were known. The fleet's spatio-temporal movement resulted from solving a variant of the well-known vehicle routing problem. Vehicle movements were coupled with a detailed database of emissions factors to estimate the total emissions per vehicle per link, which could then be aggregated to any required level.

The vehicle routing problem is an optimisation problem in which the routes of a specific fleet of vehicles delivering to a set of customers are determined. When evaluating a heterogeneous fleet of different types of electric vehicles, additional constraints can be included, such as battery capacity, energy consumption, recharging time and the availability of recharging stations. The researchers of the present study, however, only compared the total cost and emission data of a diesel fleet to that of an electric vehicle fleet. The charging would mainly take place at the company's depot.

To comprehensively investigate and compare alternative solutions, the researchers developed two scenario models. The first consisted of a purely electric fleet with the same capacities and number of vehicles as the company's current distribution fleet. This was done to determine the feasibility of directly converting the existing fleet to electric vehicles. Secondly, a dual fleet, consisting of diesel and electric vehicles, was modelled. Output generated included the total distance travelled, vehicle routes and total volumes of vehicle emissions.

Using optimal vehicle routing, the total distance travelled by the vehicles was reduced from 14 126.86 km (the actual distance travelled) to a modelled distance of 4 071.30 km. This illustrates the effectiveness of vehicle routing by solving the vehicle routing problem. However, no accurate data for vehicle emissions and costs was available, so a base case scenario was developed to simulate the current distribution fleet, presenting emissions and cost output data that could be used as a basis for comparison.

In the model that only used electric vehicles, drastic reductions in vehicle emissions were observed. Energy consumption was also reduced from 24 508.4 MJ to 12 926.5 MJ per day. Although this seems to be the answer when it comes to environmental considerations, these vehicles could not deliver 17 of the specified shipments as the customers lay outside the range of the current battery technology for electric vehicles. Since the fleet could not meet the identified demand, this solution was technically infeasible and could not be used as the final solution. Consequently, it was not possible to directly convert the company's current distribution fleet, confirming the need for a dual fleet.

The dual-fleet scenario aimed to establish the optimal composition of electric and diesel vehicles in the fleet, as well as the routes of the vehicles. Similar to the first scenario, the total distance travelled, vehicle routes and volumes of emissions were generated as output. The ideal number of each type of vehicle in the fleet and their respective capacities were also calculated. After running the model, a fleet of 18 electric and five diesel vehicles emerged as the proposed solution.

As can be expected from a fleet with a dominant proportion of electric vehicles, significant emissions savings were apparent. Both carbon monoxide and carbon dioxide emissions were reduced by approximately 50%, while hydrocarbon and nitrogen oxides were decreased even more.

MANY CONTEXTUAL VARIABLES CAN INFLUENCE THE DECISION TO ELECTRIFY THE LOGISTICS FLEET, FOR EXAMPLE, THE AVAILABILITY OF ELECTRIC TRUCK VARIANTS IN A PARTICULAR MARKET, A RELIABLE (CLEAN) ELECTRICITY SUPPLY, AND THE DISTANCES AND CARGO TYPES OF THE FLEET CONCERNED. COMPANIES ARE CAUTIONED TO UNDERTAKE THOROUGH RESEARCH BEFORE EMBARKING ON AN AMBITIOUS FLEET RENEWAL PROCESS.

A significant decline in particulate matter emissions could also be seen, with the emission levels reducing by as much as 81%. This notable reduction in pollutant emissions makes the dual-fleet scenario more favourable in terms of environmental sustainability. Unlike the electric vehicle scenario, this solution delivered all specified shipments, proving that the fleet can fulfil the company's demand. In other words, this solution is technically and practically feasible.

Having established a feasible solution regarding both environmental impact and technical functionality, it was also necessary to investigate the financial implications of such a solution. Since generating a profit is a crucial component in the survival of any business, the answer must make economic sense, explains Prof Joubert. The model therefore included two cost components: a time component to incorporate the driver and assistant's wages, and a distance component to estimate fuel expenses.

In the case of electric vehicles, local electricity tariffs, energy consumption and battery capacity were included in the model to calculate the distance cost component. When comparing the dual-fleet scenario to that of the base case scenario, it was found that R16 460,00 could be saved per day. This can be attributed to a reduction in the fleet size and optimised vehicle routings. The distance cost component also reduced significantly, enabling the company to save R44 147,00 a day. Hence, by implementing the solution fleet, the company can expect to save a total of R60 607,00 per day. This excludes the fixed capital expenses of purchasing electric vehicles or constructing the required infrastructure. Since the vehicles can only be charged at night and all 23 vehicles are fully utilised, one charger must be installed per vehicle. These capital costs could be paid back within three years, allowing the company to start making a profit on their daily savings from the fourth year.

However, before implementing this solution, it is recommended that the company conducts an in-depth financial analysis and develops a phasing plan to gradually include electric vehicles in its fleet. Since this study only used capital cost estimates, the company must obtain exact vehicle and infrastructure cost values. A detailed market analysis must also be conducted to identify suitable electric trucks and companies that could aid in implementing the charging stations at the distribution centre.

When considering the solution fleet and its significant improvements, it is tempting to conclude that the electrification of distribution fleets is ideal for urban companies.

With substantial emissions savings and long-term financial improvements, many companies may envisage converting their current fleets to dual fleets that accommodate electric and diesel vehicles.

However, it is essential to investigate the practicality of such a solution, especially in developing countries like South Africa.

The electrification of a distribution fleet depends on context-specific constraints (and opportunities). The need for charging infrastructure in most cities constrains the deliverable service area to the battery capacity of an electric truck, as the vehicles can only be recharged at the relevant distribution centre. Prof Joubert suggests that purely electric fleets will only become feasible with the progressive development of public charging infrastructure.

Many developing countries are challenged with reliable and clean electricity availability. This impacts the implementation of electric fleets. Planned power supply interruptions (load shedding) often leave cities without electricity for up to six hours a day. Although solar electricity could be used as an alternative energy source, large batteries will need to be installed.

Another challenge lies in the fact that the vehicles can only be recharged at night when solar inverters are non-operational. This furthermore increases the cost of the system. Other considerations include the adverse effects of increased battery usage and disposal on the environment.

While this study highlighted some promising aspects related to the electrification of urban distribution fleets, proving it to be a technically and financially feasible solution, it may be too early to apply such a solution in South Africa due to infrastructure and electricity supply constraints.

Automated crocodile detection using deep learning and synthetic data

Marchant Fourie, Prof Herman Myburgh and Dr Allan de Freitas

The use of Artificial Intelligence (AI) to create a more efficient and inclusive society is gaining momentum and will soon not only transform business, education and health care in Africa, but also farming and wildlife management. A master's research project conducted in the Department of Electrical, Electronic and Computer Engineering's Smart Sensing and Intelligent Systems Research Group is making use of synthetic data to develop a machine learning (ML) model to identify crocodiles from aerial images.

In recognition of the problem encountered by wildlife managers who need to perform population counts or locate crocodiles in game parks and nature reserves in dangerous situations, an ML model was developed using deep learning neural networks to train an image object detector to locate these reptiles using unmanned aerial vehicles (UAVs) or drones.

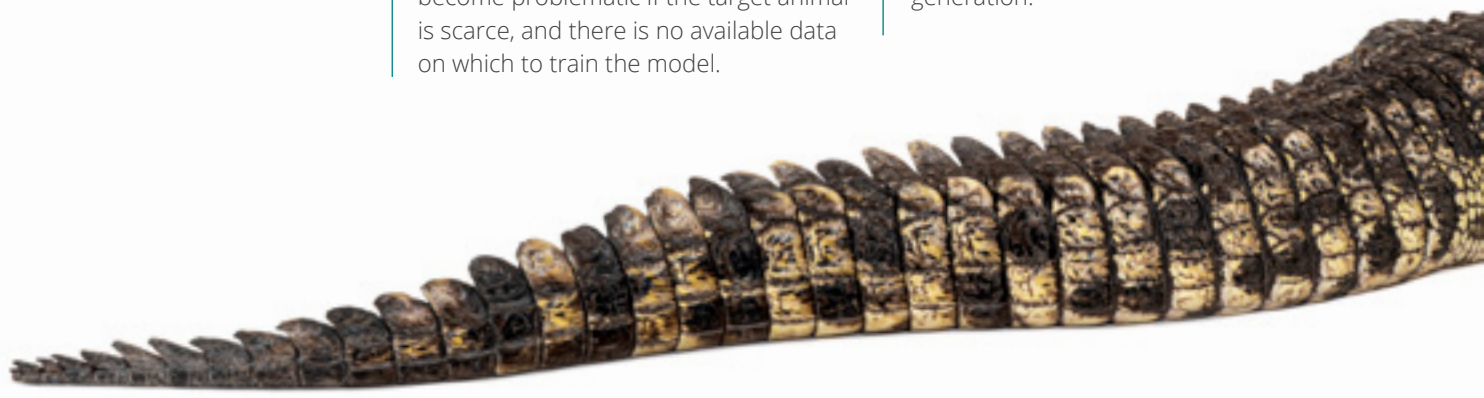
The advent of advanced image processing techniques has, in fact, revolutionised various fields, including nature surveying and agricultural practices. Among these techniques, the image object detector has emerged as a powerful tool that allows researchers and farmers to automatically detect and analyse animals in aerial images. These detectors leverage ML algorithms, particularly deep learning frameworks, to recognise and classify objects with high precision. This capability is particularly valuable in ecological monitoring and agriculture, where the accurate and efficient detection of animals is crucial.

While this technology reduces the cost and time required to perform animal surveys, a major challenge encountered by analysts is the large amount of data required to train the network. This can become problematic if the target animal is scarce, and there is no available data on which to train the model.

This was the case, in particular, with the current research project, as only ten crocodiles could be located in the river that had been identified to obtain data to populate the artificial neural network.

A major limitation of deep learning is that it involves acquiring and annotating substantial datasets for model training. These algorithms excel with vast quantities of diverse, high-quality data that facilitate the learning of complex patterns and enable users to make accurate predictions. However, capturing data for the intended purpose of this research presents multiple challenges that can hinder progress. Firstly, logistical constraints often exist during data collection, making it difficult to gather sufficient samples of rare species. Secondly, after obtaining enough data, the annotation process becomes labour-intensive and time-consuming for specialists, which makes it susceptible to human error. Insufficient data can also limit the model's generalisability and accuracy.

For this reason, the researchers decided to make use of synthetic data as an alternative method of data generation.



Synthetic images were generated through computer-based tools such as those used for game development to create realistic-looking environments for the purpose of training the image models. The research aimed to determine whether this approach would deliver a similar object detection model as one developed with live animals, and whether it would still be able to successfully perform the task of identifying the reptiles for management purposes.

If this proved to be successful, it would have the benefit of eliminating the need for researchers, veterinarians or wildlife managers having to go into dangerous rivers to find the crocodiles and count them manually. They could send UAVs into the area that could be automated to find the crocodiles. The ML model could also be used to extract information on specific features like body measurements and the crocodiles' body condition score, and perform comparative analysis on whether the crocodiles' conditions are improving or deteriorating. This data can then be used to identify ecological problems affecting the animals' health.

The utilisation of UAVs in wildlife research has escalated recently due to the increased frequency and improved data quality they offer over manned aircraft and satellites. This has the advantage of enabling comprehensive surveys without disrupting animal behaviour or endangering researchers by exposing them to potentially dangerous situations.

The research study subsequently explored the generation and use of synthetic data to train a "you only look once" (YOLO) object detector to identify crocodiles from aerial images. A virtual environment was set up to generate virtual images using domain randomisation. The images were then used to train the network. The researchers also explored fine-tuning and transfer learning methods to improve the detector's performance.

For the real-world images, aerial images of crocodiles were collected at a commercial crocodile farm. A UAV was set to survey an entire area using a predetermined flight plan and was set to fly 30 m above the ground. The drone captured 243 images at a high resolution. An orthophoto was then generated from these images. This is a single photograph constructed from multiple photographs of the same area and then geometrically corrected so that the image has an orthographic projection. This normalises the distances of all the objects in the images, allowing for constant measurements, which can be translated to real-world measurements. This also ensures that only one version of each crocodile is present in the single image so that different angles of the same crocodile are not present in the training and validation set separately while training.

The generation of the synthetic data took place by creating a virtual environment for the crocodiles. It comprised differences in altitude, and a horizontal water plane to obscure the surface with a water texture below a certain height. Grass, as well as a random number of trees, rocks and random geometric shapes were placed in the scene on top of the surface according to a randomised pattern. The crocodiles were also given a randomised texture, and a random number of crocodiles were placed in the scene a distance above the surface. This allowed the environment to be simulated.

A virtual camera was then set up above the surface looking downward to generate the synthetic images. It captured three images of each iteration. The annotation of the synthetic image could then be done automatically since the pixel positions corresponded between the images. A bounding box was marked around each of the individual crocodiles to fit the pixels that could be observed in the synthetic image.

The results obtained from the training of the object detection model demonstrated an improvement in the accuracy of the models when the backbone layers were frozen during training on a large real-world dataset. It was found that training on only synthetic images is possible, but training on a small number of real-world images outperformed the synthetic data. However, integrating small amounts of real-world data into the model through fine-tuning or by using mixed datasets that include synthetic and a small number of real-world images, together with image augmentation and transfer learning, significantly enhanced the model's object detection capabilities from aerial images. This approach is particularly effective when addressing data scarcity challenges in the detection of animals.

This research received the Best Paper Award at the Southern Africa Telecommunication Networks and Applications Conference, held at Skukuza in the Kruger National Park from 6–9 October 2024.

World-class laboratories support quality research outputs

The world-class laboratories of the Department of Electrical, Electronic and Computer Engineering provide a platform to conduct cutting-edge research. They also equip students with the practical skills they need to excel in their future careers as electrical, electronic and computer engineers. The latest addition to the Department's many laboratories is the Advanced Hybrid Microelectronics Packaging Facility (AHMPF) in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM).

The Carl and Emily Fuchs Institute for Microelectronics established this facility with funding provided partially by the National Research Foundation (NRF)'s National Equipment Grant. This grant was awarded to Prof Trudi Joubert, Director of CEFIM, and Prof Tinus Stander, who is also associated with the Institute, in 2023. According to this programme, two-thirds of the approximately R17 million in funding is provided by the NRF, with the remainder co-funded by the University of Pretoria.

The AHMPF is a microfabrication ensemble facility that allows for the creation of planar integrated electronic systems on a variety of media, the integration of microelectronics into these system packages, as well as the visual inspection and measurement of the fabrication process.

Microelectronic integrated circuits form the backbone of all modern electronic systems. Current microelectronics research in CEFIM resides at the intersection of integrated circuits and modern digital microfabrication technologies towards integrated microsystems in sensing applications and microwave and mm-wave electronics. Within the wider microsystems research context, the AHMPF focuses on the microfabrication of bespoke packaging for the integration of bare integrated circuit (IC) dies, either pre-packaged components or custom devices, that researchers at the Institute have designed.

In the case of microwave and mm-wave electronics, high frequency IC integration via wirebonding or flip-chip bonding onto printed circuit boards, ceramic substrates or in metallic waveguide split-block assemblies enable future applications in 6G mobile communications transceivers and broadband radio astronomy receivers. For microsensor applications, the IC die integration drivers are system miniaturisation. The use of technical packaging materials enable the manufacture of electronic devices that have unique functionalities, such as flexibility, biocompatibility, eco-friendliness and sample handling, as exemplified by microchannel devices for fluidic and gaseous sensing.

These next-generation applications require the fabrication of high-resolution patterned circuits with feature sizes in the range of 1 to 50 µm, as well as the co-design of the electronic system and the package that integrates the microelectronic integrated circuits.

The AHMPF enables the fabrication of fine-resolution patterned functionalised packaging for electronic systems with feature sizes below 50 µm on technical substrates such as ceramics and polymers. The functionalisation does not only include geometric features such as microchannels, but also the use of different technical materials, which range from several electrically conductive materials that are required for electronic interconnections to soft biocompatible materials for wearable sensing systems, and hard and rigid ceramics for 5G and beyond mm-wave component substrates.

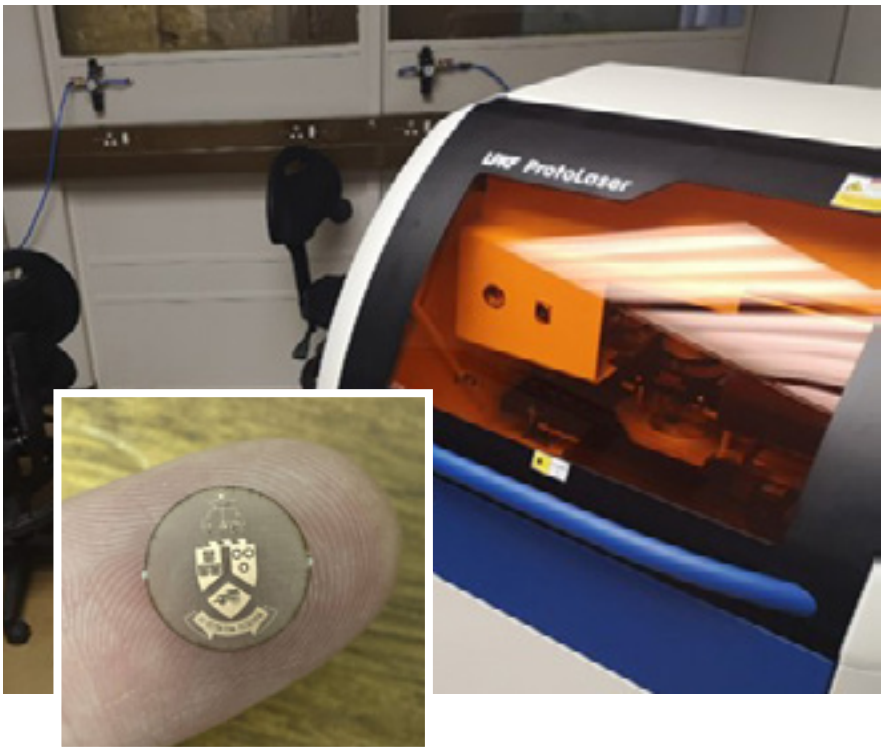
Semi-automatic integration technologies that enable both wirebonding and flip-chip bonding are included. In order to close the rapid prototyping loop, crucial capabilities for the automated visual inspection of devices are provided at both the micron-level feature scale and the centimetre device scale as part of the facility. Accurate geometrical and surface topological metrology is another important facility capability, which takes cognisance of the varied material properties used in the composite microelectronic devices.

The agile process development cycles that are provided by this co-located fabrication and visual analysis equipment alleviate the most time-consuming and least productive research and development (R&D) activity of iterative design, build and test.

The micropatterning leg of the facility is built around the LPKF ProtoLaser U4. This machine's patterning capabilities are augmented with an LPKF turnkey production solution, including a Contac S4 through-hole plating bath, a MultiPress S4 multi-layer laminator and an S64 desktop three-axis milling machine for board singulation, precision waveguide split-block machining, deep cavity milling for embedded dies and the machining of microfluidic channels.

The core of the chip assembly leg of the facility consists of the two complementary processes of die bonding and connection bonding. The Tresky 5100 die bonder is used to attach the microelectronic die to a carrier surface, and includes a flip-chip station for high-density chip integration. The F&S BondTec 53XX-BDA wirebonder is used to create the gold wire, ribbon or stud electrical connections between the die and the surrounding carrier circuit. The assembly leg is completed by the availability of a reflow oven and a desktop pick-and-place machine. These are used to mount other surface mount devices to boards that do not require wirebonding.

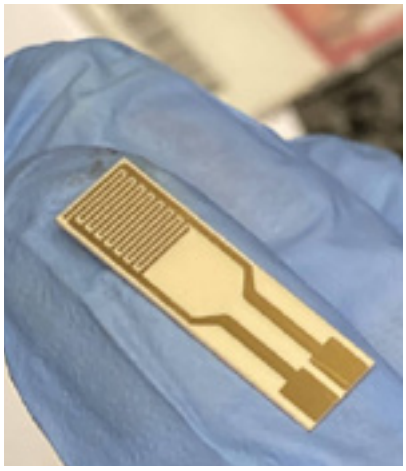
Finally, the visual analysis and metrology component of the facility consists of an automated digital Olympus DSX1000 microscope that combines optical imaging and microphotography with certified accurate measurement functions typically obtained by utilising more than one system.



The instrument can image a variety of materials used in microelectronics and microfabricated electronics systems, ranging from metallic and reflective to matt or non-reflective, or optically transparent. The macro-to-micro imaging capabilities enable metrology on different material layers of varying planar dimensions and heights, ranging from millimetres on the system level, through micrometres at the structure level, down to hundreds of nanometres for some layer thicknesses.

The CEFIM AHMPF open-access research facility is the only one of its kind in South Africa with the capability of rapid 2.5D integration at the micrometre scale of microelectronic chips into functionalised packages. Furthermore, the AHMPF complements CEFIM's existing additive micro-fabrication capabilities of the printed electronics node in the national Nano and Micro Manufacturing Facility (NMMF), hosted under the auspices of the South African Department of Science and Innovation's Research Infrastructure Roadmap.

The true 3D integration of smart systems can be fostered when precision laser micropatterning is combined with advanced additive manufacturing technologies.



MICROPATTERNING CAPABILITIES

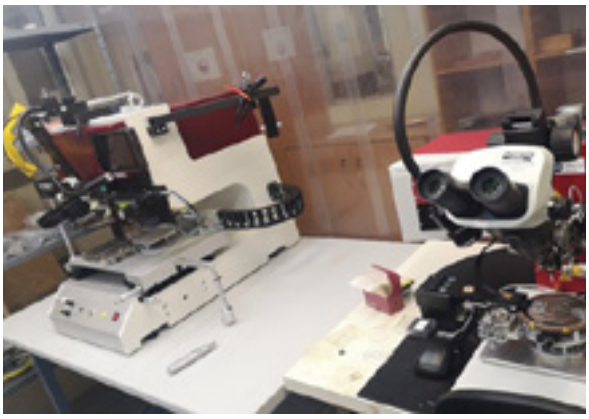
The LPKF Proto Laser U4 has a 355 nm UV laser operated in stabilised picosecond pulses with power monitoring, which provides for thermal control in the precise processing of thin or fragile substrates. The system has a large library with multiple technical and functional materials relevant to mm-wave electronics and microsensor systems (standard PCB to steel and thin glass, to rigid ceramics, to flexible polymers and plastics). It also enables the development of fabrication processes with new material compositions.

Steep cutting edges give excellent control over aspect ratio and enable precise geometries and shape fidelity. It is capable of patterning 50 µm lines and 20 µm gaps on printed circuit boards, and 20 µm lines on thin film ceramics, with 50 µm through or blind via drilling. There are pre-programmed hatching and delamination sequences, which is a key product differentiator and a requirement for the application of laser patterning to electronics prototyping. It can be used to sub-dice GaAs, GaN and Si wafer dies. Pocket engraving of ceramics or metals is possible up to 750 µm. The laser also allows the low-residue ablation and vapourising of organics that can be used for homogeneous surface layer removal and the cleaning of sensor surfaces. The system supports layer registration for 2.5D system integration.

The LPKF ProtoMat S64 is capable of the precision milling of metals up to a depth of 8 mm and the drilling and scoring of printed materials up to a thickness of 3 mm. It provides 100 µm feature size with 500 nm resolution.

The LPKF Contac S4 copper through-hole plating system is capable of unattended copper through-hole via plating at a rate of 12 µm per hour.

The LPKF MultiPress S4 lamination system is capable of laminating rigid or flexible boards of up to eight layers and a thickness of 4 mm with precision vacuum and temperature control.



CHIP ASSEMBLY CAPABILITIES

The Tresky T-5100PC controlled manual die bonder is capable of epoxy, thermosonic and eutectic die bonding. Precision Z-axis force control up to 10 N, with a flip-chip station and bonding tool, as well as split-beam optics precision alignment, are provided.

The F&S Bondtec 53xxBDA bond station is capable of the ball-and-wedge bonding of gold wire (17.5–50 µm) and ribbons up to 250 µm. It has programmable Y-Z automated bonding for pre-programmed loop shape control.

METROLOGY MICROSCOPE CAPABILITIES

The Olympus DSX1000 performs two functions as far as microscopy for electronics microfabrication is concerned: wide-range high-resolution visual inspection and image processing for dimensional and surface measurements. For visual inspection and analysis, the high-resolution (micron-scale) imaging of larger areas (millimetre to centimetre scale) is provided by the digital microscope. Fast orientation from the macro to the micro view provides positional consistency, while maintaining object focus. The microscope offers extended depth of focus for imaging complex object profiles, and tilt and rotation provide for different imaging points of view. The instrument enables a long working distance of between 0.35 and 66.1 mm, depending on the magnification. The high optical dynamic range of objects with both non-reflective and highly reflective metallic parts can be handled automatically, and features such as contrast enhancement and glare mitigation are easily accessible. At least 2.5D visualisation is required for multilayer structures, and the Olympus DSX1000 has capabilities of 3D imaging of complex functional devices. For metrology, the Olympus DSX1000 microscope certifies the accurate dimensional measurements of multilayer 2D structures and 3D objects down to 10 µm, whereas its ability to measure surface properties, such as roughness to 0.3 µm, is essential for the electronic performance of mm-wave components and sensor structures.

MICROELECTRONIC INTEGRATED CIRCUITS FORM THE BACKBONE OF ALL MODERN ELECTRONIC SYSTEMS. CURRENT MICROELECTRONICS RESEARCH IN CEFIM RESIDES AT THE INTERSECTION OF INTEGRATED CIRCUITS AND MODERN DIGITAL MICROFABRICATION TECHNOLOGIES TOWARDS INTEGRATED MICROSYSTEMS IN SENSING APPLICATIONS AND MICROWAVE AND MM-WAVE ELECTRONICS.

Growing industry collaboration in timber design and construction

There is a growing global interest in timber construction. The same trend is being observed in South Africa. This is largely due to the contributions of role players like the Department of Trade, Industry and Competition, Green Building Council South Africa, the important forestry research institutions, the large timber mills, architects, and the project and construction management professions.

At the University of Pretoria (UP), the York Timbers Chair in Wood Structural Engineering is making great strides in stimulating the development of a sustainable mass engineered timber construction industry in South Africa and the African continent. It is also promoting cross-disciplinary research through its representation within three academic disciplines in the Faculty of Engineering, Built Environment and Information Technology. Chairholder Dr Schalk Grobbelaar is also a senior lecturer and researcher in the Graduate School of Technology Management's Department of Engineering and Technology Management. Research collaborators include Dr Johann van der Merwe, a structural engineer and senior lecturer in the Department of Civil Engineering, and Christo van der Hoven, who represents the Department of Architecture.

Through the Growing Timber Connections collaboration, York Timbers has partnered with the University of Pretoria to host the annual Timber Construction Conference since 2023. The second conference was presented in 2024 with the support of the Pretoria Institute of Architecture and the Department of Trade, Industry and Competition. This is a knowledge-sharing event that brings together industry professionals and academia in forestry, architecture, structural engineering, construction and built project management to share their experiences in timber design and construction.

The 2024 event, which was held at the University's Future Africa Campus, included a pre-conference Colloquium and the Awards Dinner of the annual Timber Design Competition for architecture students on 9 September, followed by the Conference and Exhibition on 10 September 2024.

It focused on promoting the use of structural timber within the context of a sustainable, timber-based built environment to stimulate South Africa's wood-based bioeconomy.

Dr Grobbelaar explains that this year, the focus was on the entire timber value chain, as opposed to just timber construction. It took delegates through the entire process, from the planting and growth of a tree, through each phase in its processing until it is sawn and engineered into a mass timber product for inclusion in architectural designs and use as building material by a structural engineer and construction management professional. Each of these steps in the value chain has an impact on the final product and its selection for use in construction.

PRE-CONFERENCE COLLOQUIUM

With this in mind, presentations at the pre-conference Colloquium included the views of role players in each stage of the process. From the forestry industry, York Timbers' Dr Jaco-Pierre van der Merwe spoke about plantation forestry in a changing environment, while George Dowse from Merensky Timber evaluated the use of eucalyptus timber in timber products. From the perspective of forestry biotechnology, Prof Zander Myburg, a professor in Genetics at Stellenbosch University and former Chair in Forest Genomics and Biotechnology at UP's Forestry and Agricultural Biotechnology Institute (FABI), discussed the sequencing of the megagenome of tropical pines to uncover growth and wood development genes. Dr Philip Crafford, a researcher from the Stellenbosch University's Department of Forest and Wood Science, provided an overview of his scientific research on wood products.

Dr Van der Merwe explains that, by including a research colloquium the day before the conference, researchers and postgraduate students had the opportunity to present their research and be exposed to the work of specialists in the fields of forestry, architecture, structural engineering, and technology and engineering management.

Postgraduate Civil Engineering and Marketing Management students with representatives from York Timbers.

The presentations that formed part of the colloquium programme illustrated that research and the development of new timber products and services will contribute to more equitable, sustainable forms of construction that enhance business competitiveness and promote education and skills development, with a key focus on mass timber construction and design. "By using mass timber instead of steel or concrete," explains Dr Grobbelaar, "strong and durable structures of substantially lower embodied carbon can be developed."

Structural Engineering

Perspectives from structural engineering provided a good understanding of the mechanical properties of various types of timber, including South African eucalyptus and pine, as well as engineered timber products such as cross-laminated timber (CLT) and plywood from South African timber species.

Research was also presented on the capacity of dowelled connections loaded perpendicular to the grain and CLT-concrete composite construction with South African timber species. Other interesting presentations included a structural fire engineering perspective on the characterisation of South African plywood in fire, and a chemical engineering perspective on biomass washing pre-treatment using wood-derived hybrid timber-concrete (HTC) aqueous effluent.

This provided the architects in the audience with a good indication of what is possible when specifying timber construction in their designs, while the construction managers got a good understanding of the strength of various types of timber and their ability to resist forces of different strengths. Dr Van der Merwe emphasised that the structural engineering research presented at the Colloquium aims to support revisions to local design standards to better align with developing international standards such as Eurocode. He emphasised the importance for structural engineers to realise the vast opportunities that exist when it comes to designing with engineered wood products, as there is definitely a gap in the market. "We need to develop future structural engineers who are comfortable designing with timber," he says.

Architecture

The architectural research projects that were presented focus on a regionally appropriate approach to engineered timber. They also illustrated the close relationship between architecture and prefabricated or modular structures, which enable tenants to occupy their homes or business premises much sooner, with welcome cost-savings generated in the process. The projects also presented a change in values, where existing structures are repurposed using engineered timber products, instead of being torn down and rebuilt from the ground up. Van der Hoven explains that the adaptive re-use of buildings allows one to retain the existing, while adding to them with a lightweight, low-carbon material like wood, instead of steel or concrete. "This is a very important quality of wood that few other materials have."

Presentations included professionals' perspectives on adaptive reuse, the co-existence of existing building stock and mass timber for environmental sustainability and user wellbeing, the value of prototyping as part of a circular design process in the South African built environment, the performance of segmented timber shell structures, and critical barriers to the adoption of green building methodologies in southern Africa.

Van der Hoven is enthusiastic about the renaissance of timber design, particularly through the use of mass timber technologies. "In addition to looking at new ways of making timber buildings, we are also looking back at the history of timber in architecture. Wood is one of the oldest building materials. With new design and digital fabrication methods, we can even reimagine timber craft techniques that have not been seen in generations. This is creating new opportunities for the built environment and construction industry." Other interesting presentations included an industrial design view on digital fabrication and conservation, and the perspective of Dr Laetitia van der Merwe of UP's Department of Construction Management on opportunities for timber construction to improve sustainability in the South African built environment.

Lucky Bread at Castle Gate Lifestyle – designed and built by Earthworld Architects.

Engineering Management

Perspectives from engineering management entailed a technology and innovation management approach to housing in South Africa through the development of the WikiHouse platform.

Dr Grobbelaar reflects that the research presented at the Colloquium was aligned to the objectives of the York Timbers Chair in Wood Structural Engineering. The projects were related to engineering and technology management concepts such as open innovation, which emphasises the importance of using external resources, including ideas, technologies and talent, to drive innovation and growth. Another business concept that was illustrated was that of frugal innovation, which focuses on simplicity, affordability and functionality; finding creative ways to reduce costs and increase efficiency in the product development process, and involving the people who will use the product in its development. "I was pleased to see a focus on strategies that can be implemented to get the market to accept new innovations, such as engineered timber, by concentrating on people's perceptions and misconceptions," he concluded.

TIMBER CONFERENCE

Dr Grobbelaar explains that the whole mass timber movement responds to the United Nations' Sustainable Development Goals (SDGs) to draw on innovation and create sustainable infrastructure, cities and communities. "Throughout the world, mass timber is leading the charge, and South Africa needs to be part of this." This can only be achieved by training good structural and chemical engineers, architects, data scientists, geneticists, breeders and forest scientists who can lead the development of a new, sustainable, wood-based bioeconomy.

In South Africa, unlike Europe, North America, Canada and parts of South America, forestry plantations did not originate as natural forests. Trees were planted to respond to a need for timber structures and housing in the mining industry. Grasslands were therefore strategically converted into plantations that were populated with trees that could rapidly grow tall and straight to meet the demand for lumber. Pine was imported from South America and North America, and eucalyptus from Australia for this purpose.

Dr Grobbelaar describes the belief that harvesting trees for timber will lead to deforestation as a misconception, since South Africa's structural timber species comprise exotic, cultivated trees that are actively managed, with new saplings planted to replace the trees that are cut down. By way of example, he says that York Timbers owns 90 000 ha of land, of which only 60 000 ha is under cultivation. It is therefore responsible for the upkeep of the uncultivated land, contributing to the conservation of the country's natural forests.

Although the Forestry Stewardship Council (FSC) prohibits the genetic manipulation of trees, forestry managers can intervene naturally in the propagation of species to obtain trees with improved characteristics, such as trees that grow faster and deliver wood of a better quality and strength for the construction industry.

Several disciplines interact with each other within the timber value chain, explains Dr Grobbelaar. This enables the optimisation of the timber processing industry. "As a complex ecosystem, each contributing role player needs to understand the timber industry. This can only be done by focusing on one's specific core area and then expanding upon it systematically." This was the inspiration behind the wide range of topics included in the conference programme.

The event proved to be an enlightening and collaborative gathering of industry experts, academics, government officials and thought leaders, who shared their knowledge, insights and experiences through engaging presentations, panel discussions and exciting exhibitions. It also provided a valuable platform for networking, knowledge exchange and exploring the latest innovations in timber construction.

Industry delegates benefitted from presentations by associations such as Green Building Council South Africa, the Forestry Stewardship Council, the South African Council for Project and Construction Management Professions and the National Home Builders Registration Council. They were also introduced to the role played by the Industrial Development Corporation, as well as the work of Forestry South Africa, UP's Forestry and Agricultural Biotechnology Institute, New Forests, the South African Forestry Company (SAFCOL), Stellenbosch University's Department of Forest and Wood Science, York Timbers and Merensky Timber.

Van der Hoven reflects that the presenters at the conference succeeded in illustrating the renewed interest in timber construction, in which architects are following global trends that reflect their desire to be internationally relevant. In addition to sharing first-hand encounters with engineered timber and how it has been successfully used in design, delegates were inspired by success stories of using mass timber in construction instead of steel and concrete, and its possibilities for design and construction. Its use not only contributes to a reduction in carbon emissions, the promotion of a circular economy and the reduced use of non-renewable resources, it also brings about savings on another valuable resource in the 21st century – time spent on construction.

The presentations by suppliers of mass timber products gave delegates an idea of who to approach to solve problems when designing timber structures, and who to include in the design and construction team.

Vertical expansion of a residential building by Mass Timber Technologies.

Dr Grobbelaar explains how the diffusion of innovations that was illustrated by the presenters shows what other people are doing. He is pleased to see how people are looking strategically at timber construction. "There are many people in South Arica who are building with wood. Customers who are driven by the latest trends will definitely latch onto timber as the next big thing in design and construction."

Dr Van der Merwe found a highlight of the conference to be its illustration of ways to design and build with timber. It not only showed delegates what was possible and what is already being done, but demonstrated that local projects are comparable to those implemented internationally, and that we are able to meet global standards.

Delegates enjoyed the insights of seasoned entrepreneurs in the construction industry like Louis van der Watt, a UP alumnus and Group CEO of the Atterbury Group. They also marvelled at the work and products of companies such as Earthworld Architects, which specialises in timber design, XLAM South Africa, which manufactures sustainable CLT, Mass Timber Technologies, which produces complex, large-scale prefabricated timber components, and Holzbau Hess, the world-renowned timber construction company in Namibia.

Reflecting on the proceedings, Dr Grobbelaar believes that the conference succeeded in its aim of fostering collaboration between government, academia and industry to promote low-carbon sustainability, competitiveness and excellence in South Africa's bioeconomy and built environment. This is aligned with the goal of government's National Development Plan (NDP) to create a prosperous country for all our people, ensure shared success, reduce inequality, harness potential, and build skills and capabilities.

It is hoped that events such as this will succeed in promoting the widespread and interdisciplinary adoption of timber construction throughout South Africa, and that industry will continue to embrace its many benefits, as well as its vast potential.

TIMBER DESIGN COMPETITION

The 2024 Timber Design Competition, which formed part of the conference events, was open to all architectural students across Africa. It provided the students with the opportunity to explore new ideas to solve a real-world design challenge, while exploring novel applications of timber.

The entrants were required to present conceptual plans for the vision of UP's Forestry and Agricultural Biotechnology Institute to extend its existing FABI II Building using mass timber construction. The objective was to achieve a masterful design with a low environmental impact and high operational performance. The projects were required to accommodate all manner of research and teaching functions, including spaces for collaboration, offices, laboratories, greenhouses and even a hydroponic tower.

The competition received 31 entries of an incredibly high quality from five South African universities: the University of Pretoria, the University of the Witwatersrand, the Nelson Mandela University, the Tshwane University of Technology and the University of Johannesburg. The winners were Rudolph Botha and Noa Solomon from the Nelson Mandela University.

Speaking at the Awards Dinner, Prof Themba Mosia, the University's Interim Vice-Chancellor and Principal at the time, explained that the built environment currently contributes approximately 40% of global greenhouse gas emissions, with about a third emitted during the construction phase of buildings. By developing better designs and using bio-based materials like wood in construction, we can meet the demand for new buildings, while conserving the environment, drive job creation and economic growth, and ensure that our graduates are skilled for the current and future world of work.

Rudolph Botha (left) and Noa Solomon from Nelson Mandela University earned first place with their proposal titled "Blooming branches".

Regenerative Public Space: A transdiciplinary project

Public spaces are not only public parks, but any space that is accessible to the public, generally owned by a public institution and/or co-created by the people that use it.

A regenerative public space serves as a catalyst to create positive change in the larger urban environment through the reorganisation and transformation of the micro system (site) to create new possibilities that ripple out into the neighborhood and beyond.

Regenerative development and design are just as much about the process of transformation as the outcome or product. It is a co-creative process that enables the emergence of health and wellbeing at scales from the local to the global. Thinking about regenerative public space therefore requires the consideration of a number of starting principles to establish a common foundation for further action and engagement.

Regenerative development is not a fixed-term endeavour, but an ongoing and iterative process of transformation, adaptation and evolution.

Teams from the University of Pretoria (UP) reviewed four projects to serve as case studies to illustrate the breadth and variability of regenerative public space projects. These hope to serve as a catalyst to promote the regeneration of public space across the City of Tshwane.

MOJA GABEDI

Moja Gabedi is a community garden located in the densely populated neighbourhood of Hatfield. It functions as a site for UP's curricular community engagement, but is also a productive urban agriculture project and a therapeutic garden. The site has experienced a process of formalisation and has changed over the years. While originally developed to include the wider community, including support programmes for the local unhoused community, through collective reflection and consideration with its principal project stakeholders, the project evolved to focus on the UP student community and the wider communities UP serves.

Developed on an existing unused land parcel, the park is organised as a formal garden that is densely planted with different crops. It houses several community spaces, offices, and a bakery and coffee shop on the western, more public entrance to the park. Centrally located in the park is a sculpture and boma (fireplace), which provides a form of identity and marks a place for the people to meet.

A series of dams and water bodies allow the site to have a rich biodiversity. Being densely planted, the site makes a marked difference to the local microclimate. Its structured layout and continued maintenance ensure that it is a highly productive landscape, while integrating an accessible public space.

The rapidly changing and growing neighbourhood in which Moja Gabedi is located houses a large student community. The University's Hatfield Campus is also located in the neighbourhood and UP is an important stakeholder in the community.

The neighbourhood has changed significantly since its development in the early 20th century. It has transformed from a small suburb with single-stand homes to a dense neighbourhood with multistorey apartment buildings and a central business district. While the neighbourhood has undergone significant densification, the associated public spaces and green open spaces did not keep up with this development. As a result, the neighbourhood is visibly under-resourced in terms of its green space provision.

The Moja Gabedi project therefore responds to the need for urban green open spaces and the provision of alternative space for the student community to engage with the wider communities that UP serves through curricular community engagement.

MUCKLENEUK COMMONS

Muckleneuk Commons is a small community park, developed on a piece of leftover land that has been neglected for several years. The park is located at the top of a hill, and acts as a thoroughfare for several commuters walking from the Pretoria city centre to the neighbourhoods located towards the southeast of the city centre.

It is a small park with a simple layout, planned along a series of desire lines (preferred routes). A large hand sculpture is centrally located in the park and acts as a focal point along which a small copse of indigenous trees, to the south of it, and a larger open lawned area, to the north of it, have been developed.

While the park retained most of the existing trees located on the property, the project added several new trees and indigenous plants to create an open, yet well-defined park. The park also has a drinking fountain that is positioned along one of the central thoroughfares.

As a whole, the park is often used by commuters who briefly rest during their commute to and from their destination. The park also hosts many community events organised by the local group that manages the park.

The Muckleneuk Commons is located between two older neighbourhoods, Muckleneuk and Lukasrand. The neighbourhoods are low in density and predominantly residential. The residential fabric is mostly made up of single-standing homes.

The neighbourhood has extensive vegetation coverage, with streets lined with jacaranda trees, private gardens and the Kruinpark nature reserve, which is located on top of the hill, adjacent to the Muckleneuk Commons.

The neighbourhood borders a much denser residential neighbourhood, Sunnyside, which is predominantly made up of multistorey apartment buildings. As a result, the park plays an important role in providing open outdoor space to the neighbouring communities.

BURGERS PARK

Burgers Park is one of the first parks to be established in Pretoria. It was developed as a public park and botanical garden in 1874. The park's layout is based on typical Victorian principles, which resulted in a highly formalised and symmetrical layout. A series of historic structures are housed within the park. These include the curator's house, the greenhouses, the central fountain, the centrally located bandstand and existing maintenance offices.

Most of these structures are in a state of disrepair, with only the curator's house presently being occupied.

Apart from the existing structures, the park is home to several very large and well-established exotic trees. These trees have endured the changes that the park has experienced over the years and have become important features of the park's identity.

Although large sections of the park are in general disrepair, it is still used extensively by the surrounding residents and the unhoused community. The park, therefore, plays an important role in the daily lives of the surrounding community.

Burgers Park is located in central Pretoria, within the most urbanised and densely populated area of the City of Tshwane. This context has changed significantly since its inception. Originally home to several single-stand homes built during the inception of the park, the context changed significantly in the mid-20th century with the development of several high-density apartment buildings and hotels surrounding the park.

The area underwent important changes during the early 1990s after South Africa's first democratic election in 1994. This resulted in a change in demographics with working-class residents moving into the area. As a result, the economic standing of the neighbourhood has shifted. The neighbourhood has been steadily densifying and growing, and accommodates a diverse and cosmopolitan population.

In spite of all of these changes, the park itself has always played a pivotal role in the daily lives of the local community. Despite the fences and locked gates, the park is still considered an openly accessible park that is extensively used by the local community, as is evidenced by the removed fence panels that allow access into the park. This also speaks to its value among the local urban community, who consider access to the park necessary for their daily lives.

MELUSI YOUTH DEVELOPMENT ORGANISATION

On the western periphery of the City of Tshwane is an inspiring story of the regenerative potential of people and place. North of the Daspoort tunnel, and adjacent to the suburbs of Claremont and Booysens, is an informal settlement called Melusi. Within Melusi are two important community spaces: the Melusi Clinic and the headquarters of the Melusi Youth Development Organisation (MYDO). These two public spaces provide significant support programmes to the local community – a community that is otherwise faced with dire living conditions, characterised by a lack of services, infrastructure and formal living conditions.

The Melusi Clinic offers basic health care services to the local residents, including immunisations, testing for sexually transmitted infections (STIs), counselling and awareness, and community education campaigns. The MYDO centre is community-initiated and manages a series of programmes. These include after-school services for children and young adults, including study groups, feeding schemes and art programmes. Additionally, the amenities of the MYDO centre are also used by cultural and religious groups for meetings and cultural activities – cementing its value within the community.

The centre is located on a piece of land off one of the main routes into the informal settlement, and adjacent to the Booysens nursery. The centre is housed in one main building, as well as a series of smaller buildings and outdoor shaded areas. The main building functions as a community centre, with a large central hall, several smaller halls and classrooms, a kitchen and public toilets. The outdoor spaces are largely devoid of vegetation, lawns and trees, but there is evidence of community gardening and care of the property.

The MYDO centre was built to house the activities and after-school programmes offered by the non-governmental organisation. Since then, the programmes offered by the MYDO have continued to grow. Developing from its early origins as an after-school tutoring programme, the MYDO centre continues to evolve into an important community landmark within Melusi. A group of motivated and visionary young people began a small, grassroots tutoring and mentoring programme to assist primary, secondary and tertiary students with their homework, at-home tasks, study groups and finding direction in their lives, especially as the youth face uncertainty and high levels of unemployment in South Africa. This programme started as a tutoring programme on the property of a small day care centre in 2009. Since then, it has evolved into the organisation it is today. With help along the way, from people offering advice, and small and large donations, the organisation was formally registered in 2015.

Although organisationally separate from the clinic, the two community initiatives work collaboratively to provide services to the local community. A community hall was constructed in 2023 to supplement and complement the existing public spaces in Melusi, highlighting the continued growth and development of public space and entities in the community.

Regenerative urbanity: **Four public spaces show what is possible**

Dr Dayle Shand, Dr Jan Hugo and Cowan Pringle

From globally unmatched levels of socio-spatial disparity to unprecedented rates of urbanisation; from increasing destruction of urban nature to almost unimaginable levels of food, education and shelter insecurity – there is much to be despondent about regarding our South African urbanity. Even so, among all these fateful scenarios, we find truly inspiring stories of hope and tenacity that illustrate the value of regenerative development for South Africa.

THE GOAL OF REGENERATIVE DEVELOPMENT IS TO GO BEYOND FINDING EQUILIBRIUM AND SUSTAINING A HEALTHY STATUS QUO, TOWARDS GIVING BACK TO SOCIETY AND THE NATURAL WORLD BEYOND IN A POSITIVE WAY.

The Regenerative Public Spaces (RPS) research project is driving the development of a digital tool to support enhanced urban development. The conceptualisation of the tool encompasses the consideration of existing regenerative public spaces in the City of Tshwane. The RPS team visited four case studies, providing much insight into the realities of regenerative urban development in the South African context.

The **Moja Gabedi** productive gardens are situated in the student suburb of Hatfield, on a previously degraded dumping site, known as a crime and substance abuse hotspot. **Muckleneuk Commons**, a significant community park, transformed an unsafe, leftover piece of land between Muckleneuk and Lukasrand. The popular and enduring **Burgers Park** is situated in an inner-city, high-density neighbourhood, and acts as a refuge for unhoused communities in an area characterised by many social disparities. Finally, on the far western periphery of the city, the **Melusi Youth Development Organisation** (MYDO) provides educational and training support in a community where informality and dire economic realities are prevalent.

The researchers identified four lessons that they learnt from each of the case studies:

LESSON 1: THE PEOPLE MAKE THE PLACE

Both physically and metaphorically, in all four instances, the involvement of local people ranges from the physical alteration of space to ongoing community-building activities. The ongoing agency and advocacy of local role players has consistently revealed the regenerative potential in each of the sites. Sharing their visions and dreams for a better local environment, the various role players range from professional landscape architects to community workers and individuals with precious little resources, yet, who are determined to make a difference.

> "We went to churches, trying to get everyone involved... We went and tried to talk to the businesses that are around Burgers Park, the schools because everyone is benefitting from the park, to be part of building the park, to be in a better space than it is now."
> *(Community member, Burgers Park)*

> "So, what happens in a process like this? The people on site make certain decisions and things go on...."
> *(Community member, Muckleneuk Commons)*

> "Social functions and getting the people here involved and interacting again, and so we have movie nights. We have cake bake sales, which were initiated by the neighbourhood children...."
> *(Community member, Muckleneuk Commons)*

LESSON 2: OUT OF MUCH NEED EMERGES MUCH POTENTIAL

Each of these projects emerged as a response to a truly concerning lived reality, including safety in public space, the need for education, the degradation of urban environments, homelessness and substance abuse. Rather than giving in to the increasingly dire conditions and realities in which community members found themselves, they saw the potential for change, and acted on it.

> "We are youngsters of this community [and] something needs to be done [...] our hearts were around youth and children who were coming to this community that had no opportunities, where it is easy to lose hope. We said: "No, we want to create a space that can, you know, serve as a support system for youth and children, who find themselves in this community"."
> *(Community member, MYDO)*

> "I'm saying that it was negative, [there] was a house that was captured by drug lords [...] and crime was one of the biggest things that was happening around Hatfield.... It was a dump site and it was negative [...]. This place is indeed changing, and it's changing the environment around Hatfield. The crime is no longer that much and then this place, now they are safe, both of them."
> *(Community member, Moja Gabedi)*

LESSON 3: NO MATTER WHAT, TAKE ACTION

Given the political, social and economic turmoil and apathy faced in South African public and private institutions at present, there are precious little resources and initiatives reserved to support the development of good public spaces, meaning that if local community members do not take action, very little will happen.

> "We just decided to do [it]. Yeah, it was a pretty conscious decision, not to get ourselves bogged down with formalities and administration and legalities and stuff like that, because it can consume all of your energy...."
> *(Community member, Muckleneuk Commons)*

We also saw that, in each instance, only once someone had initiated action did the next steps become evident. In many instances, starting the process also caused further role players and contributors to come on board in collaborative ways. Thus, even small steps have the potential to initiate great things.

> "One thing that really kept us going back then was that every door that we were knocking [on], it's like people were already expecting us. It's just open, wide open...."
> *(Community member, MYDO)*

LESSON 4: LOCAL PROBLEMS NEED LOCAL SOLUTIONS

From the above, we can see that the grassroots, community-led initiatives have contributed to the long-term sustainability and regenerative potential of the projects. Each of the projects is a place-specific response to a local problem, again indicating that the success of the projects lies also in their specificity to certain contexts. These projects show us that collaborative potential between big business and various institutions is not only possible, but powerful. The caveat being that local buy-in, or better yet, projects initiated from within the community, is the basis for collaboration.

> "So, we started with one small container, and then... we tried to provide the things we can, with that little container. And then [...] shacks were donated by the local businesspeople, who just liked what we were doing, and they saw potential [...] and then another businessman came and bought another second container...."
> *(Community member, MYDO)*

Ultimately, the goal of regenerative development is to surpass sustainability thinking (currently focused on maintaining the status quo) by aiming instead to positively impact society and the natural world beyond, thereby improving the status quo. Place-based responses, coupled with passionate individuals who are prepared to see potential where others only see problems, and who act on their vision, are integral to such development.

These lessons, among others, will be showcased on the Regenerative Public Spaces Digital Tool with the hope of illustrating the regenerative potential within our urban settings, inspiring similar projects to share their successes, and to catalyse those just starting out.

Connecting people and places: **The Regenerative Public Space Digital Platform**

Prof Karina Landman, Ilan Guest, Prof Chrisna du Plessis and Prof Stephan de Beer

In 2022, a team from the University of Pretoria (UP) and Satplan Alpha embarked on a three-year project on Regenerative Public Space (RPS). The RPS project was funded by the South African National Research Foundation (NRF). The intention of the project was to recognise the true value of public space in cities, especially in South Africa, and contribute to uplifting changes in these spaces.

EXPLORE THE RPS PORTAL

To achieve this objective, public spaces need to be able to adapt and transform to address the challenges of rapid urbanisation, densification, climate change, social conflict, exclusion and disconnection to nature. Through transdisciplinary cooperation and various interactive methods aimed at understanding and working with spatial transformation, the project intends to take forward the United Nations' Sustainable Development Goals (SDGs) through an exploration of the regenerative potential of public space. The aim of the RPS project was to outline a process to create regenerative public space by exploring transformative processes in four public spaces and develop a digital platform to facilitate its implementation.

The project followed a trans-disciplinary approach to facilitate regenerative sustainability.

Firstly, it enabled members from various disciplines to work together to develop a common conceptual framework and methods, fused together from various disciplines, including architecture, planning and theology, and emerging from ongoing discussions at community workshops. Secondly, the project involved members from academia, private practice and communities with various backgrounds. Finally, the research process managed to incorporate all three phases of transdisciplinarity: collaborative framing, co-producing solution-orientated and transferrable knowledge through collaborative research, and the (re)integration and application of produced knowledge.

Following a common understanding of regenerative public space, the team developed a digital platform to start connecting various existing and potential future stakeholders. In recent years, geographic information systems (GIS) have evolved from being primarily desktop software, dedicated to working with spatial data and creating maps, to include internet-based systems. Such systems can be configured as "digital platforms", or Web GIS, that have the look and feel of an interactive web page. A Web GIS takes advantage of the internet by allowing for customised GIS web app development, with selected geospatial functionality, that can be served to users through a web browser.

Examples of GIS web apps include Interactive Webmaps, Spatial Data Dashboards, Field Survey and Data Collection Tools, Interactive Reporting and Project Management Tools, Spatial Data Catalogues and Immersive Experiences. Web GIS allows for combinations of GIS web apps to be brought together in a single platform, or portal, with customised user experience (UX) and user interface (UI) design.

The RPS portal is a Web GIS platform developed by the project's industry partner, Satplan Alpha, a firm of town planners and GIS specialists located in Johannesburg, that is

focused on harnessing spatial data technologies for development planning, research and decision making. The founder of Satplan Alpha, Ilan Guest, is an alumnus of the Department of Town and Regional Planning and was a Fulbright Scholar. He was the lead designer of the RPS portal.

The portal has the following objectives in support of the project:

- Explaining the concept of regenerative public space
- Showcasing the RPS case studies of the project
- Providing access to a toolkit of useful RPS resources
- Creating a registration platform for RPS projects, practitioners and partners

The RPS portal functions like a typical scroll-down website with subsections, image and text combinations, and hyperlinks. What distinguishes the RPS portal from a traditional web page is its ability to integrate GIS web apps into the page itself. For example, the showcase section of case study projects makes use of a dynamic background map that shifts to the location of each case study being presented.

Further, the registration platform for RPS projects, practitioners and partners combines a location-enabled survey form that feeds into an interactive map. This map highlights the spatial distribution of the respective parties across the City of Tshwane. The map is dynamic and builds over time as more registrations are made through the portal. Each completed registration features as a colour-coded point on the map that can be clicked to open an information pop-up that describes that particular project, practitioner or partner. Effectively, the registration process slowly builds a GIS map layer over time that is safely archived in the back end and is fed live into the interactive map on the RPS portal.

The main aim of the registration platform is to foster the development of an RPS community in the City of Tshwane by establishing a spatial database of members and allowing all parties to have visual access to the database itself through the interactive map on the RPS portal. This is done in the spirit of boosting potential interaction and collaboration between the various parties.

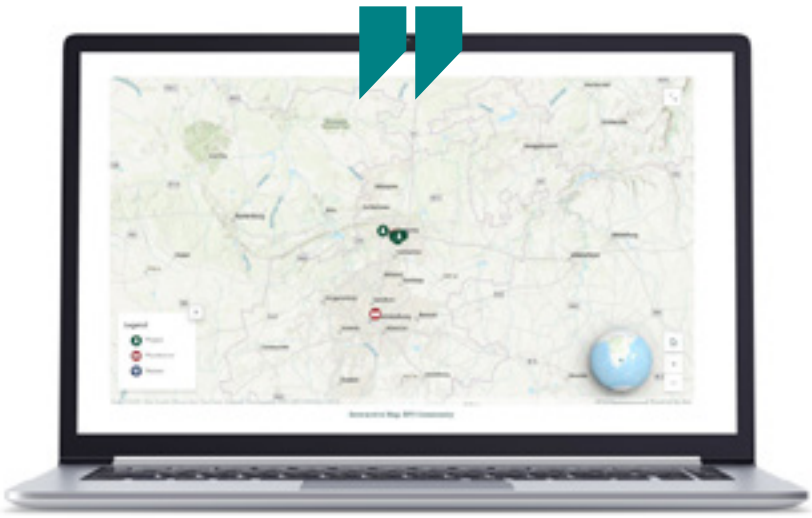
By registering on the RPS portal, projects can identify themselves in terms of their particular objectives and location. Practitioners who are interested in getting involved can identify themselves in terms of their expertise and location. Partners who wish to contribute can identify themselves in terms of their areas of interest, available support and location. The potential for further collaboration between these parties and academia, government departments and the business sector is boosted through exposure on the RPS portal.

Complementing the case studies' showcase and registration platform is the RPS toolkit, which provides hyperlinked access to a variety of helpful resources in the RPS space, e.g. detailed case study summaries, publications and articles, useful links, videos and selected spatial datasets.

One could possibly question whether the digital tool on its own is sufficient to support local communities and sites for their regenerative processes. The outcomes of this project might require ongoing collaborative processes of capacity building and strategic dialogue in intervening solutions, backed by the evidence-based tool currently being developed. However, it offers a point of departure for ongoing collaboration and intervention.

The University of Pretoria will host and manage the RPS portal on an Enterprise GIS. Additional features and augmentations may be added in future based on the experiences of this first phase. The RPS digital platform symbolises new modes of collaborative project planning and research potential between multidisciplinary teams, with technology as the medium and the internet as a catalyst. The platform offers a stimulating way of engaging technology to build connections between people and place to enable regenerative public space in practice.

THE PLATFORM AIMS TO FOSTER THE DEVELOPMENT OF AN RPS COMMUNITY IN THE CITY OF TSHWANE BY ESTABLISHING A SPATIAL DATABASE OF MEMBERS AND ALLOWING ALL PARTIES TO HAVE VISUAL ACCESS TO THE DATABASE ITSELF THROUGH THE INTERACTIVE MAP ON THE RPS PORTAL.



Public space and peace building: **From degenerative to regenerative public space**

Prof Karina Landman, Prof Chrisna du Plessis, Dr Kundani Makakavhule and Prof Stephan de Beer

The world is in turmoil. Across many continents and countries, people are meeting to discuss ways to find solutions to ongoing violence. In many cities, urban residents gather in public spaces to search for inner and outer peace. But what is peace? What role do public spaces in the city play to assist with peace building? How can we construct such spaces?

Albert Einstein once said: "Peace cannot be kept by force; it can only be achieved by understanding." This necessitates people from different backgrounds finding space and time to deliberate the meaning of peace and develop understanding.

In January 2024, a number of local and international delegates from academia, the private sector, government and communities gathered to discuss the role of public space in peace building in South Africa. The workshop and conference was part of a series of events contributing to the 2022–2024 working theme of the Association of European Schools of Planning (AESOP)'s Thematic Group for Public Spaces and Urban Cultures, titled "Public spaces, urban cultures and peace construction".

Conflict, crime and contestation are major concerns in many public spaces, and influence the experiences and perceptions of users in many ways. Peace building is an ongoing process that requires constant negotiation and improvement of what is present, especially in common spaces shared by diverse people in cities. This implies a context with the potential for transformation and regeneration through collaboration, participation and cooperation.

Regenerative sustainability argues for a paradigm change to an ecological or "living systems" world view, which considers entire socio-ecological systems across many scales and the influences of these on each other to find ways to improve the health and wellbeing of humans and nature. Given this, the conference events explored the meaning of peace through a regenerative lens and as part of the broader National Research Foundation (NRF) project on Regenerative Public Space.

SITE VISITS

The conference was preceded by a site visit to three public spaces in different parts of Tshwane. Delegates visited Burgers Park, where a representative from the Tshwane Leadership Foundation explained the inner city challenges, together with the interventions that had been provided in the park. This was followed by a visit to Moja Gabedi, where the park managers narrated the transformation of the space from a mere dumping site to a regenerative garden serving the community of Hatfield with fresh fruit and vegetables. The final visit was to the Muckleneuk Commons, where one of the community members explained how they had assisted with the transition of the space into a well-kept community park.

None of these spaces are neutral, and diverse aspirations often contend to be accommodated. Peace building requires careful listening, discerning how to possibly host contesting voices and aspirations in a synergetic way, making allowance for regenerative spaces that are also expressions of socio-spatial justice.

WORKSHOP AND CONFERENCE

The workshop and conference took place on the University of Pretoria's Hatfield Campus on 29 and 30 January 2024. Delegates ranged from built environment professionals to active community representatives working in the various public spaces. The workshop aimed to explore the construction of peace in various types of public spaces. The intention was to interrogate the relationship between safe and unsafe spaces from a transdisciplinary perspective, with the aim of moving from degenerative to regenerative environments.

This means moving between theory and practice, and involving participants from academia, the private sector and communities to share their thoughts and experiences to reimagine the construction of peace in public spaces through and towards regenerative sustainability. It also means moving beyond short-term peace construction or peace making and peace keeping to longer-term efforts that focus on peace building. This is critical in spaces of conflict and violence, which are not only limited to the Global South, but are growing in the Global North as well.

The workshop and conference both revealed the need to continue the discussion of peace, what it means for different individuals and communities, and how it can be actualised. It called for an interrogation of ethics, values and standards that exist on different scales and inform the creation, maintenance and experience of peace.

The keynote address was delivered by Dr Matej Nikšič, an international scholar on public space from Slovenia. He is also the coordinator of AESOP's Thematic Group for Public Spaces and Urban Cultures. Dr Nikšič shared many initiatives to transform public spaces in rural areas in Slovenia through community participation and bottom-up approaches, highlighting the value of inclusive processes to build peace in public space. Several other presentations highlighted the relationship between peace construction in public space and the critical notions of urban justice, security, conservation, a sense of place or "home", stewardship, spirituality and the role of human-nature relationships.

Prof Chrisna du Plessis from the University's Department of Architecture delivered a presentation on regenerative thinking. She discussed how regenerative design and development had evolved from recognising the limitations of sustainability to resilience thinking and resolving many of the current urban challenges. This entails a shift in thinking from focusing on problem solving and reducing negative impact to focusing on the development of latent potential to identify opportunities for creating positive ripple effects in the larger urban system, thereby creating an alternative model of development that would transform degenerated and dysfunctional spaces into thriving and life-affirming spaces.

This was followed by an understanding of patterns of violence and conflict in Tshwane at a macro and micro level, presented by Willem Badenhorst from Mandala GIS to contextualise experiences in various public spaces. Having set the scene, representatives from four public spaces that formed part of the RPS project (Moja Gabedi, Muckleneuk Commons, Burgers Park and the Melusi Youth Development Organisation) narrated the process of transformation, and highlighted how they had addressed issues of conflict and peace building in their respective communities.

What became clear from these stories is that regenerative development and peace construction is very context-specific. While common lessons could be extracted from the processes, the detailed actions and experiences were particular to each community and set of circumstances.

In the afternoon, participants gathered in smaller breakaway groups to discuss different pathways to peace construction in South African public spaces. Representatives from each group then offered feedback on issues related to the meaning of peace; whether it matters in public space, how to reconsider peace construction in public space, and the role of regenerative development and design to enhance peace construction in public spaces.

PEACE BUILDING

On the final day of the conference, academics and built environment practitioners from various universities in South Africa, including the University of Pretoria, the University of Johannesburg, the University of the Witwatersrand and the Durban University of Technology, gathered to listen to presentations on peace construction in public space. The discussion was enriched by participants from the City of Tshwane and the City of Johannesburg.

REGENERATIVE SUSTAINABILITY ARGUES FOR A PARADIGM CHANGE TO AN ECOLOGICAL OR "LIVING SYSTEMS" WORLD VIEW, WHICH CONSIDERS ENTIRE SOCIO-ECOLOGICAL SYSTEMS ACROSS MANY SCALES AND THE INFLUENCES OF THESE ON EACH OTHER TO FIND WAYS TO IMPROVE THE HEALTH AND WELLBEING OF HUMANS AND NATURE.

Learning from complex living environments to beat the heat

Dr Jan Hugo

Tuesday, 4 July 2023, marked a significant moment in our history. While it was possibly an inconspicuous day for most of us, this day had the hottest average global temperature measured in earth's modern history. A year later, experts confirmed that we have been living in climate conditions that are just below 1.5 °C above pre-industrial temperatures since May 2023 – a threshold the Paris Accord aimed to preserve.

OUR RESEARCH SHOWS THAT, WHILE THE BUILT ENVIRONMENT IS HIGHLY EFFECTIVE IN LOWERING EXPOSURE TO CLIMATE-DRIVEN CRISES, THE INVERSE OCCURS WHERE POORLY CONSTRUCTED BUILT ENVIRONMENTS INCREASE OUR EXPOSURE TO EXTREME WEATHER CONDITIONS SUCH AS HEAT WAVES AND EXTREME HEAT.

The Melusi informal settlement.

While this temperature increase seems small, the past few years have also been marked by several extreme weather events resulting from these higher temperatures. These events affected many African countries and ranged from flooding in Libya and cyclones in the eastern regions of southern Africa to significant droughts over the central southern African regions. Although extreme weather events are widely documented, the increase in heat stress and extreme heat days that affect marginal communities in our society often go undetected.

At the University of Pretoria, the Department of Architecture is working on solutions to lower heat stress exposure in our cities and improve the health and wellbeing of our urban residents. Understanding the extent of heat stress exposure and how it can be addressed in the built environment, specifically in vulnerable environments such as informal settlements, has been the research focus of an interdisciplinary team of researchers from the Department of Architecture, the Department of Chemical Engineering and the School of Public Health and Health Systems, together with research teams from the University of the Witwatersrand's Reproductive Health and HIV Institute (RHI) and the Centre for Sexual Health and HIV AIDS Research (CeSSHAR) Zimbabwe.

Through a series of research projects, located in the City of Tshwane, South Africa, and Mount Darwin in Zimbabwe, the research team has been documenting the built environment of dwellings and early childhood development centres in informal and rural settlements, and monitoring heat exposure in these contexts.

The immersive, context-driven research projects that actively involve interdisciplinary work from specialists in the health sciences and the built environment allow us to holistically understand informal, self-constructed built environments and simulate the current and future performance of these environments. The latest research project, Heat Adaptation for Pregnant Women and Infants (HAPI), funded by the Wellcome Trust, extends the project's focus to consider multi-level interventions that include health practitioners, policy makers and residents in defining heat health solutions.

CLIMATE CRISIS AND HEAT STRESS

Heat stress can be defined as the increased stress on the human body to regulate its internal temperature when exposed to high thermal conditions. As a result, the body is put under strain to cool itself. Heat stress can have multiple impacts on individuals, ranging from irritability and discomfort to heat stroke and death. It has also been noted to affect communities financially due to lower labour efficiencies, and socially with a marked increase in violence and violent behaviour.

Our research has also shown that, while the built environment is highly effective in lowering exposure to climate-driven crises, the inverse occurs where poorly constructed built environments increase our exposure to extreme weather conditions such as heat waves and extreme heat. This is especially evident in marginalised and poor communities that have little resources to address this and often have little to no access to formal cooling technologies such as air-conditioners.

Researchers from the City of Tshwane and the Council for Scientific and Industrial Research (CSIR) have suggested that we will experience an increase in extreme heat days. Large portions of the South African urban population living in informal settlements run the risk of being increasingly negatively affected.

As a result, our research projects have been implemented in the Melusi informal community in Pretoria West. We also recently expanded our focus to include Itireleng and Mooiplaas, close to Laudium, and further into Africa to more rural settings in Mount Darwin in northern Zimbabwe. All these communities live in informal, self-built settlements with limited infrastructure.

Installing indoor environment sensors in a dwelling.

MULTI-LEVEL INTERDISCIPLINARY WORK IS VITAL TO DEVELOP SOLUTIONS

Researchers have argued that solutions to address heat stress typically take place on three levels: personal practices, technical solutions and social/cultural adjustments. This highlights the importance of understanding that heat stress solutions cannot be developed by a single discipline, but needs to involve multiple stakeholders.

Subsequently, the HAPI study aims to define response strategies that can be developed, tested and implemented synergistically. The focus is on multiple levels, ranging from dwellings (at the household level), health facilities and community to the national policy level. We envision that the work will result in strategies that affect national health policies, considerations to adapting the built environment, strategies to improve the capacity of residents to undertake climate change adaptation measures, and guidelines to develop heat health practices in clinics.

BUILT ENVIRONMENT SPECIALISTS SUPPORTING THE MULTIDISCIPLINARY TEAM

The research team in the Department of Architecture has been actively documenting and monitoring various buildings and informal dwellings. This immersive process of visiting, observing and working with communities allows the team to better understand the environments that individuals inhabit, and helps us to formulate typical buildings and building practices. Once back in the "lab", the data is utilised to develop digital models of these dwellings, allowing for further simulations and analyses that consider both current and future climate change-affected conditions.

DIGITAL SIMULATIONS

While working in the field is critical to understand these typically "hidden" informal conditions and the communities that are affected, digital simulations enable us to test and develop response measures and solutions that can have long-term benefits before implementing them *in situ*. These solutions range from testing cool paints and developing water walls and shading structures to optimising the synergy of solutions currently being implemented in informal settlements by homeowners.

Recently, we have also been able to develop a testing facility to simulate an informal dwelling in real-world conditions to enable physical simulations. This ultimately allows us to test solutions and identify possible disparities between physical and digital simulations.

Researchers collecting data on site.

THE WAY FORWARD – SYNERGISTIC BUILDING TECHNOLOGY LABORATORY

Immersing ourselves as research teams into existing contexts and simulating them digitally allows us, as researchers, to use cutting-edge technologies to understand typically ignored built environments. The integration of the digital realm with physical simulations is also an important future step towards developing a living lab at the University of Pretoria where we can create a context for solutions to be developed using interdisciplinary teams, and finally, to prepare technologies in a transdisciplinary manner, with community members, to benefit society at large.

Real-world simulations on the Innovation Africa @UP campus.

Trends on the cost and business case of green building – a South African perspective

Dr Danie Hoffman

In 2014, Green Building Council South Africa (GBCSA), the Association of South African Quantity Surveyors (ASAQS) and the University of Pretoria (UP) joined forces to start a long-term study on the Green Building Cost Premium (GBCP) to refute the unaffordability argument against green building. The findings of this study, supported by grounded industry data from Morgan Stanley Capital International (MSCI) South Africa's Green Annual Property Index, reveal interesting and exciting trends regarding the capital expenditure and the business case for green building.

The joint study on the GBCP has published its findings in three industry booklets released in 2016, 2019 and 2022, with the booklet for 2024 in preparation. The average GBCP found for 2009–2021 was only 3.63%. This study confirms that the South African green building industry is innovative and quick to learn and adapt. The industry's growing maturity is apparent from the declining trend of the GBCP over time, from an average of 5.95% for 2009–2014 to 3.15% for 2018–2021. Larger office buildings and office buildings with a higher base building cost (R/m²) were found to achieve Green Star certification at a lower GBCP.

The green building cost data is sourced using an Excel spreadsheet developed for this purpose, named the Financial Transparency Tool. The successful submission of financial transparency earns buildings innovation credits towards achieving the desired Green Star rating. The success of this study resulted in the forwarding of green building cost data being integrated into the new V2 Green Star Tool.

Although the GBCP study focused on the costs of green building, other interesting aspects were also revealed. One such green building aspect was the changing nature of the tenant makeup of green office buildings.

The first South African office buildings to achieve Green Star status during 2009 and 2010 were single-tenanted buildings occupied by large corporate tenants. From 2011 to 2013, a new trend emerged, with between 30 and 40% of the Green Star certifications being generic office buildings developed for multiple tenant occupations. Since 2014, this market share has increased to between 50 and 80% – a trend that is expected to stabilise and continue. This trend confirms the widening acceptance of green in the South African office space market and the growing maturity of the green building industry.

Another set of green trends was identified by a UP postgraduate study in 2021 on the use and achievability of credits in the new built and major renovations V1.1 Green Star rating tool. The study was based on a similar Australian study, conducted by Zuo et al.[1] in 2016 on its Green Star rating tool. The study considered the frequency of projects applying for specific credits, defined as the credit application rate (CAR), expressed as a percentage of the total number of certified projects against the points obtained per credit as a percentage of total points applied for, defined as the credit achievement degree (CAD). The Credit Gain Index (CGI) is calculated as CAR multiplied by CAR. This indicates a measure of the achievability of specific Green Star credits. A total of 17 credits had a CGI above 90%, while 15 credits had a CGI under 10%. This data was considered by the committee of Green Building Council South Africa (GBCSA) responsible for developing the V2 Green Star tool.

1 *Zuo, J., Xia, B., Chen, Q., Pullen, S. and Skitmore, M. 2016. Green building rating for office buildings – lessons learned. Journal of Green Building 11(2).*

The GBCP study confirmed that the upfront capital cost of green building is only part of the challenge towards a more sustainable industry. The business case for green building and comparing the cost of ownership and the return on investment achieved by green buildings are critical aspects in the drive towards a sustainable built environment.

A simple example can be used to evaluate the business case for green buildings based on findings from the above GBCP study and data from the MSCI South Africa Green Annual Property Index 2022. The example uses first-year and marginal returns to evaluate the modelled green building performance relative to a similar non-green building.

Assume the following details of an A-grade office building:

- Construction area: 10 000 m^2
- Gross lettable area: 9 200 m^2
- Estimated building cost: R15 000/m^2
- Green building cost premium: 3.0%
- Estimated land cost: R30 million
- Gross monthly rental: R170/m^2

MSCI findings on its green property portfolio:

- Green building rental premium: +14.2%
- Green building vacancy premium: -4.3%
- Green building operational cost: -10.6%
- CAP rate: -0.5%

TOTAL PROJECT COST

Based on the construction area and the estimated construction cost, the **non-green** building will cost R150 million (10 000 m^2 x R15 000/m^2). By adding the land cost (R30 million), the total project cost will be R180 million. The GBCP of 3.0% will result in an additional cost of R4.5 million and a total project cost of R184.5 million for the **green** building.

NET ANNUAL INCOME

The **gross monthly income** for the non-green building is R1 564 000 (9 200 m^2 x R170/m^2), while that for the green building is R1 786 088 or R222 088 more due to the 14.2% rental premium. Assuming an average vacancy factor of 16.3% for the non-green building or R254 932 per month, the **vacancy factor** for the green building is 15.6% (4.3% lower than for the non-green building). The gross monthly income (after vacancies) is then R1 309 068 for the non-green building compared to R1 509 478 for the green building.

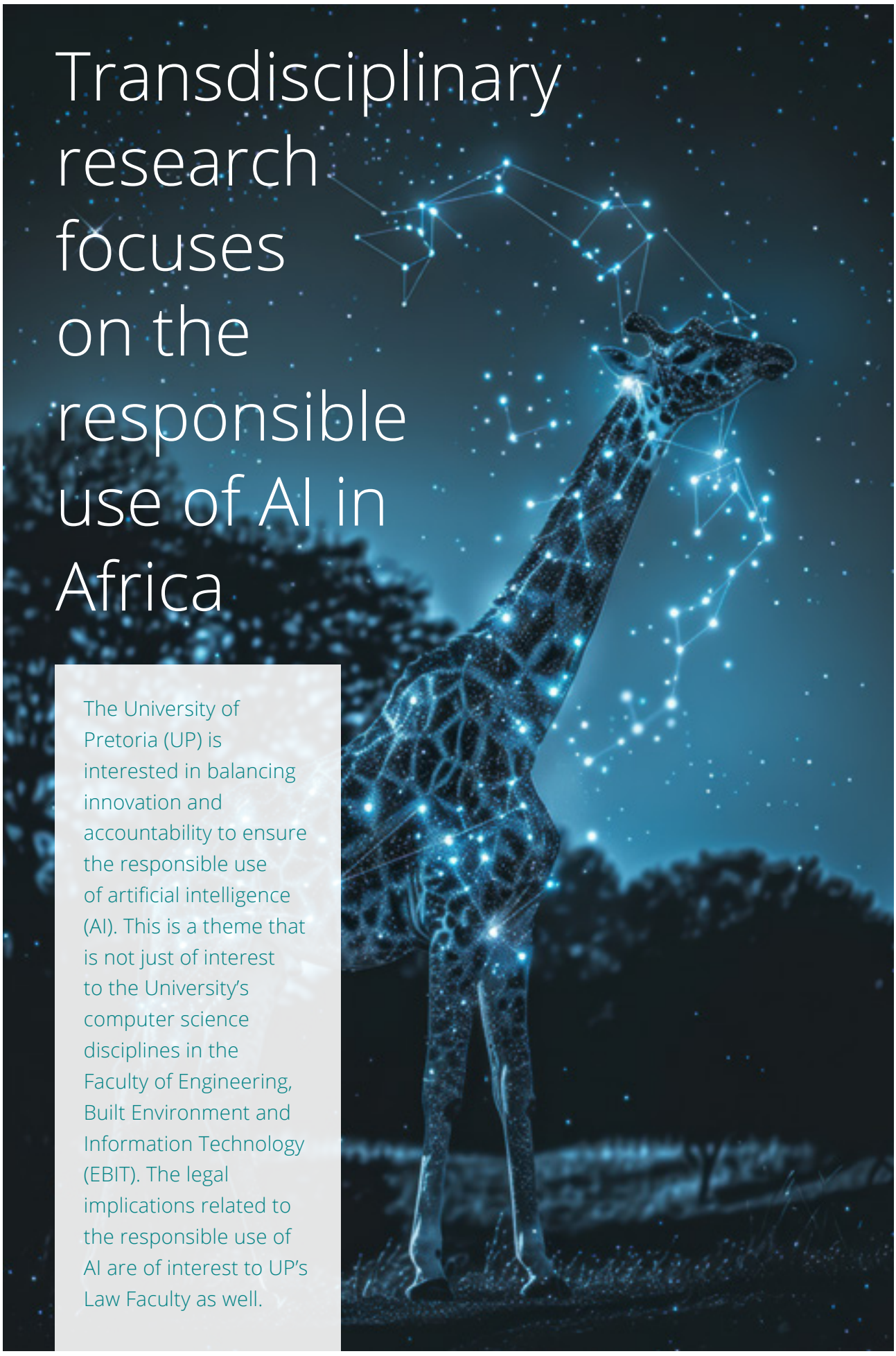
Assuming an average **operating cost** of 15%, this will amount to R234 600 per month for the non-green building. The operating cost for the green building is **13.6%** (10.6% lower than for the non-green building), amounting to R239 510 per month. The net monthly income is then R1 074 468 for the non-green building compared to R1 267 968 for the green building. The net annual income is then R12 893 616 for the non-green building compared to R15 215 616 for the green building. The net annual income of the green building, therefore, exceeds that of the non-green building by R2 322 000.

FIRST-YEAR RETURN

The first-year return of the non-green building is 7.16% compared to 8.25% for the green building. The modelled **first-year return** of the green building exceeds that of the non-green building by **15.13%**. The **marginal return** on the R4.5 million additional investment required amounts to **51.6%**. Although this is a modelled exercise, these are significant performance numbers based on proven industry data and should be very achievable in the real world. The exercise confirms that green buildings are indeed doing well, while they are doing good.

Adapted from an article published in issue 29 of Green Building Council South Africa's +Impact *magazine.*

Transdisciplinary research focuses on the responsible use of AI in Africa



The University of Pretoria (UP) is interested in balancing innovation and accountability to ensure the responsible use of artificial intelligence (AI). This is a theme that is not just of interest to the University's computer science disciplines in the Faculty of Engineering, Built Environment and Information Technology (EBIT). The legal implications related to the responsible use of AI are of interest to UP's Law Faculty as well.

Joining forces to develop a two-pronged approach to tackle this theme are Prof Vukosi Marivate, holder of the Absa UP Chair of Data Science in EBIT's School for Information Technology, and Dr Chijioke Okorie, leader of UP's Data Science Law Lab. These two researchers believe that AI producers need to better consider the communities that directly and indirectly provide the data used in AI development.

Their recent focus, which resulted in an article published by Carnegie Endowment for International Peace, examined how African natural language processing (NLP) experts are navigating the challenges of copyright, innovation and access.

In the introduction to their article, they explain how, as an ideal or a practice, openness in AI involves sharing, transparency, reusability and extensibility that can enable third parties to access, use and reuse data, and deploy and build upon existing AI models. This includes access to developed datasets and AI models for purposes of auditing and oversight, which can help establish trust and accountability in AI when it is done well.

Prof Marivate explains how some common sayings in African languages encapsulate how issues of agency and community ownership are implicated or threatened when openness is embraced in a bid to include Africa and other parts of the Global South in discussions about the responsible use and development of AI.

While actors in the Global North have been the primary drivers of discussions about responsible AI by focusing on concepts like openness, privacy and the protection of copyright, there have been increased efforts to amplify perspectives from under-represented jurisdictions. This is in an effort for them to help shape discussions about responsible AI use and development in the Global South. Within this atmosphere of inclusion, openness, privacy and copyright have continued to feature as important and indispensable considerations. This is referred to as the Global South inclusion project.

To highlight these interests and concerns, the research featured a study of the African NLP community, presenting insights from the work of the Masakhane Research Foundation, a distributed research organisation with the mission to advance African NLP, as well as Ghana NLP, an open-source initiative focused on NLP involving Ghanaian languages, and KenCorpus, a community-driven project to create large Kenyan language datasets. The experiences of this community would help ground the practical trade-offs and challenges that arise in this discipline.

The research furthermore highlighted some of the opportunities and challenges presented by considerations around openness as a way to address copyright and privacy concerns. Openness must be practiced in a manner that considers the communities that provide the data used in commercial and non-commercial settings for AI development. Depending on the use case, the interests of these communities may involve financial and social benefits, or mere attribution or acknowledgement.

As a result of their proprietary and rule-based nature, copyright and privacy rules may result in practices that discourage openness. Yet, addressing the restrictive and proprietary nature of these rules through openness does not mean that openness is adopted without attending to the nuances of specific concerns, contexts and people. In adapting openness to the nuances of the contexts of Africa, consideration must be given to the agency and autonomy of specific stakeholders to make decisions about the uses of their data contributions, created and annotated datasets, and the needs that AI tools and development are designed to address. The intersectionality of these concerns necessitates a comprehensive approach to data governance, which addresses the multifaceted challenges and opportunities presented by Africa's evolving data landscape.

From a regulatory point of view, copyright and privacy laws may need internal reforms, explains Dr Okorie. There may even be the need for a specific piece of legislation, such as the European Union has undertaken with its recently passed Artificial Intelligence Act. However, of more immediate benefit, given the protracted nature of legislative reforms, is the use of contracts and private ordering regimes. "The doctrine of freedom of contract means that changes and tweaks can be made in existing open licensing regimes to address relevant challenges and harness relevant opportunities."

The researchers conclude that the good news for private actors is that they can directly make changes and tweaks in the open licensing regimes to address the challenges and harness the opportunities encountered in this research.

THE RESEARCH HIGHLIGHTED OPPORTUNITIES AND CHALLENGES PRESENTED BY CONSIDERATIONS AROUND OPENNESS AS A WAY TO ADDRESS COPYRIGHT AND PRIVACY CONCERNS. OPENNESS MUST BE PRACTICED IN A MANNER THAT CONSIDERS THE COMMUNITIES THAT PROVIDE THE DATA USED IN COMMERCIAL AND NON-COMMERCIAL SETTINGS FOR AI DEVELOPMENT.

Language without borders: tired of being lost in translation?

Researchers in the field of computational linguistics believe that we need language models that represent the actual ways in which people use language, and conversational interfaces that give people the feeling they do not have to disregard their own linguistic identities.

Researchers in the Department of Computer Science, under the supervision of Prof Vukosi Marivate, Chairholder of the Absa UP Chair of Data Science, sketch the following scenario: Imagine walking down a bustling street in one of Africa's cosmopolitan cities, listening to the echo of voices. What do you hear? Words. Foreign and familiar, a mix of languages, even in one conversation. This phenomenon is known as code-switching – a common linguistic practice in multilingual cultures where people switch between languages in a single discourse.

Prof Marivate explains that, currently, about 40% of the world population is bilingual and almost 20% is multilingual. Africa alone accounts for approximately 2 000 of about 7 000 languages in the world, making code-switching an inevitable occurrence. However, most African languages are low-resourced and under-represented in recent natural language processing (NLP) technologies. The most popular NLP technologies are the large language models (LLMs). "It is therefore imperative to move towards equitable representation of these languages and ensuring that everyone has equal access to these technologies," he says.

Current research into code-switching has received increased attention in the past decade, with the most being on corpus creation, benchmark development and the evaluation of downstream tasks between English and Spanish, Hindi and Chinese. Very little research or available data exists for African languages.

To address this issue of data scarcity, the research team embarked on utilising LLMs such as ChatGPT to generate code-switched text. Methodologies include linguistic prompting, in-context learning and zero/few-shot fine-tuning. Initial results suggest that the embedded knowledge of high-resource languages can be useful in closing the gap in low-resource language availability. The goal is to develop sustainable methods for corpus creation and to make these resources available to the larger community to continuously support advancements in this research field.

This research opens the possibilities for transdisciplinary collaboration in, but not limited to, three fields: linguistics (to understand the constraints of how and why code-switching occurs), education (to allow for a mixed-language setting to promote both teaching and learning) and speech-language pathology (to assist researchers and practitioners in improving recommended development plans).

"Data quality is at the centre of the research," says PhD candidate, Michelle Terblanche. As part of her research, she is focusing on developing methods to evaluate synthetic data with minimal human intervention and low-cost computational resources. "We can then address a broader range of applications, catering for language diversity," she says.

"Our aim is to position Africans at the forefront of shaping AI for our own benefit," says Prof Marivate.

This research is a step towards preserving a rich culture and focusing attention on developing technologies that serve the ever-growing multilingual population.

In alignment with this goal, Prof Marivate, who received the Faculty Research Award from JP Morgan Chase AI, is channelling a portion of these funds into a specific aspect of the broader research of Dr Kayode Olaleye, a postdoctoral fellow in the Department. This collaboration aims to enhance financial inclusion, irrespective of linguistic habits or educational background.

As Dr Olaleye puts it: "Through breakthroughs in code-switching modelling, we envision financial institutions being able to offer more relevant, accessible and engaging experiences to a wide array of customers." Dr Olaleye further explains: "This research can potentially facilitate the provision of bilingual customer service, the creation of multilingual documentation and the crafting of marketing material specifically designed to resonate with the diverse linguistic habits of customers."

Can Artificial Intelligence create itself?

Prof Nelishia Pillay of the Department of Computer Science is a recognised expert on emerging topics in computational intelligence, and evolutionary learning and optimisation. During the 33rd UP Expert Lecture, held at the University of Pretoria (UP) on 29 August 2024, she asked the question whether artificial intelligence (AI) can create itself.

Prof Pillay holds the Multichoice Joint Chair in Machine Learning, as well as the South African Research Chairs Initiative (SARChI) Chair in Artificial Intelligence for Sustainable Development at UP. She is involved in various activities of the Institute of Electrical and Electronics Engineers (IEEE) Computational Intelligence Society (CIS). She is Chair of the IEEE CIS Mentoring Programme Subcommittee, the IEEE Subcommittee for Diversity, Equity and Inclusion, and the IEEE CIS Award for Outstanding PhD Dissertation Subcommittee.

Her research areas include hyper-heuristics, the automated design of machine learning and search techniques, transfer learning, combinatorial optimisation, genetic programming, genetic algorithms, and machine learning and optimisation for sustainable development.

She established the Nature-inspired Computing Optimisation research group in the Department of Computer Science, which focuses on creating new and extending existing AI techniques to solve problems related to the United Nations' Sustainable Development Goals (SDGs). This includes innovation in industry, health and wellbeing, lifelong learning and renewable energy. Research conducted under her supervision has contributed to the automated diagnosis of various diseases, including COVID-19, diabetes, heart disease and depression, as well as plant diseases.

Artificial intelligence has had a major impact in the Fourth Industrial Revolution, and has been instrumental in finding scalable solutions to complex problems related to the SDGs.

Prof Pillay explains that AI has developed from basic and knowledge-based systems. Today, computer scientists are even contemplating the automation of AI to get it to learn from itself.

There are three types of machine learning: reinforcement learning, supervised learning and unsupervised learning. Reinforcement learning is based on changing behaviour according to the responses received. Supervised learning involves learning by making mistakes and using artificial neural networks to simulate the human brain. Unsupervised learning is learning that does not need annotated data.

Prof Pillay has been supervising several projects related to AI for sustainable development.

Much of the work conducted in the Multichoice Joint Chair in Machine Learning is linked to innovation in the broadcasting industry, such as the use of AI for automated thumbnail selection for movies using a combination of optimisation, and the genetic programming and convolutional neural networks of machine learning.

In terms of health and wellbeing, researchers have been working with a chemical pathologist at UP to automate the process for myeloma detection through supervised machine learning. They have also been working with the Department of Dentistry to detect oral lesions. This entailed comparing supervised and unsupervised machine learning. Machine learning techniques are also being used for cancer detection from images, including skin cancer, brain tumours and lung cancer using artificial neural networks.

Lifelong learning is another area that is benefitting from machine learning. A project to role out intelligent tutoring systems was conducted in the training of speech therapists in South Africa. These systems employ AI techniques to provide individualised tuition in an attempt to mimic human tutors. A further development in this area is automated marking techniques in the answering of short text answers provided by the user.

However, explains Prof Pillay, as the adoption of AI grows, we find ourselves in a situation where AI has moved out of computer science laboratories and is being used by non-experts. This brings us to the point where the question arises whether AI can be used to create AI. "To solve this problem, one needs some knowledge of neural networks," she says. Getting computer scientists to tune the necessary parameters is a laborious process. "This makes many people speculate whether we can get AI to do this for us." A lot of work has been conducted in the area of automated machine learning. Will computer scientists eventually be able to package AI in such a way that it can be used by a non-expert to design solutions to the threats posed to sustainable development?

She observes that the reason for automating the design of AI using AI lies in the need for expert specialist knowledge when designing AI approaches to problem solving.

AS THE ADOPTION OF AI GROWS, WE FIND OURSELVES IN A SITUATION WHERE AI HAS MOVED OUT OF COMPUTER SCIENCE LABORATORIES AND IS BEING USED BY NON-EXPERTS. THIS BRINGS US TO THE POINT WHERE THE QUESTION ARISES WHETHER AI CAN BE USED TO CREATE AI.

Unveiling hidden knowledge: Dark data management as a catalyst for digital decarbonisation

Prof Hanlie Smuts

The rapid evolution of information and communication technologies, coupled with globalisation and digitalisation, has led to a vast network of inter-connected devices, which contribute to the exponential growth of data. While big data offers organisations valuable insights and transformative opportunities, such as enhanced customer engagement and business model optimisation, it also presents significant challenges.

AS ORGANISATIONS STORE MORE DATA WITHOUT EFFECTIVE MANAGEMENT, DARK DATA GROWS, LEADING TO INCREASED STORAGE NEEDS AND INEFFICIENCIES.

One pressing concern is the environmental impact of data storage, with data centres contributing to 2% of global greenhouse gas emissions. They are also projected to consume up to 4% of global electricity by 2030. The concept of digital decarbonisation has emerged as a critical focus, aiming to reduce the carbon footprint associated with digital storage and processing. A key aspect of this effort lies in the management of dark data – unused information that, if effectively leveraged through knowledge management practices, artificial intelligence (AI) capability and machine learning (ML) models, could support sustainability goals.

Dark data refers to the information that organisations collect, process and store, but do not actively use or analyse. This often includes unstructured data from sources like emails, old documents and logs, which remain hidden or unused. The accumulation of dark data is typically caused by factors such as poor data management practices, inadequate data governance and the failure to implement systematic data archiving processes.

As organisations store more data without effective management, dark data grows, leading to increased storage needs and inefficiencies. The implications for carbon emissions are significant, as storing and managing large volumes of dark data require substantial energy consumption, contributing to higher carbon footprints. The inefficient use of resources associated with dark data can also hinder sustainability efforts and inflate operational costs.

Organisations need to unlock dark data's hidden value by applying technologies such as AI and ML to derive insights from dark data. However, relying solely on technology is insufficient. Organisations need comprehensive strategies to discover dark data, map its contents, establish policies for its retention and destruction, develop the necessary data science skills and integrate dark data analytics into their business processes.

From a knowledge management practice focus, organisations should invest adequately in the development of human and social capital. This investment ensures that the organisation has the necessary tools and skilled personnel to handle, analyse and derive value from dark data. By applying advanced technology, organisations can enable substantial and targeted knowledge sharing across geographical barriers, ensuring that insights derived from dark data are accessible to all relevant stakeholders. This approach not only enhances the organisation's ability to manage and utilise dark data, but fosters collaboration and innovation across different regions and teams, driving overall organisational growth and resilience.

There are seven key strategies organisations may consider to address the digital decarbonisation concern through knowledge management practices, AI capability and ML models:

Data discovery and classification: Use automated data discovery tools such as AI and ML to identify and classify dark data across the organisation. These tools can help categorise data according to its relevance, sensitivity and potential for reuse, which is critical in minimising data storage costs and energy consumption. Metadata management practices must be implemented to improve data discoverability and ensure that dark data is properly tagged for future reference.

Data retention and disposal policies: Develop and enforce data retention schedules to specify how long different types of data should be kept. This helps in systematically purging obsolete or non-essential data and reducing storage requirements and energy use. Data deletion protocols for securely disposing of data that no longer serves a purpose ensure that it is done in an energy-efficient manner.

Data governance and compliance: Implement data governance frameworks that include the management of dark data. This ensures accountability, data quality and compliance with regulations related to data privacy and environmental sustainability. The incorporation of sustainability metrics into data governance enables one to track and minimise the carbon footprint of data storage and processing activities.

Data utilisation and repurposing: Use data mining and analysis techniques to support the valuable extraction of insights from dark data. This can lead to better decision making and the identification of opportunities to reduce waste and improve efficiency. Organisations should identify opportunities to repurpose dark data for new applications, such as enhancing predictive models, optimising operations or supporting sustainability initiatives.

Data minimisation and streamlining: Encourage the practice of data minimisation, i.e. only collect and store necessary data. This reduces the volume of dark data and the associated energy costs of managing it. Streamlined data management processes reduce redundancy and improve the efficiency of data handling. This also contributes to lower energy consumption.

Education and culture change: Educate and train employees on the importance of processes that generate dark data and its impact on the organisation's carbon footprint. This awareness can lead to more mindful data practices across the organisation. A culture that prioritises digital sustainability should also be fostered, encouraging employees to contribute to efforts that reduce unnecessary data accumulation and promote the responsible use of resources.

Continuous monitoring and optimisation: Implement real-time monitoring systems to continuously track the volume and types of dark data within the organisation. This enables proactive management and optimisation efforts. Regular data audits should be conducted to assess the effectiveness of dark data management strategies and identify areas for improvement in line with digital decarbonisation goals.

By exploring the intersection of knowledge management, dark data management, and sustainability, this research project offers actionable knowledge management strategies and tactics to enhance organisational practices and decision making in dark data management.

Prof Hanlie Smuts *is the Head of the Department of Informatics and Chair of the School of Information Technology at the University of Pretoria. She is currently working on a research project focused on sustainability, with one of the key topics being addressing digital decarbonisation. This article is an excerpt from a conference paper published in the conference proceedings of the Southern African Conference for Artificial Intelligence Research (SACAIR) 2024.*

ORGANISATIONS NEED TO UNLOCK DARK DATA'S HIDDEN VALUE BY APPLYING TECHNOLOGIES SUCH AS AI AND ML TO DERIVE INSIGHTS FROM DARK DATA. HOWEVER, RELYING SOLELY ON TECHNOLOGY IS INSUFFICIENT.

Better solutions through better requirements: The link between business analysis and user experience

Prof Hanlie Smuts and Mikhail Edwards

In the digital era, merging business analysis (BA) with user experience (UX) design has emerged as crucial for crafting products and services that not only achieve business objectives, but also deeply resonate with end-users. This convergence advocates a holistic approach to product and service development, ensuring alignment with both strategic business aims and user satisfaction.

Business analysis is centred on understanding and articulating business needs, strategic goals and project requirements. It plays a pivotal role in capturing the business context, which includes market conditions, competitive dynamics and internal processes. These aspects are essential for defining the scope and vision of projects. On the other hand, UX design prioritises the end-user, focusing efforts on understanding user behaviour, preferences and pain points, thus ensuring that the solutions developed are not only functional, but also enjoyable.

The integration of BA and UX recognises the importance of satisfying user needs as fundamental to achieving business success. Products developed without considering user experience fail to make an impact in the market, regardless of their strategic alignment or technical sophistication. This integration is therefore not merely beneficial, but essential for developing solutions that are both commercially viable and user-centric.

A systematic methodology that includes both BA and UX encompasses stages from requirement gathering to continuous user feedback and iteration. The initial phases, where business analysts and UX designers collaborate closely, are critical for setting the direction and ensuring that the proposed solutions meet dual objectives of business viability and user satisfaction. Effective collaboration between these fields can result in products that not only meet business goals, but also foster user loyalty and advocacy, thereby enhancing the competitive edge of the business.

Moreover, the process of integrating BA and UX extends beyond initial development phases to include continuous monitoring, adaptation and refinement based on user feedback and changing market conditions. This adaptive approach ensures that products remain relevant and continue to satisfy user needs as those needs evolve, thereby sustaining organisational agility and responsiveness.

In practice, the successful integration of BA and UX can be facilitated through various methods, such as joint workshops, cross-functional teams and iterative development cycles. These practices encourage ongoing communication and collaboration between business analysts and UX designers, ensuring that insights from both domains are effectively incorporated into the development process.

In conclusion, the synergy between business analysis and UX is a critical factor in creating successful digital products and services. By bridging the gap between business objectives and user needs, organisations can develop solutions that not only fulfil strategic goals, but also enhance user engagement and satisfaction. This integrated approach is vital in today's competitive market, where user satisfaction is as important as commercial viability. The collaborative efforts of business analysts and UX professionals are thus valuable in steering projects toward success by aligning business strategies with user-centric designs, ultimately fostering both organisational value and user delight.

Navigating the digital frontier: Ethical challenges and transdisciplinary innovations

Rachel Fischer

The emergence and continuous evolution of technological devices have undeniably transformed the world, reshaping how individuals navigate and experience their unique environments. Traditional methods of accessing research and literature – such as visiting libraries, consulting with librarians, or searching through catalogues – have been significantly supplanted by online catalogues and searches. The vast development of AI and emerging technologies has also impacted the fields of engineering, the built environment and IT.

Platforms like Google and other search engines render vast amounts of information readily accessible. However, this does not guarantee that all data is accurate or of high quality. In engineering, the built environment, and information technology (IT), the quality of information is paramount, as it directly influences design decisions, construction methodologies and the development of software solutions.

In these fields, the integration of immersive technologies – such as virtual reality (VR) and augmented reality (AR) – has further transformed the landscape of teaching and learning. These tools facilitate experiential learning, enabling students and professionals alike to visualise complex systems and scenarios in ways that traditional methods cannot match. For instance, engineering students can simulate the structural integrity of buildings in a virtual environment, allowing them to experiment and learn from failures without real-world consequences. Such immersive experiences foster transdisciplinary collaboration, bringing together insights from engineering, architecture, environmental science and IT to create holistic solutions to complex problems.

Gone are the days when one had to secure an appointment with the bank manager or other authority figure to discuss issues or obtain information. Today, individuals can connect virtually through various devices, raising and addressing concerns in real-time, while still retaining the option for in-person interactions. Moreover, users can document discussions and decisions on their personal devices for future reference. This shift in communication modalities enhances the ability to conduct research and share findings across disciplines, fostering a culture of collaboration that is essential in today's interconnected world.

Socially, digital technologies facilitate global communication, enabling people to connect with colleagues, friends and family regardless of geographic barriers. Tools like Skype, Zoom and WhatsApp allow for virtual face-to-face interactions, all without the need to leave home, thus saving time, effort and money. In the context of education, these platforms have allowed institutions to offer online courses, expanding access to knowledge and fostering an inclusive learning environment. This is particularly important in fields such as engineering and IT, where the demand for skilled professionals continues to grow.

Nevertheless, this digital landscape has a darker side. While the ease of connectivity offers unparalleled opportunities for information exchange, it also raises significant privacy concerns. Malicious actors may exploit digital technologies to invade privacy – hacking systems to track individuals' location and behaviour without consent, leading to potential threats of humiliation, abuse or identity theft. Thus, while these tools can foster connection and collaboration, they also have the potential to devastate lives.

Underlying these issues is the recognition that digital technologies, no matter how advanced, are not infallible. There is no assurance that users on either side of the digital divide will engage ethically with these devices or the information generated through them. Growing concerns about the misuse of digital technologies have catalysed a global movement, advocating for a digital code of conduct. This code of conduct seeks to delineate ethical digital behaviour, while proposing measures to safeguard users and ensure the responsible use of emerging technologies, particularly Artificial Intelligence (AI).

This necessity for ethical oversight emphasises the responsibility of both users and designers of digital technologies to prioritise safety and ethical considerations. In engineering and IT, this includes the need to incorporate ethical frameworks into the curriculum, ensuring that future professionals understand the implications of their work. The argument posits that, by establishing their own values around ethical behaviour and design, stakeholders can better control the risks associated with technology, rather than leaving it to external authorities – such as policy makers – who may not appreciate diverse value systems or cultural contexts. This is especially critical in discussions surrounding AI, where ethical considerations must be woven into every aspect of development and implementation.

The swift progression of digital technologies, powered by AI, has spurred extensive debates on their ethical implications – both positive and negative – and their environmental impact. Although the Institute for Electrical and Electronics Engineers (IEEE) advocates the alignment of autonomous and intelligent systems with societal values and ethical principles, existing research reveals significant gaps in ethical practice during the design and implementation of these technologies.

This concern has led to the IEEE's ambitious initiative, the Global Initiative for Ethical Considerations in Artificial Intelligence[1], which aims to create an ethical framework for AI development and application, fostering a focus on human wellbeing.

Members of this initiative are encouraged to place ethical considerations at the forefront of AI technology creation. Their commitment revolves around ensuring that AI and autonomous and intelligent systems are not only efficient, but also aligned with human moral values and ethical principles. This approach is vital for cultivating trust between humans and technology, which is essential for the pervasive use of AI in everyday life. In engineering and the built environment, this alignment can facilitate innovations that not only meet technical specifications, but also enhance community wellbeing and environmental sustainability.

By aligning autonomous and intelligent systems with societal values, the aim is to enhance human wellbeing as a measure of progress in an increasingly algorithm-driven world. This alignment also seeks to mitigate unforeseen consequences stemming from information and communication technologies, such as algorithmic biases that disadvantage certain demographics. The opaque nature of AI-driven decision making can lead to unfair outcomes, prompting a critical examination of the ethical balance between human free will and data-driven dominance.

Responses to these ethical dilemmas have primarily concentrated on improving accessibility to information technologies, while emphasising the importance of ethical usage. The discourse has largely revolved around "opening the black box" of technology to ensure transparency.

However, there remains a significant need to explore the ethical dimensions of AI in greater depth, and define its role in shaping the design and application of information technologies moving forward. This includes integrating transdisciplinary approaches that draw on insights from various fields, ensuring that technological advancements are not only innovative, but also socially responsible.

As we move into a future, where the impact of research and teaching in engineering, the built environment and IT becomes ever more significant, it is essential that we embrace a holistic approach that prioritises ethics, transdisciplinary collaboration and immersive technologies. This will not only enhance learning and research outcomes, but will ensure that the technologies we create serve to enrich human lives rather than diminish them. By fostering a culture of ethical awareness and collaborative innovation, we can navigate the complexities of our digital age, harnessing the power of technology for the greater good.

This article is derived from the author's PhD thesis in Information Science , "Developing a framework to guide the design of value-pluralistic AI ethics policies", completed in 2024.

AS WE MOVE INTO A FUTURE, WHERE THE IMPACT OF RESEARCH AND TEACHING BECOMES EVER MORE SIGNIFICANT, IT IS ESSENTIAL THAT WE EMBRACE A HOLISTIC APPROACH THAT PRIORITISES ETHICS, TRANSDISCIPLINARY COLLABORATION AND IMMERSIVE TECHNOLOGIES.

1 *IEEE (Institution for Electrical and Electronics Engineers) Standards Association 2019. Ethically aligned design: A vision for prioritising human well-being with autonomous and intelligent systems. Piscataway, New Jersey: IEEE. Available at: https://standards.ieee.org/content/ieee-standards/en/industry-connections/ec/ autonomous-systems.html.*

Decarbonising the global economy with green hydrogen

Prof David Walwyn

Green hydrogen offers considerable potential for the decarbonisation of the global economy, but it cannot be "all things to all sectors" in the way that fossil fuels have been in the past. Using a techno-economic approach, green hydrogen has been shown to be too expensive as a high-temperature furnace fuel, as a reductant in the refining of metal ores or as a chemical feedstock.

More competitive applications are its use as a transport fuel, and as a means of energy storage in the operation of electricity systems with high levels of intermittent supply. Research should therefore focus on these latter applications to make a full contribution to the commercialisation of green hydrogen.

The research community's present interest in green hydrogen is intense. Articles in the academic literature and the popular media on the feasibility of green hydrogen as an energy carrier and storage material are published daily, and Scopus-listed publications have climbed exponentially over the past decade.

The leading country in terms of research and installed capacity is China, with 17% and 43% of the global publications and installed capacity, respectively.

The global operational (and close to operational) electrolyser capacity is now 1.1 GW, capable of producing about 2 700 kilotonnes (kt) of green hydrogen per year. Given that for every kilotonne of green hydrogen used in energy production, 7.2 kt of CO_2 is avoided, the existing capacity is already preventing the release of 20 million tonnes of CO_2 or 0.05% of global emissions. This is a small step forward, but there is still a long way to go!

The appeal of green hydrogen is not without controversy. It is still costly (about 170 times the cost of coal as a reductant and double the cost of grey hydrogen). It has a high freshwater consumption (almost three times that of dry-cooled coal-fired generation). It could have a high environmental cost, particularly in terms of the mining of the necessary minerals to manufacture fuel cells and hydrolysis equipment. It could also have consequences for land utilisation due to the need for large wind and solar facilities to provide low-cost renewable energy for hydrolysis.

South Africa was an early entrant to the green hydrogen arena, driven partly by the potential demise of platinum mining due to the phasing out of internal combustion engines, which require platinum in exhaust catalytic converters and the hardening of spark plugs. It launched the National Hydrogen and Fuel Cell Technologies Research, Development and Innovation Strategy (HySA) in 2007, and established a number of Centres of Competence for hydrogen research in the country. This strategy has been followed by a number of planning documents, including the Hydrogen Society Roadmap of the Department of Science and Innovation in 2021, the South Africa Hydrogen Valley report of ENGIE Impact in 2021 and the Green Hydrogen Commercialisation Strategy of the Industrial Development Corporation in 2023.

These strategies have been accompanied by pilot and proposed commercial projects to produce green hydrogen, including the Boegoebaai Hydrogen Cluster, the Coega Hydrogen and Ammonia Development (to the value of R105 billion) and the Freeport Saldanha Industrial Development Zone. The Development Bank of South Africa has also announced plans to establish the SA-H2 Fund, a dedicated green hydrogen fund with the intention of raising $1 billion in international finance. The total value of all proposed green hydrogen projects now exceeds R250 billion.

The University of Pretoria is active in the technology, economic and policy aspects of green hydrogen. Important research priorities for the application of green hydrogen

are based on the urgent decarbonisation imperatives and the present cost structure of its application for various uses, including as a viable energy source, as an energy carrier and as a means of energy storage.

TECHNO-ECONOMIC ASSESSMENTS OF GREEN HYDROGEN

The viability of green hydrogen in South Africa depends on improvements in two key areas: the cost of wind- or solar-based electricity and the cost of electrolysis.

A study conducted at the University of Pretoria assumed that wind and solar energy can be produced with present technology at values close to tender prices for utility-scale projects submitted under the Renewable Energy Independent Power Producers Procurement Programme (about ZAR 0.46/kWh).

The cost of conversion to hydrogen via electrolysis is typically about $3 per kg of hydrogen. This cost is widely predicted to decrease over the next 25 years, possibly reaching $2 per kg by 2030 and the fossil fuel equivalent value of $1.5 per kg by 2025.

Six different use cases for green hydrogen have been considered: as transport fuel, energy storage, gas reforming, electricity, high-temperature energy and minerals processing. Table 1 identifies a comparator energy source for each case and its present market price retrieved from international sources. The unit of energy differs according to the use case; for instance, the unit of comparison for the transport sector is the levelised cost of ownership, expressed as $/100 km. In the case of electricity, the unit of comparison is the levelised cost of energy, expressed as $/kWh, etc.

Table 1: Cost comparisons for green hydrogen in different applications

Use case	Comparator	Units	Cost ($/unit)		
			Green hydrogen cost	Comparator cost	Ratio
Transport fuel	Petrol/diesel	$/100km	50.4	41.4	122%
Energy storage	Battery	$/kWh	0.278	0.222	125%
Gas reforming	Grey hydrogen	$/kg	2.75	1.5	183%
Electricity	Coal	$/kWh	0.139	0.07	199%
High-temperature energy	Coal	$/kWh	0.097	0.016	610%
Minerals processing	Coal	$/MT Ce[1]	1 067	58	1 829%

The results indicate that green hydrogen, as a chemical feedstock, high-temperature furnace fuel or reductant in minerals processing is not competitive, nor will it be competitive in the foreseeable future. In these three applications, the cost of green hydrogen is two to 20 times higher than its comparator, and further improvements in the production technology will be essential before its prospects improve.

However, green hydrogen, as a transport fuel (to replace petrol, diesel and kerosene) and as a storage means for electricity generation, is close to feasibility, particularly in the case of transport, for long distance rail and for truck haulage. In its application within the electricity sector, green hydrogen could be an important technology for the storage of intermittent renewable energy and to replace natural gas as a back-up for utility-scale electricity supply.

IMPLICATIONS FOR GREEN HYDROGEN RESEARCH AND HUMAN RESOURCES

The use cases are relevant to the determination of priorities for research and education within South Africa. Although the longer-term imperative of technology development for the decarbonisation of hard-to-abate sectors, such as metal processing, are important, such projects should not be prioritised. The more immediate concerns are the performance metrics for hydrolysis, fuel cells and hydrogen gas turbines, and the integration of renewable energy systems with green hydrogen platforms. This research will also support the export of green hydrogen and ammonia, which is a priority area in the Hydrogen Society Roadmap and the associated Green Hydrogen Commercialisation Strategy.

The tertiary sector must ensure that it provides the necessary skills and human resources that will be required in the green economy, and specifically in the green hydrogen sector. There will be a need for specialists in electricity infrastructure, software, hydrogen certification and safety, the maintenance of hydrolysis equipment, the management of behind-the-meter electricity systems, and the design of hydrogen facilities and transport equipment, among others.

The application of green hydrogen to the decarbonisation of the global economy is most competitive in the transport and electricity sectors. University-based research and education should therefore be focused in these areas for maximum impact.

1 *Metric tonnes carbon equivalent*

Developing investment planning models for wind and solar fleets

Anthony Stephens and Prof David Walwyn

Previous research at the Graduate School of Technology Management (GSTM) has led to the development of an energy model to assess the efficiency of wind and solar power fleets. The model has shown that, as wind and solar fleets increase in size, shedding of renewable energy will become inevitable, resulting in lower efficiency levels. A recent study reports on how these results can be used to determine the maximum size of these fleets for any given level of efficiency or capacity utilisation.

Governments and energy advisors face a significant challenge in developing energy systems. Designing, installing and commissioning generation and transmission capacity take years, while future demand is uncertain. This uncertainty stems from factors like the adoption of electric vehicles, heat pumps and the replacement of natural gas with electricity in industries.

Energy system models play a crucial role in assessing the supply-demand balance. Steady-state models, like the one used to inform the United Kingdom's National Grid 2035 scenario, appear promising as they suggest that increasing wind and solar capacity could achieve net zero. However, these models often overlook the intermittency of wind and solar generation; the latter leading to high levels of excess energy that cannot be used efficiently. As wind and solar fleets expand, this excess energy leads to lower fleet efficiency, eventually limiting their deployment. The authors' model, referred to as the compound model, incorporates real-time historic wind and solar data, and helps to understand the dynamic nature of future energy systems, predicting the efficiency of wind and solar fleets, and thereby providing an upper limit for their deployment.

The compound model uses historical data from 2017 as a reference for future demand comparisons since, at that time, the system could still accommodate all wind and solar generation. Using these records, the model calculates the incremental wind efficiency (IWE) and incremental solar efficiency (ISE), and then uses these values to estimate the upper economic limit of renewable energy deployment for a range of input assumptions.

Although simpler than conventional energy systems models, the compound model offers valuable insights. For instance, it is used in this study to calculate the wind and solar generation values for any IWE/ISE combination, and hence to generate an investment planning table applied to assess the UK's electricity system in 2035, predicting the appropriate wind capacity for 2030, and the relationship between IWE/ISE values and residual CO_2 emissions.

The investment planning table offers a way to calculate the economically justified amount of wind and solar generation, based on system demand. The study suggests that the UK Government's proposed offshore wind capacity of 50 GW by 2030 will exceed the forecast electricity demand and will be economically wasteful.

The research concludes by proposing that the upper deployment limits for wind and solar fleets can be determined by analysing IWE/ISE values across likely future electricity scenarios. While the lowest acceptable IWE/ISE values depend on factors such as the cost of alternative emissions reduction measures, they are unlikely to be below 0.5. Applying these findings to the UK National Grid's 2035 system prediction, the authors estimate that wind and solar generation will, at most, decarbonise about 70% of the electricity system. The remaining 30% would need to be provided by combined cycle gas turbines, with enough capacity to meet demand during periods of low wind in winter.

Combined cycle gas turbines are likely the only power source that can respond quickly enough to cover rapid declines in wind and solar generation. This limitation on wind and solar deployment restricts their ability to fully decarbonise the electricity system by 2035 and potentially leaves 72 million tonnes per annum of CO_2 emissions unaddressed by renewable sources.

The commercialisation potential of bio-based chemicals from waste

Prisha Mandree, Prof George Alex Thopil and Santosh Ramchuran

Globally, more than 30% of waste is disposed of in some form of landfill. It is estimated that annual waste-related emissions will increase by up to 76% by 2050. Emissions arising from fossil fuel-derived products and waste disposal in landfills have prompted the development of alternative technologies that utilise renewable resources.

Biomass feedstock is being investigated globally to produce renewable fuels and chemicals. Across the world, crop-based and waste biomass are the major feedstocks for chemical production, and the market value of crop-based biomass is expected to increase rapidly. South America, Europe and North America are currently the global leaders in renewable or bio-based chemical production. South Africa is still heavily reliant on landfilling as a waste solution.

Waste from agricultural production processes in South Africa are considered promising feedstocks for beneficiation opportunities to produce bio-based chemicals. South African second-generation agricultural feedstocks include fruit waste, sugarcane by-products and waste, forestry, timber, pulp and paper waste, and invasive alien vegetation.

Fermentation, or "green chemistry" technologies, can be used to convert various feedstocks into bio-based chemicals. These chemicals may be used as drop-in substitutes for existing petrochemical products for use in end-user industries such as the automotive industry and transportation, textiles, pharmaceuticals, consumer and home appliances, healthcare, and food and beverages.

Research conducted in the Graduate School of Technology Management (GSTM) and the Council for Scientific and Industrial Research (CSIR) identified 25 bio-based chemicals and the technology used to produce them. It provided an overview of the global waste and bio-based chemicals markets, with a focus on the South African markets, including potential municipal, industrial and agricultural waste biomass available for conversion to high-value products.

The researchers furthermore described the global bioproducts market and market share of bio-based chemicals, the role of microbes in producing bio-based chemicals, and renewable chemicals that are products of "green chemistry". The main objective of the study was to establish a link between waste biomass and industry-relevant bio-based chemicals in South Africa.

The development of biorefineries to produce bio-based chemicals can achieve two goals: it can replace petroleum-derived products in favour of renewable, domestically available raw materials and sustainably derived products, and it can establish a robust bio-based industry. Efforts to achieve petroleum-derived replacement products include known processes for producing bioethanol and biodiesel, as well as advanced processes for biofuel production, such as bio-butanol and algal biodiesel. However, the return on investment for biofuels alone remains a significant barrier to the commercial operation of biorefineries. High-value, low-volume bio-based chemicals provide the financial incentive to progress technologies to commercial scale. Therefore, biorefineries that integrate both biofuels and chemicals offer a higher return on investment.

The period that a bio-based chemical or bioproduct takes to reach commercialisation depends heavily on the economics or value proposition of producing that product, whether it requires further or new integration and infrastructure, the adoption of conversion technologies, or partnerships secured in the value chain. Overall, bioethanol remains the dominant sugar platform product globally. A platform product is a product that serves as a starting material for higher value-add products. As South Africa is not considered a major player in bio-based chemical production, for entry into the market, it is proposed to focus on opportunities within the top 25 sugar platform products. Drawing on global trends, the potential options for the South African market include bioethanol, n-butanol, acetic acid and lactic acid. There is a large range in market maturity for platform biochemicals, ranging from mature markets for chemicals such as lactic acid to emerging markets for chemicals such as succinic acid. The strongest growth is forecast for secondary chemicals such as bioethylene that is used to manufacture bio-based plastics.

Bioethanol, specifically, can be used in transport fuel, as feedstock for power generation, as an energy source for fuel cells along with hydrogen, and as feedstock in the chemicals industry. Bio-butanol, an olefin derivative, can be used as a drop-in replacement for petroleum-based butanol in all its applications. Different monomers of bio-based chemicals can be used to produce biopolymers, polyhydroxyalkanoates (PHAs), and polylactic acid (PLA), which are subsequently used to produce bioplastics.

Synthetic biology is a key technology in designing novel organisms to break down cellulose or for the synthesis of compounds into speciality chemicals, and could assist as an alternative to costly feedstock pre-treatment processes. This expands feedstock options beyond food crops to include cellulosic biomass and CO_2. Engineering microbe strains that can break down both hexoses and pentoses have been the most significant contribution of synthetic biology.

Various initiatives have been launched globally to support biofuel, bioenergy and bio-based chemical production, including mandated blending fuel targets in the USA, Brazil, Canada and several European Union member states. South Africa's Biofuels Strategy was aimed at including 2% of liquid biofuels in the national fuel pool, with the main goal of stimulating the rural economy and creating sustainable or "green jobs".

It is estimated that the conversion of 70% of the lignocellulosic biomass available in South Africa could meet 24% of the country's liquid fuel requirement as a bioethanol equivalent. The most feasible sources of lignocellulosic biomass or waste for beneficiation in South Africa are generated by the agricultural sector, including sugarcane by-products and waste.

Depending on the availability of waste resources and other considerations, it may be possible to convert biomass to high-value products. With the abundance of lignocellulosic biomass, adequate market segment sizes and socio-economic factors, there may be potential opportunities to investigate the co-production of bioethanol with lactic acid or other bio-based chemicals on an industrial scale. Further research is being undertaken to investigate the market appetite for these chemicals, and also to investigate the techno-economics associated with industrial-scale production.

THE DEVELOPMENT OF BIOREFINERIES TO PRODUCE BIO-BASED CHEMICALS CAN ACHIEVE TWO GOALS: IT CAN REPLACE PETROLEUM-DERIVED PRODUCTS IN FAVOUR OF RENEWABLE, DOMESTICALLY AVAILABLE RAW MATERIALS AND SUSTAINABLY DERIVED PRODUCTS, AND IT CAN ESTABLISH A ROBUST BIO-BASED INDUSTRY.

The future shaping drivers and the role of technology foresight

Dr Petrus Letaba

The current global environment is a jungle that is not easy to navigate. Many organisations are increasingly forced to consider issues such as emerging technologies, sustainable development and socio-technical transitions such as the Fourth Industrial Revolution, as well as environmental, social and governance (ESG) principles.

There is no consensus on what is considered to be an emerging technology, but the ones that are taking a lead in actual implementation or are at the peak of the hype seem to be Artificial Intelligence (AI), virtual reality (VR), augmented reality (AR), machine learning and the Internet of Things (IoT).

These technologies, coupled with big data analytics, contribute to a wave of digitisation, which is shaping many industries and redefining government service delivery channels. Intertwined with other emerging technologies, such as nanotechnology, robotics, photonics, 3D/4D printing and biotechnology, these technologies present multiple future technological innovation pathways that have the potential to give birth to new industries, but also present a disruptive potential to existing ones.

A global drive towards development that is sustainable forces organisations to have a long-term view in terms of the future of the world in which they live by adapting to the practices of social responsibility, waste minimisation and management, clean energy adoption, water efficiency, environmental protection and rehabilitation, and climate change adaptation and mitigation. Such multiple transitions, which are often socio-technical in nature, are not always voluntary at the organisational level as they can be enforced by the operating environment or imposed by shareholders and/or funders. Due to a huge overlap between the ESG principles and the United Nations' Sustainable Development Goals (SDGs) at an organisational level, the transition emphasis tends to be towards the ESG principles. Several countries (including South Africa) have introduced a compulsory reporting of adherence to ESG principles.

The industrial revolutions, by nature, bring about a transformative change – at least at the levels of society, economy and technology. In the four industrial revolutions that have taken place, technology has always been a catalyst of change (e.g. steam machines, electrical energy, transistors and digitisation). What is evident is that the time period between the industrial revolutions is becoming shorter, adding further complexity. Whereas most countries are still contemplating how best to adapt to the Fourth Industrial Revolution, the European Commission has already approved the concept of a Fifth Industrial Revolution that emphasises a shift in focus from an economic approach to an approach that focuses on society and wellbeing. Therefore, a change itself is changing at an accelerated pace.

THE VUCA ENVIRONMENT

The abovementioned drivers of change are felt at the managerial and leadership ranks through what is termed the volatile, uncertain, complex and ambiguous (VUCA) environment. The volatile environment demands a dynamic approach in making organisational decisions as the organisation's external environment can change drastically without prior notice. Different leadership and managerial styles can determine how well the organisation thrives or is left confused in volatile environments. The ability to embrace change becomes an important leadership and managerial attribute.

In an uncertain environment, there is an information deficit, making organisational decision making difficult. The uncertain trajectory of emerging technologies is a good example, making it risky for new companies entering the market through these technologies, but making it much more high-risk for established companies that are not sure how to respond to change without the benefit of completeness of information.

A main characteristic of a complex environment is that it is composed of multiple components and that there is no single decision point for the whole system. For most managers and leaders, navigating such a web of complexity can lead to a virtual cycle of failure as the inputs do not translate directly to outputs. Lastly, an ambiguous environment results in managers and leaders being unable to make sense of current events due to a lack of clear causal relationships in the business environment, without any precedents to refer to. Indeed, most socio-technical transition decisions are ambiguous in nature as managers are seeking to preserve the current operating business, while adapting to a renewed organisation.

A CHANGE ITSELF IS CHANGING AT AN ACCELERATED PACE. THE EUROPEAN COMMISSION HAS ALREADY APPROVED THE CONCEPT OF A FIFTH INDUSTRIAL REVOLUTION THAT EMPHASISES A SHIFT IN FOCUS FROM AN ECONOMIC APPROACH TO AN APPROACH FOCUSING ON SOCIETY AND WELLBEING.

THE ROLE OF TECHNOLOGY FORESIGHT

Researchers in the Graduate School of Technology Management (GSTM) are investigating various foresight and foresight-like tools as solutions to managing and leading turbulent organisations. The usefulness of technology foresight and other future thinking tools originates from the fact that individuals have variations in thinking about the future. A technology foresight exercise assists with the synchronisation of how different people in an organisation and its immediate stakeholders anticipate the future.

The main issues that are researched within the GSTM include deepening the scenarios, transformative foresight, corporate foresight and innovation, data-driven foresight, the institutionalisation of foresight and capacity building, and the successful translation of foresight into strategies and policies.

Other foresight-related tools that are the subject of the GSTM's research focus areas include transformative innovation and socio-technical transition technology roadmaps.

EBIT teaching and learning

FIVE-YEAR PROGRAMME

The **engineering five-year programme** provides a carefully structured engineering curriculum to help students adjust to university life and cope with academic demands.

STUDENT SUCCESS COACHES

The EBIT student success coaches support students by providing ongoing assistance with study and examination skills, time management and other co-curricular issues. Academic support is rendered through an open-door policy. The coaches seek to empower students by teaching them life skills through holistic development interventions so that they can become well-rounded individuals, employers or employees, and responsible citizens. They also have professional qualifications in counselling, which means that they can identify issues and refer students to the correct support structures.

COMMUNITY-BASED PROJECT MODULE

Through the Faculty's compulsory Joint Community Project (JCP) module, students participate in community service and service-learning projects for 40 hours during the course of their studies.

23 000+ **STUDENTS HAVE COMPLETED THE JCP MODULE SINCE ITS INCEPTION IN 2005**

The University of Pretoria produces graduates with scarce skills in the engineering, technology and built environment sectors.

AMONG THE TOP
engineering schools in **Africa**

TOP 334
in the world for engineering and technology (featuring in the top 650 in **SIX** different engineering and technology subject areas)

TOP 36
in the world for mineral and mining engineering

#1
in South Africa for electrical and electronic engineering (five years running)

#1
in South Africa for mechanical engineering
Shanghai Rankings

#1
in South Africa for metallurgical engineering
Minerals Education Trust Fund

An information science perspective on metacognition and metaliteracy in teaching and learning

Dr Brenda van Wyk

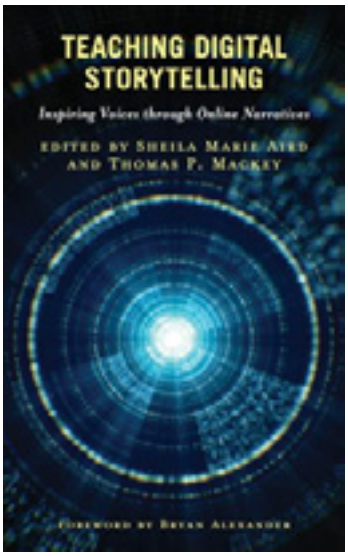
Globally, higher education remains a highly competitive environment, where striving towards a good institutional reputation, as well as academic and research stature, is high on the agenda. Producing impactful and quality research is essential in the advancement of knowledge and our society as a whole. Moreover, in our teaching and learning, we actively enrich our undergraduate curricula with the latest research to prepare our graduates for the competitive world of work.

Several of the research groups in the Department of Information Science are focused on sustaining this pathway. One such group, Metacognition and Metaliteracy in Learning and Research (METALIT), headed by Dr Brenda van Wyk, has been making inroads, with results being published in book chapters and academic hot papers. The multi- and interdisciplinarity nature of this research group draws from disciplines such as educational technology, multimedia studies, information science, ethics and philosophy, and computer science.

THE METALIT RESEARCH GROUP

The METALIT Research Group has set out to explore how digital tools could offer support to enhance the metacognition of students. Its members are collaborating with a global metaliteracy initiative, in particular, with Prof Tom MacKey, professor and programme coordinator for Digital Media Arts at the State University of New York (SUNY)'s Empire State University. They presented their work at the International Conference on Information Literacy (ICIL)-Africa Conference in Egypt in October 2024, where UP was also an ICIL-Africa co-chair.

One of the first studies of the METALIT Research Group entailed digital storytelling as a subset of metaliteracy, and how this could be used in student support. Digital storytelling, as part of teaching and learning, is an ideal vehicle for students to self-identify with specific metaliterate learner roles. The use of this educational technology tool potentially allows students to assess their learning through four domains of metaliterate learning: the affective, behavioural, cognitive and metacognitive domains. This study explored the awareness of digital storytelling affordances in three South African universities. The results were published in a book titled *Teaching digital storytelling: Inspiring voices through online narratives*, published in 2024 by Rowan and Littlefield.



According to Dr Van Wyk, digital storytelling is not merely making use of one-directional predesigned videos for online tutorials. It is deeply ethnographic, auto-ethnographic and participatory. The educational value and strengths of digital storytelling manifest in developing cognitive fluency. Cognitive abilities such as critical thinking, reflection, creative problem solving and reasoning in an academic learning environment allow for new knowledge creation through immersive experiences for the recipient. Designed correctly, it has the potential to motivate, create interest and increase user engagement for deeper learning. It is a tool that could potentially address the literacy challenges of the South African undergraduate student.

WHY IS METALITERACY IMPORTANT?

A strategy of the Faculty is to understand the needs of its students and embrace independent thinking and a human-centred perspective of technology to change the world. Finding centrality in metaliteracy and metacognition, METALIT's work can potentially add value.

The concept of metaliteracy builds on earlier frameworks of information literacy. As such, metaliteracy is seen as a reframing and reinvention of information literacy. It developed into a pedagogical framework to include a comprehensive focus on four domains of metaliterate learning, metaliterate learner roles and metaliterate learner characteristics. Much as we have experienced with developments on applied ethics, standard definitions of information literacy are insufficient for the disruptive innovations and revolutionary social technologies in our world today.

The metaliterate learner is empowered by being reflective and informed, within a connected world using technology. Metaliteracy promotes critical thinking and collaboration in a digital age. It provides a comprehensive framework to effectively participate in social media and online communities. It is a unified construct that supports the acquisition, production and sharing of knowledge in collaborative online communities. Metaliteracy challenges traditional skills-based approaches to information literacy by recognising related literacy types and incorporating emerging technologies.

Metaliteracy competencies can develop students to become reflective and critical thinkers, who are able to study both individually and in collaboration with others. It forms the foundation of a range of literacies, including computer literacy, Artificial Intelligence (AI) literacy, visual literacy, digital literacy and media literacy.

THE CONNECTION BETWEEN METALITERACY AND METACOGNITION

Metaliteracy and metacognition go hand in glove. Typically, a metaliterate student will be able to form networks, coupled with a level of literacy fluency, to succeed in a connected world. As such, metaliteracy combines the cognitive, behavioural, procedural, motivational and other practices towards more context-specific and context-appropriate applications.

Metaliteracy focuses on metacognition, which basically translates to thinking about thinking. Where students develop the ability to reflect on their own strengths and weaknesses, and actively and collaboratively build these skills, their chances for success multiply. More importantly, students who develop metacognition and metaliteracy skills are better equipped to act autonomously and take responsibility for their own success – to become self-reliant and to take responsibility for their own academic growth. They have a sense of mastery and a growth mindset. Ideally, these competencies are developed where students are sufficiently challenged academically, but also supported in a structured learning and teaching environment. In this environment, students experience a sense of belonging, and they feel valued.

As a basic concept in cognitive psychology, metacognition points to the responsiveness of an individual's thinking process. A student's success depends on their ability to self-regulate studies and learning, which, in turn, depends on requisite cognition. A student's cognitive processes must translate into reflection and knowledge to arrive at the product or outcome they signed up for. This process is metacognition and is the cornerstone of motivation. Metacognitive strategies can ignite one's thinking and can direct to much deeper learning and improved performance, especially among learners who are struggling. Understanding and managing cognitive processes can be one of the most crucial skills that teachers can conduct for students to increase their achievement.

SUCCESSFUL STUDENTS DISPLAY SELF-DETERMINATION BEHAVIOUR

Within the Department, we are subject matter experts, and not necessarily education or education technology experts. We may even struggle to embed metacognitive support within the digital learning environment. Our focus is on discipline content. However, abstractions such as self-determination impact our world, and we need to get a better understanding of what it entails.

Self-determined learning and its subset of self-regulation is a deliberate and planned process. It is through this process that students set goals for their progress and then attempt to monitor, regulate and control their cognition, motivation and behaviour. Eelco Braad, a researcher in human-technology interaction at the Eindhoven University of Technology in The Netherlands, shares three basic types of support: direct instruction, metacognitive scaffolding and metacognitive prompting. Knowing and understanding these should assist the student to become autonomous and self-regulate their studies.

Much of the work done in the METALIT Research Group is underpinned and guided by the theories of Albert Bandura, John Flavell, Richard Ryan and Edward Deci on metacognition, self-determination and motivation. Deci and Ryan's self-determination theory argues that students, employees and researchers need to feel three components to become motivated: autonomy, competence and relatedness/connection.

EXPLAINING SELF-REGULATION AS A SUBSET OF SELF-DETERMINATION

As educators, we have all had to deal with first-entry students who struggle with an articulation gap from school to university. What does it take to develop self-regulation and self-determination among our undergraduate students? Self-regulation refers to the wisdom and capacity to make the best choices, particularly to regulate behaviour when there is a strong desire to do the opposite, and mentions procrastination as an example. The reality is that high dropout rates present a curveball in our aspirations for sustained excellence.

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THE NEXT STEP

Producing impactful and quality research is essential in the advancement of knowledge and our society as a whole. Exploring the affordances of metacognition, metaliteracy and effecting the self-determination theory holds much promise in navigating the changing research environment. METALIT's next project will therefore focus on postgraduate success and motivation.

Postgraduate students and early researchers need to experience autonomy, competence and relatedness to become motivated. In this sense, autonomy refers to feeling in control of one's own behaviour and goals. Competence is a sense of mastery and of being able to succeed and have a growth mindset, It is established in an environment where optimal challenges exist, and where positive feedback and growth opportunities are supported within a well-structured working environment.

The Council for Higher Education (CHE), in its March 2022 national review of South African doctoral qualifications, tracked the demographic attributes, work experience, career paths and mobility of over 32 000 doctorate holders who graduated from South African universities between 2000 and 2018. It concluded that the quality of the doctoral qualification is of critical importance, not only to the National Research Foundation (NRF) and the CHE, but also to the public, the institutions awarding doctorates, and their students.

Quality has an impact in a number of ways: on international comparability, competitiveness and mobility; on the preparation of future researchers and their likely research output; and on national capacity to respond, through research, appropriately and innovatively, to the various demands of globalisation, localisation and transformation, in the context of a rapidly changing knowledge economy.

Added to this is the complexity of AI, conversational AI and generative AI. As supervisors, we should be aware of the challenges of our educational ecosystem, and we should evolve to guide our students to become self-determined in an increasingly complex and connected world. The question we need to ask is: What motivates emerging researchers and postgraduate students to enrol for research and postgraduate programmes, and what motivates them to complete their studies. We need to ascertain how students doing research could be supported and developed to become self-directed and motivated to conduct and complete quality research.

Overall, the value-add of the departmental research group is to grow our own timber, empower our emerging researchers and academic staff, and, most importantly, enhance student-centred learning experiences to support student success. A further advantage lies in adding new knowledge to under-explored multidisciplinary areas with technology as the key focus.

Launching the new Immersive Technology Lab

Annique Smith

On 10 April 2024, the Department of Information Science proudly inaugurated its new Immersive Technology Lab in the Information Technology Building on Hatfield Campus. This cutting-edge facility is designed to immerse both students and staff in the dynamic world of virtual and mixed-reality technologies. It serves as an open-access space where students can explore various applications for learning and entertainment. At the same time, staff members can utilise the lab to enhance teaching and conduct pioneering research on user interactions with these advanced technologies.

IMMERSIVE TECHNOLOGY PLAYS A CRUCIAL ROLE IN EDUCATION BY ALLOWING STUDENTS TO EXPERIENCE COMPLEX CONCEPTS AND SCENARIOS THAT CANNOT BE SIMULATED IN TRADITIONAL LEARNING SETTINGS.

With immersive technology gaining global traction, driven by advancements in device accessibility and affordability, universities are increasingly investing in these innovations to bolster their educational and research missions. The rapid evolution of virtual and mixed-reality technologies has made it possible to create highly interactive and immersive environments that offer students and researchers new ways to engage with content. This growth is not merely a trend, but is a significant shift that aligns with the broader Fourth Industrial Revolution, emphasising the need for educational institutions to adapt and integrate cutting-edge technologies into their curricula and research agendas.

Immersive technology plays a crucial role in education by allowing students to experience complex concepts and scenarios that would otherwise be difficult to simulate in traditional learning settings. For instance, virtual reality can transport students to historical events, distant planets or intricate molecular structures, offering a first-hand experience that enhances comprehension and retention. This immersive approach supports experiential learning, where students engage actively with the material, leading to deeper understanding and skill development. Such technologies also cater to diverse learning styles, accommodating visual, auditory and kinaesthetic learners, thus creating more inclusive educational environments.

The new lab boasts three “play areas” and four development pods. Students can book the play areas for 30-minute sessions to enjoy a range of virtual reality (VR) experiences using Meta Quest headsets. The development pods are equipped with high-performance computers and HTC Vive and Valve Index headsets, allowing students to hone their development skills and create new virtual experiences. A student employee manages the lab, assisting with device usage and ensuring proper care of the equipment. A custom-built online booking system simplifies the scheduling and monitoring of lab usage.

The benefits for students are manifold. The lab not only enhances their familiarity with immersive technology, but also broadens their understanding of its potential applications. Students can experiment with virtual simulations that make abstract concepts more tangible and accessible, helping them grasp complex theories through interactive experiences. The lab also offers relaxation tools, such as virtual meditation sessions during high-stress periods like exams, providing students with innovative ways to manage their wellbeing. Furthermore, BIS Multimedia Honours students are actively using the lab to acquire practical skills in VR development, working on projects that contribute to their academic and professional growth.

For staff, the lab provides a valuable resource to enhance teaching and research. It allows educators to integrate immersive technology into their curriculum, creating engaging and interactive learning experiences that can make complex subjects more understandable and memorable.

UP staff can also collaborate with the lab's staff to develop novel educational tools and research projects, which can potentially make significant contributions to the field. Student staff are already utilising the lab's technology to create content for external companies, reflecting the University's commitment to expanding research capabilities and fostering industry connections.

Looking ahead, the lab plans to expand its capabilities by working closely with staff to develop new teaching and research applications. This expansion aims to deepen engagement with immersive technology and foster collaboration across departments and with industry partners.

As universities strive to prepare students for a future where technological proficiency is essential, integrating immersive technology into their programmes is crucial.

It equips students with the skills and experiences necessary to navigate and excel in a technology-driven world. Simultaneously, it strengthens research capabilities, enabling institutions to contribute to cutting-edge developments and remain at the forefront of scientific and technological progress. This investment in immersive technology enhances educational outcomes and drives forward the frontiers of research, ensuring that universities play a pivotal role in shaping the future.

Staff members are always welcome to visit the lab, and those interested in exploring potential projects or scheduling a tour can visit the web page to learn more about booking a visit. The lab staff are eager to initiate discussions about collaborative opportunities and further integrate immersive technology into academic and research activities.

LEARN MORE ABOUT THE IMMERSIVE TECHNOLOGY LAB

Developing professionals through vertical integration and immersive theatre

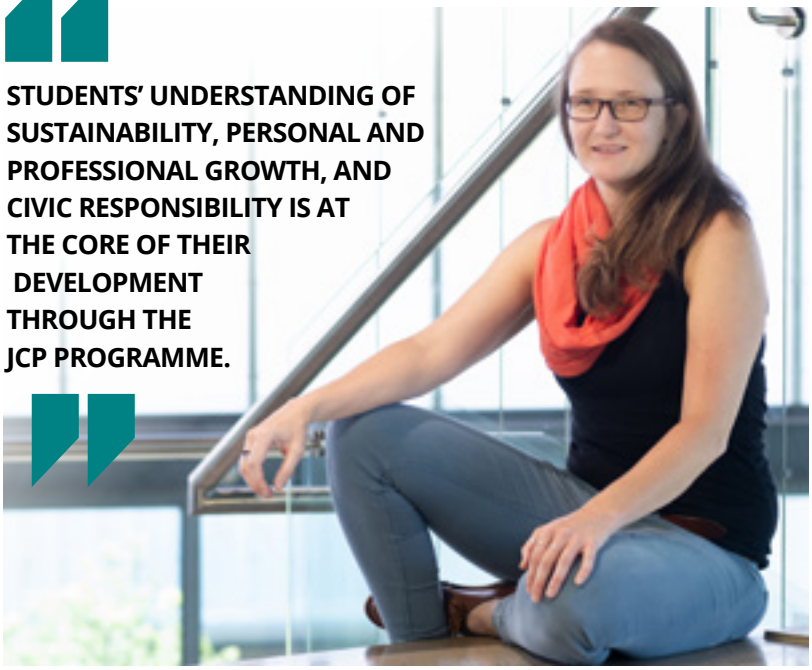
The compulsory Joint Community Project (JCP) module is offered to all 1 600 second-year students in the Faculty's 18 degree programmes. It caters to students of varying abilities and backgrounds, fostering their growth as responsible, engaged and skilled individuals. It aims to build social awareness, teamwork and civic responsibility.

As the JCP Coordinator, Prof Lelanie Smith from the Dean's Office uses service learning as a pedagogical approach that provides students with the opportunity for hands-on skills development with a community partner of their choice. Each student is required to devote 40 hours to preparation and 40 hours to fieldwork in the community. During 2024, the students were involved in 346 projects with more than 50 community partners across Gauteng. Two strategies are used to support this learning agenda: vertically integrated mentorship and an immersive theatre experience.

VERTICALLY INTEGRATED MENTORSHIP

The vertically integrated mentorship team comprises 15 fourth-year students (senior mentors) and 35 third-year students (junior mentors) who have already completed the JCP programme. The training and development of the mentors takes place in collaboration with success coaches from Curiosity Campus. The senior mentors complete two full days of interactive sessions aimed at developing skills in supporting and listening, giving and receiving feedback, asking clarifying questions and caring responsibly. During their second year of involvement, they complete a second round of training, which includes negotiation and spheres of control. These skills equip the mentors to guide the JCP students in their engagement with the community and their team-mates, as well as in their self-discovery.

STUDENTS' UNDERSTANDING OF SUSTAINABILITY, PERSONAL AND PROFESSIONAL GROWTH, AND CIVIC RESPONSIBILITY IS AT THE CORE OF THEIR DEVELOPMENT THROUGH THE JCP PROGRAMME.



Each senior mentor supports three junior mentors, and each junior mentor supports approximately 40 JCP students in eight to ten groups. The structure simulates the workplace, in which the project is framed as a "company", with the JCP Coordinator as the CEO. The community partners are the clients, the senior and junior mentors are the members of the company's respective management levels, and the JCP students are the new employees. All the learning exercises and casual engagements are framed within this context so that the students can appropriately contextualise their learning.

The immersive experience is designed with a collaborative team, including the JCP Coordinator (an engineer), an independent theatre-maker and researchers, a corporate coach and undergraduate drama students. Each team member has a specific role to play in the construction of an embodied experience, where professional development components are

The vertically integrated mentorship team supports the learning agenda of the JCP programme.

linked to a narrative and interactive exercises for the students to engage with and reflect on with guidance from their mentors.

THE IMMERSIVE THEATRE EXPERIENCE

The immersive theatre experience was designed around the development of the necessary skills for the module. These include responsibility (negotiation), team cohesion and team dynamics, levels of listening (growth mindset and empathy), giving answers and asking questions (problem solving), conflict and tension resolution, and giving and receiving feedback.

Eight activities were designed that took place in sequence, with a variable starting point at different locations on campus. This learning experience offered the kind of real-world, embodied, relational situations to which the taught skills would be applied. It included spatial mapping, walking, a narrative and interactive exercises. Students were constantly asked to reflect and decide on means of adaptation to support their connection with the material. They were also provided with opportunities to practice reflection.

A narrative was conceptualised that tied the learning objectives together in a story format. It centred around a fictitious character, "Trinity", a world-famous transdisciplinary researcher in computational biology and organic architecture in the year 2123. She required the students' assistance to collect information and clues, and to complete activities that would restore a distorted timeline to ensure that she receives a funding grant to develop a significant hallmark to curb climate change.

The theatre immersion took approximately two hours to complete, and was repeated four times with seven subgroups. The subgroups were supported by a mentor, and were added to a WhatsApp group. Each subgroup was directed to a different starting location on campus by a message on the WhatsApp group, through which they continued to receive instructions in the form of text messages or short videos of Trinity.

These messages supported movement between locations, and built the story for the students. When the students arrived at each location, senior mentors engaged them in the activity, or served as "actors" who appeared as part of the storyline to act out certain scenes.

The immersion was designed to serve key objectives in the students' learning experience. It linked the exercise and experience to a specific space on campus, grounding the learning spatially. It engaged the students' imagination and curiosity in terms of the storyline that was unfolding. Finally, the activities supported an embodied experience of the learning material that had been covered online.

Prof Smith explains that students' understanding of sustainability, personal and professional growth, and civic responsibility is at the core of their development through the JCP programme. It is centred on the pivotal role that engineering, built environment and information technology professionals play in finding solutions to complex global challenges.

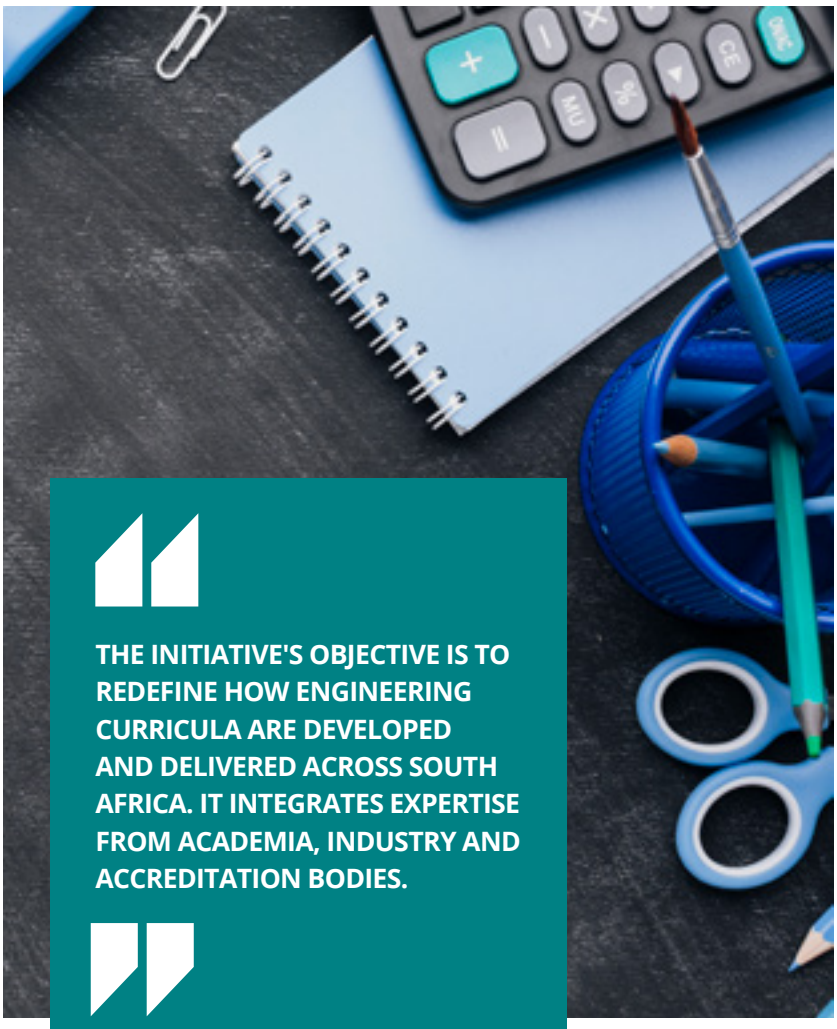
Redefining the South African engineering curricula

The University of Pretoria (UP) is at the forefront of an exciting transformation in engineering education, spearheaded by Prof Lelanie Smith of the Dean's Office. The focus is on developing innovative engineering curricula.

The initiative, funded by the Royal Academy of Engineering and the University Capacity Development Programme, is displaying pioneering efforts and international collaboration. The initiative is coordinated and funded by a national team representing 11 of South Africa's 16 engineering schools, the University College London (UCL) and Aalborg University in Denmark as formal partners. Its primary objective is to redefine how engineering curricula are developed and delivered across South Africa. It integrates expertise from academia, industry and accreditation bodies. The programme focuses on developing a cohesive understanding of an integrative curriculum in the South African context, and preparing students and staff for innovative and creative engineering education.

Over the past year, the team has visited two Scandinavian universities: Aalborg University in Denmark and the KTH Royal Institute of Technology in Sweden. Aalborg University is renowned for its evidence-based teaching and problem-based learning practices, while the KTH Royal Institute of Technology has institutionalised academic development, specifically for engineering. The team spent a week at each institution to understand the resources required, the buy-in from academic staff, and institutional support required.

Following these visits, Prof Smith participated in a global symposium at the UCL to celebrate its 10 years of conducting the integrative engineering programme. UP was one of 35 institutions invited to this prestigious event. Participants included delegates from top universities like the Massachusetts Institute of Technology (MIT), the Imperial College London and the TU Delft. This provided a valuable platform to share insights and benchmark UP against leading global practices in engineering education.



THE INITIATIVE'S OBJECTIVE IS TO REDEFINE HOW ENGINEERING CURRICULA ARE DEVELOPED AND DELIVERED ACROSS SOUTH AFRICA. IT INTEGRATES EXPERTISE FROM ACADEMIA, INDUSTRY AND ACCREDITATION BODIES.

The symposium provided insight into three aspects in particular:

- **Structured frameworks and staff development:** All the participants shared the concern of change management when embarking on a new curriculum and involving staff in a process of change. The challenges in the sector are shared: significant pressure on staff to publish and very little space or recognition for teaching and curriculum endeavours.
- **Resource optimisation:** It is crucial to address resource constraints. The temporary nature of many staff appointments can lead to burnout and hinder long-term curriculum innovation. The Innovative Engineering Curricula team aims to create more sustainable and supportive environments for the staff members of their representative institutions.
- **Integration and collaboration:** Effective curriculum renewal requires breaking down silos within institutions. The collaborative models observed at the symposium will help the Innovative Engineering Curricula team build cohesive teams at its members' representative institutions that can work towards shared educational goals.

Prof Smith's involvement in the global symposium showcased the Innovative Engineering Curricula team's leadership in curriculum innovation. UCL's integrative engineering programme is globally recognised, and UP's participation alongside top universities like MIT and the Imperial College London highlights its commitment to excellence.

Building on these international insights, UP is poised to launch a new first-year engineering programme in 2026, with initial changes starting in 2025. The objective of the programme are as follows:

- **Empower our staff:** By providing robust support and development opportunities, its educators' ability to deliver high-quality, innovative teaching will be enhanced.
- **Engage industry and accreditation bodies:** By aligning our curriculum with industry needs and professional standards, graduates will be well prepared for the workforce.
- **Involve students:** By establishing dynamic and engaging learning environments, the curriculum team includes students in the needs analysis and design process.

The success of national changemakers' workshops highlights the potential to create supportive learning communities across the engineering sector. These workshops have already positively impacted departments at the University of Pretoria and the University of Cape Town, taking a step towards fostering a culture of collaboration and integration.

The visit of the Innovative Engineering Curricula team to Aalborg University and the KTH Royal Institute of Technology, together with Prof Smith's participation in the UCL symposium, has provided invaluable insights into effective curriculum renewal practices.

UP is well positioned to leverage these learnings to enhance its engineering programmes, ensuring sustainable growth and producing graduates that are equipped to meet South Africa's economic and societal needs. Prof Smith's leadership and the collaborative efforts of her national team will be crucial in driving this transformation.

Prof Smith believes that the transformation of the engineering curriculum depends on strategically connecting partners and developing a clear understanding of each partner's potential role and influence.

The process entails prioritising the resourcing of engineering staff as the priority for success, integrating diverse tools, engaging trusted partners, fostering open dialogue and being patient in creating sustainable, authentic transformation.

International support for engineering education in Africa

Emanating from her involvement in the national Innovative Engineering Curricula team, Prof Lelanie Smith joined forces with Dr Esther Matemba of Curin University, Australia, to establish the Engineering Education Research Network Africa (EERN-Africa). This network has secured support from the Intra-Africa Mobility Scheme of the European Education and Culture Executive Agency (EACEA). This funding was the result of a proposal submitted by a consortium that had been formally established through connections made via the EERN-Africa network.

The Capacity-building for Engineering Education (CB4EE) project focuses on developing transformative research capacities and co-creating actionable knowledge to inform and support the systemic change that is needed for the development of engineering education and the integration of modern global challenges. Currently, Engineering Education Research is not recognised as a field the academics can contribute to and, as a consequence, sharing practice from the rich engineering educational experiences across the continent remains silent. It also influences the ability to make data-informed decisions on the ground with no clear process to support such initiatives.

The project has the following aims:

- Facilitate and mentor the development of engineering academic staff to become expert facilitators of active integrated learning (addressing the exhaustion of staff members and promoting innovation in the classroom)
- Promote and develop engineering educators, as well as doctoral and master's students, in the field of engineering education research with clear dissemination strategies through peer-reviewed papers, conference proceedings and seminars
- Investigate the support structures for programme accreditation towards the facilitation of changes in the curriculum in line with the regional and global requirements for "green jobs" in collaboration with industry
- Investigate contextual frameworks appropriate for Africa for an integrated curriculum in engineering programmes (addressing sustainability and climate action)

Strengthening human capacity within engineering education practice and engineering education research becomes imperative to ensure that engineering educators are equipped with the knowledge and skills required for "green jobs", which are under-emphasised within their current training.

The CB4EE Intra-Africa mobility project and funding opportunity provides a unique chance to address this gap by leveraging existing expertise within Africa through partnerships between African universities and a European Union (EU) partner. Key partners include the University of Cape Town's Centre for Research in Engineering Education (CREE) and the University of Pretoria's integrated curriculum project in South Africa, the Mbarara University of Science and Technology in Uganda, the Murang'a University of Technology and Strathmore University in Kenya, the University of Lagos in Nigeria and the KTH Royal Institute of Technology in Sweden.

Innovative initiatives in engineering education have emerged across Africa. These include curriculum development and advancements in teaching and learning. Furthermore, academia-industry collaborations have increased, largely driven by international funding organisations. These initiatives, although promising, are often small-scale and isolated, limiting their impact. In addition, the uptake of engineering education initiatives is constrained by limited resources, existing policies and institutional structures.

These constraints impede sustainable growth and the development of engineering education initiatives, as well as long-term curriculum transformation that is capable of serving local and regional social and professional needs. This project and funding opportunity can therefore play a pivotal role in driving the recognition, development and internationalisation of engineering education in Africa.

WHAT IS ENGINEERING EDUCATION RESEARCH?

Engineering education research is an interdisciplinary field aimed at enhancing the teaching and learning of engineering concepts, skills and professional practices. It integrates methods from engineering, psychology and the social sciences to investigate how students learn and how instructional practices, curricula and educational environments can be improved to foster better learning outcomes. Researchers in this field explore various topics, including the development of problem-solving skills, design thinking, teamwork, ethical decision making and technical competencies. They also examine the influence of diversity, equity, inclusion and emotional intelligence on engineering education. The primary goal is to apply evidence-based approaches to transform engineering education, producing more innovative, effective and socially responsible engineers.

In Africa, one of the major challenges is the lack of recognition of engineering education as a distinct research field. Outside of South Africa (where only the University of Johannesburg and the University of Cape Town have formal programmes for engineering education), the subject is often not acknowledged as a formal discipline, which leads to a lack of institutional support for engineering educators to engage in educational activities and build their expertise. This lack of recognition hampers the development and dissemination of Afro-centric engineering education practices, which are essential in addressing the unique regional contexts and challenges.

African engineering educators face similar pressures to their counterparts in the Global North, such as severe time constraints and the pressure to publish, with little to no formalised educational development, which makes it difficult for them to engage with and apply pedagogical research effectively. Building the capacity of educators to integrate educational research and pedagogy into their work is critical for evidence-based decision making, which can ultimately improve engineering education across the continent.

HOW DOES ENGINEERING EDUCATION RESEARCH CONTRIBUTE TO SUSTAINABLE DEVELOPMENT?

Traditionally, engineering education has focused primarily on technical content delivery, but the landscape has shifted. Contemporary engineering practice requires professionals to consider not only technical aspects, but also the social, economic and political dimensions of their work. In addition, student-centred approaches require consideration of student diversity, which necessitates teaching approaches that foster critical thinking, problem-solving and teamwork.

The complexities of developing engineering graduates that are prepared for the nature of work, where the Sustainable Development Goals (SDGs) are truly integrated, require academics across the world to transform themselves and their way of thinking. African universities, like the rest of the world, struggle with transformation processes, where change is advocated, but remains significantly under-resourced. This is compounded by the lack of recognition of engineering education as a research field, which leads to incredible potential leaders leaving the continent to work and flourish in Europe, the United Kingdom and the USA.

To address these challenges, initiatives such as the proposed engineering academic educational development programmes and capacity building in engineering education research are crucial. It is also important to lobby for support from deans across the continent to support these champions on the ground. These efforts aim to promote scholarship in engineering education and inform recommendations that can translate into support for teaching staff and engineering education practitioners in adapting teaching practices, integrating sustainable development principles and enhancing students' learning experiences.

The Capacity-building for Engineering Education team.

Immersing new first years in life as an engineering student

The University of Pretoria's annual Academic Orientation Week is a tradition of long standing. Over the years, it has transformed based on students' needs and the current situation. For example, during the COVID-19 pandemic, it developed into an online support programme. It has since been presented as a hybrid programme. Each Faculty has the option to present its own customised sessions. During the 2024 Orientation Week, the School of Engineering grasped the opportunity to completely revisit its students' first exposure to campus by presenting an innovative, immersive Orientation Week.

With Dr Helen Inglis at the helm of the Planning Committee, representatives of a selection of departments within the School of Engineering developed a unique programme to introduce new first-year students to the engineering profession, as well as to the graduate attributes of the Engineering Council of South Africa (ECSA), to the Hatfield Campus and to the University's learning management system, clickUP.

The team included Prof Tania Hanekom from the Department of Electrical, Electronic and Computer Engineering, Dr Disaapele Mogashana and Rotondwa Ramabulana from the Department of Mechanical and Aeronautical Engineering, Anthea Venter from the Department of Industrial and Systems Engineering, Malika Khodja-Moller, Lesedi Fish and Mfesane Tshazi from the Department of Materials Science and Metallurgical Engineering, and Elizbé du Toit from the Department of Chemical Engineering. The students from the Vertically Integrated Projects (VIP) Engineering Education team (known as VEEP) were integral partners in planning the Orientation Week programme, with Keraiya Naidoo from Chemical Engineering taking a leading role.

Dr Mogashana describes Orientation Week as part of the first-year experience. "It starts with welcoming them to the University, exposing them to its grounds and facilities, and making them accustomed to the space that is to be their new home." Tshazi concurs. "It is important for them to become familiar with it."

The five-day programme included the customary introduction to the University and the Faculty of Engineering, Built Environment and Information Technology (EBIT), and a welcome to the new first-year students. This was followed by the opportunity to meet the respective heads of department, and attend the departmental tours and computer lab sessions. However, engineering students were treated to a unique experience that no other faculty or even school within EBIT had the privilege of receiving, explains Venter.

The programme was based on Dr Inglis's research on engineering education and study success. In the process, the students were guided to form strong peer networks and open their minds to changing the way they had thought in high school and becoming critical, analytical thinkers.

PEER NETWORKS

During her research, Dr Inglis had sought to determine what first-year students need in terms of information and support when they enter university for the first time. Her research entailed qualitative interviews with 14 second-year students who had completed their first year in 2019. She was particularly interested in finding out what had contributed to their success as first-year students. The feedback she received pointed out the critical importance of peers, and connecting with other first-year students. Peers provided a support network when it came to asking for help with academic work, as well as with logistical matters and other problems. They also provided their fellow students with a source of emotional support.

Dr Inglis emphasises that peers form part of a student's support system and influence their academic progress, as well as their attitudes and behaviour. She noticed that, in 2021, when the Orientation Week programme was presented fully online due to the restrictions on personal contact imposed by the COVID-19 pandemic, students had been unable to form peer groups, and nothing was put in place to allow them to form a support network.

An important function of Orientation Week is to provide new first-year students with the opportunity to make new friends. "That is why we made the formation of peer groups such an important element of the 2024 Orientation Week programme," says Dr Inglis.

Prof Hanekom explains that, in the past, students were swamped with information during Orientation Week, which they would forget as soon as classes started. "The revised format of Orientation Week for engineering students was a welcome change," she says. "Especially for students who come from remote areas or other provinces, who do not know anyone at the University, it is important that they should be made to feel comfortable in their new environment and have the opportunity to meet people who are studying the same programme as they are". Venter remarks that many new students experience a sense of isolation. "It is important for them to get a feeling of the campus and what university life entails."

Since the students had been given ample opportunity to get to know each other during the week, they were able to elect their class representatives at the end of the week. This is normally only done a few weeks into the semester. In some departments, the class representatives started a WhatsApp group for their class group. This was particularly useful when communicating during the strikes that took place in the first two weeks of the semester, allowing students to ask questions that were quickly answered by their peers, and enabling staff to share information at short notice with large class groups.

NAVIGATING THE FIRST YEAR

The Orientation Week programme included in-person sessions during the day, followed by daily online activities to complete in the evening.

Assisting students to navigate their first year, the programme introduced them to the language of the University, explaining what is meant by the study guide, which provides essential information and resources for each module; contact time, which includes lectures, tutorials and practical sessions; where to find their timetables; Engineering Week, also known as test week, when the semester tests are written; the composition of their semester marks and value of their exam marks, as well as what marks they need to obtain for entrance to the examination or to gain a distinction; the perusal sessions, when they can review their examination paper after it has been marked; and the supplementary examination, and summer and winter schools.

They were also introduced to the "who's who" of the School of Engineering. This included the Faculty's academic success coaches, who are there to provide academic support, and help students with stress management, goal setting and motivation, efficient time management and other challenges. They learnt about the roles of the teaching assistants, lecturers, class representatives, Head of Department and Dean of the Faculty. They were furthermore made aware of some essential "do's and don'ts" (maintain a healthy balance, find a support network, don't fall behind, don't underestimate the workload) and the process to follow if they need to raise a concern.

Feedback received from the academic success coaches, Maridian Mawelele, Reginald Kanyane, Megan Mackenzie and Caitlin Vinson, was that introducing students to this indispensable service at such an early stage in their academic careers led to a few proactive students seeking assistance earlier than had occurred in the past. This assistance includes individual consultations and a range of workshops on topics such as adapting to university life, effective study methods, preparing for the examination and exploring potential careers. Mawelele explains that the academic success coaches work diligently with the students throughout the first semester to reach and support as many first-year students as possible. "We conduct class visits for core modules and make regular contributions to the Orientation module on clickUP for the first seven weeks of the year."

The Orientation Week Planning Committee in the School of Engineering.

COMPUTER LITERACY

A valuable presentation in the Orientation Week programme was the Computer Lab session, which gave students additional exposure to what they would be expected to do using a computer. Students had three opportunities to attend this session, and could even attend it a second time if they felt they needed additional assistance. This gave them the opportunity to experiment and follow up if their computer skills were lacking. The feedback received on this session was very positive. It provided students with the critical computer skills they would need from their first day of class. They learnt to log onto a computer, sign into Google Chrome, as well as their Gmail accounts, which would give them access to the various Google applications, such as Google Drive, sign into One Drive and create an online document, sign into the UP portal to view their lecture timetable, as well as the timetables for semester tests and examinations, and sign into the University's learning management system, clickUP, and use this system.

Prof Hanekom concurs with the importance of the Computer Lab session to ensure that students' computer literacy is at an acceptable level. It prepared them to go online and ensured that they were able to operate clickUP, as this is where they would find all the information they needed for assignments, semester tests and examinations. This is also where they would be required to upload their assignments and access additional module content.

"I AM AN ENGINEER"

Another important element of the Orientation Week programme was to help students develop a sense of identity as an engineer. They were exposed to various engineering activities as part of their initiation into the engineering profession. This included introducing them to the graduate attributes they would acquire during the course of their engineering studies: problem solving, the application of scientific and engineering knowledge, engineering design, investigations, experiments and data analysis, engineering methods, skills and tools, professional and technical communication, the impact of engineering activity, individual, team and multidisciplinary working, independent learning, engineering professionalism and engineering management. "They also learnt about other things engineers do, such as asking for help, making mistakes, working in teams, communicating and relying on each other to reach an answer," says Dr Inglis. "This helped to overcome an issue that is often experienced when first-year students are afraid to respond to a question for fear of being wrong." This is important, as one of the reasons students fail is because they are hesitant to approach the necessary support structures for help.

They engaged in groupwork activities to discuss the graduate attributes, as well as several immersive sessions, such as one on seeing the Big Picture, where groups of 60 to 80 students were given a bag with eight packs of papers that fit together. This required them to work together to see what worked. Other activities included ones on visioning the future, building a spaghetti tower and a team-building activity that demonstrated the importance of teamwork.

SCAVENGER HUNT

A highlight that attracted the attention of students from other faculties based on the amount of "engineering fun" the students were seen to be having was the Scavenger Hunt, designed and managed by VEEP. This doubled as an activity to explore the Hatfield Campus and included a tour of the UP Library. There were three stations from which the students could start the scavenger hunt, which included a blank map with the shapes of various buildings on campus.

Students also had to apply engineering skills, such as estimating the height of buildings or the distance between buildings, and completing mathematical problems. Dr Inglis describes this as a high-impact activity, as it implemented some of the graduate attributes that the students were expected to acquire, and contributed to developing their identity as an engineer. Naidoo mentions an important element of the activity to be its emphasis on team-building while exploring the campus. Among its advantages was the fact that it took many of the engineering students out of their comfort zones, explains Venter.

The students received a token as a reward for completing activities successfully. At the end of the week, the students with the most tokens were awarded a prize during a special awards ceremony. They also received a certificate welcoming them to the engineering profession, stating that they had started their journey as an engineering professional.

Reinforcing the value of preparing students for their first year of study, Ramabulana explains that it is important for students to realise the need to manage their expectations, to see the value of learning and to find like-minded people.

The members of the Planning Committee each played an invaluable role in presenting a unique Orientation Week offering. Prof Hanekom stressed that everyone had their own unique strengths, which contributed to the success of the programme. "Their passion to help students transition from high school to university was clear in everything they did." The overall consensus from the committee members was that they were satisfied with the revised format of Orientation Week for engineering students, and hoped to take the lessons learnt from the activities presented in the 2024 programme to develop an even better programme for 2025.

From first year to fully fledged mechanical engineer

Prof Schalk Els

A love of mathematics and science is necessary – but not sufficient – to become a good engineer. Well-rounded engineering students need to be equipped for industry by being exposed to both practical and theoretical engineering challenges as they collaborate on hands-on projects. This requires them to design, manufacture and test their ideas to solve complex problems. They also have to learn to balance the responsibilities of daily life with passion-driven initiatives.

A WELL-OILED TUKSBAJA TEAM CAN HANDLE ANYTHING, FROM FINITE ELEMENT ANALYSIS, MULTI-BODY DYNAMICS AND VEHICLE TESTING TO THE CNC MACHINING AND TIG WELDING OF A CHROMOLY FRAME. NEW DESIGNS ARE EXTENSIVELY TESTED, REDESIGNED AND CONTINUOUSLY REFINED.

There are many ways in which academic curricula can be developed to achieve this goal, but one thing is certain: the more passionate you are about what you have to do, the better your chances of achieving success and living a rewarding life. That brings us to one of my passions: TuksBaja!

TUKSBAJA

TuksBaja is the University of Pretoria's BajaSAE® team, hosted by the Faculty of Engineering, Built Environment and Information Technology. BajaSAE® is an intercollegiate competition that requires engineering teams to build and design a compact single-seater off-road vehicle. Vehicles are tested in annual competitions on tough terrains featuring steep, rocky hills and muddy lakes. The competition aims to develop practical design, production and management skills.

Every year around March, the team recruits first-year students. They arrive full of energy and excitement, often wondering how their Mathematics and Physics are going to help them solve the complex engineering problems required to develop a new vehicle. Initially, they are introduced to basic tasks such as disassembling an old car and fixing a few problems before reassembly and getting the car to drive.

This first drive leaves an impression in their minds, a smile on their faces and excitement that lasts for months and even years. As they progress, they start manufacturing simple parts. Later, they design and manufacture more complex subsystems using advanced simulation tools and experimental testing. Senior students develop a complete car.

A well-oiled TuksBaja team can handle anything, from finite element analysis, multi-body dynamics and vehicle testing to the computer numerical control (CNC) machining and tig welding of a chromoly frame. New designs are extensively tested, redesigned and continuously refined. Not only are the students technically skilled, but they develop an ethos of excellence, the ability to work in a team and mutual consideration for the world and the people around them. This development cycle culminates in a brand-new car every few years, developed to a state of maturity that can compete in the big competition held annually in the USA.

TuksBaja has embarked on a journey to compete in the USA in 2025. This marks our first in-person attendance in five years, and we are thrilled to showcase our innovative new four-wheel-drive car, which is currently in the design phase. This is an ambitious goal that can only be reached with the right resources. After careful evaluation – as good engineers do – the team has identified key areas that are critical to ensuring a successful 2025 season, as well as the long-term growth of the team. We are upskilling team members in design principles, the use of simulation tools, as well as manufacturing. A dedicated part of the team is responsible for marketing, social media presence and fundraising.

Companies and individuals that get involved with TuksBaja receive multiple benefits. Companies get extensive brand visibility through the team' s participation in high-profile competitions, both locally and internationally, as well as through an active social media presence. Additionally, TuksBaja engages with the community through initiatives such as Choose UP Day, EBIT Week, and hosting secondary school students, inspiring and encouraging others to get involved in engineering.

Partnerships with TuksBaja also provide direct access to a pool of talented, industry-ready engineering students, offering recruitment opportunities for internships or future employment. By aligning with TuksBaja, partners demonstrate a commitment to supporting innovation, education and the development of the engineering industry's next generation of leaders. Supporting the team can even have positive tax implications – many good reasons to help first-year students become engineers!

Biogas and fertilizer production in an African informal settlement

Prof William Nicol

The ten fastest-growing cities in the world are all in Africa. Urban expansion in Africa is mostly in the form of informal settlements. Accordingly, one of Africa's main challenges is to allow for the development of sustainable and environmentally friendly informal settlements.

From an energy and a food production perspective, the use of anaerobic digestion has been suggested and explored in numerous studies. The expansion of the use of anaerobic digestion in rural China, where 14 million digesters have been installed over four decades, has prompted the discussion of the potential of anaerobic digestion in Africa, where tropical climates ensure higher average temperatures than those in China.

Given that a large fraction of people in Africa reside in informal settlements, this project explores the potential of using food waste for cooking gas (biogas) and fertilizer generation. We envisage free household biogas and high-density vegetable gardens in the settlements, accompanied by educational efforts to teach basic soil biology and the core principles of nutrient recycling.

The approach uses minimal container plastic, with polyethylene bags partly buried in the soil to harvest solar radiation heat for an improved operating temperature. One of the major challenges is to educate the digester caretakers to take care of the "living organism" in the plastic bag. In light of this, the initial exploration of the project utilises third-year laboratory students in Chemical Engineering to take care of a miniature (10-liter) digester bag. Given that the laboratory environment allows for tighter temperature and feed composition control, the project can also be used to investigate envisaged obstacles to developing a functional, reliable and consistent prototype.

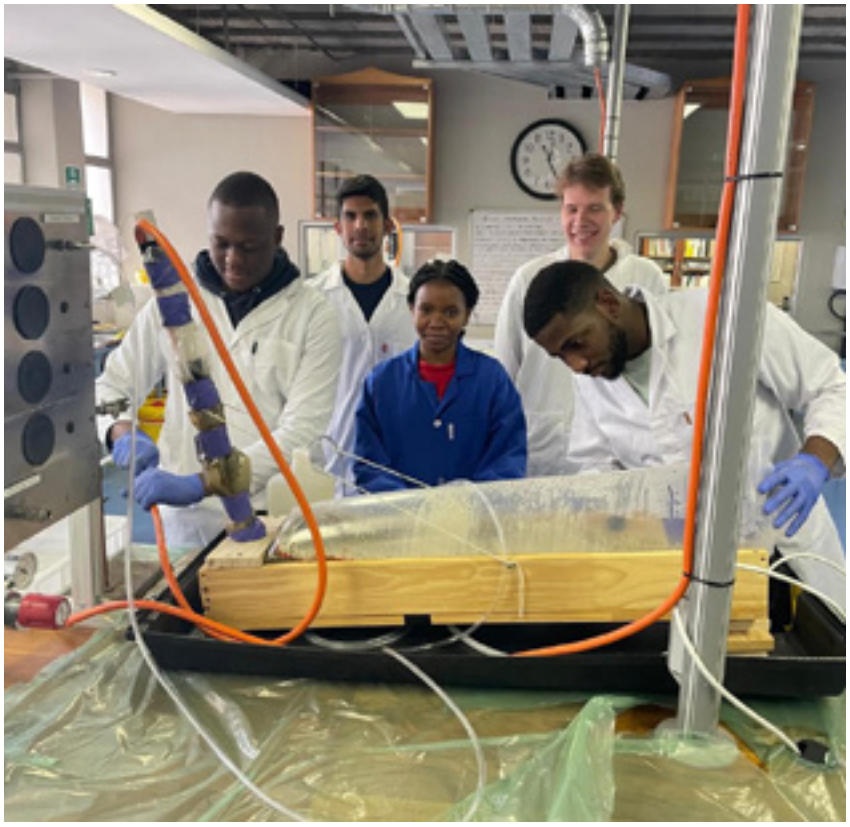
The proposed prototype uses zero animal manure, not even during start-up. An anaerobic seed culture will be supplied to initiate the digestion process. This aids in selling the concept since manure will not be associated with the garden digester. It is, however, imperative to keep the culture alive and growing. Accordingly, a continuous process has to be employed to ensure stable operation. This implies that regular maintenance is a prerequisite; also for the students performing the initial trial experiments. Reference is made to the digesters as "babies", since gas purging, liquid extraction and feeding take place daily. Through this project, the students will be exposed to the principles of ownership and caretaking.

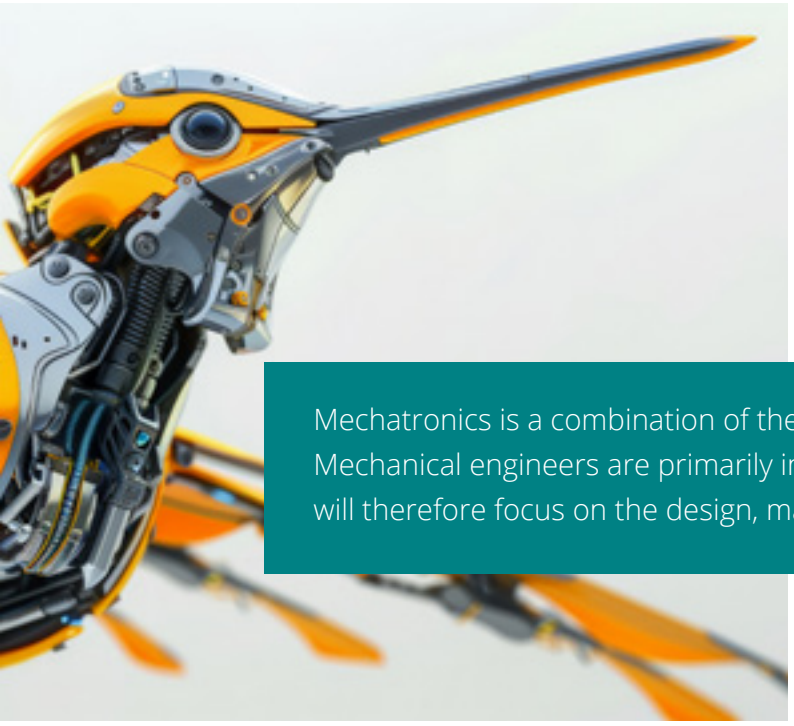
Anaerobic digestion is most commonly associated with the digestion of animal manure. Manure comprises biomass that is already partially digested. In this regard, the breakdown process in the subsequent anaerobic digestion unit occurs at a very slow rate. In contrast to this, the breakdown of vegetable waste occurs at a faster rate. Although this allows for smaller reactor volumes, it also poses more control challenges. By using a well-defined vegetable mixture, students will be able to investigate pH stability under various feed strategies. The influence of temperature on production rate is also studied. The results generated by the third-year students will be directly applicable to the development and design of the final domestic prototype.

Chemical engineering students in the laboratory.

The laboratory project exposes the students to real African problems, where fundamental Chemical Engineering principles are applied to interpret and improve the operation of the digesters. Most students have completed the CBI 310 Biochemical Engineering module, where an in-depth approach to modelling anaerobic digestion was a major part of the course.

Guidance is provided to the students to link the experimental results to the theoretical approach of CBI 310. This is a prime example of how the gap between engineering modelling and real-life practice can be bridged, while social and environmental awareness is stimulated via the project. The project is well aligned with the revised Engineering Council of South Africa (ECSA) graduate attributes, and the intention is to create a fun environment in the learning space.





Mechatronics: where mechanics and electronics meet

Prof Schalk Els and Dr Theunis Botha

Mechatronics is a combination of the principles of mechanics, electronics and computing. Mechanical engineers are primarily interested in the mechanical nature of objects and will therefore focus on the design, manufacture and maintenance of physical systems.

Mechanical engineers led the early development of aircraft and automobiles, where motion was controlled through mechanical systems. Initially, aircraft were equipped with cables or hydraulic systems that physically connected the pilots with the flaps or control surfaces of their aircraft. The pilot's own energy was therefore used to move the flaps. In the automotive industry, physical linkages were used to control the vehicle body's motion and improve the occupants' safety and comfort.

The advent of electronics led to the development of small devices that can be used to control actuators such as motors. This allowed electrical energy to be applied to mechanical systems. Devices could be easily rotated or moved by using simple electronic components and electrical actuators. The further development of sensors allowed electronics to sense the physical world. An electronic system can now record the temperature of an object, the force applied to a system, the positions of objects and much more.

The invention of microprocessors, which can effectively act as brains for electronic systems, allowed electronics to use sensor inputs to apply energy to mechanical systems and obtain the desired outcomes. Aircraft now use sensors to interpret what the pilot wants to do, and a processor decides which actuators should be used to move the flaps to the optimal position to ensure that the aircraft will do exactly what the pilot wants it to do. In automobiles, actuators are used to engage vehicles' brakes when collisions are detected without the driver having to do anything.

Mechatronics uses sensors to sense what is happening, and a processor to take the sensor information and decide which actuators to actuate to ensure that a mechanical system does what needs to be done. Whether this process is used to control robots, to manufacture more robots or to develop autonomous robots that can move from one point to another through obstacles without human intervention, a combination of mechanical and electronics expertise is used. Almost all mechanical systems currently in use are equipped with sensors, actuators and processors to make them safer and more efficient for human use.

What do you have to study to become a mechatronics engineer?

Some universities offer dedicated mechatronics degrees, but at most universities, you will need to register for a degree in Mechanical Engineering, Electrical Engineering, Electronic Engineering or Computer Engineering.

At the University of Pretoria, the Mechanical Engineering curriculum includes courses in electrical engineering, electronics, programming and control systems, which make provision for all the building blocks of mechatronics. Furthermore, all final-year students do Mechatronics and Control, and can choose a mechatronics-related final-year research project. Mechatronics is also offered at postgraduate level.

Should you consider a degree specifically in mechatronics, it may be worth remembering that, although your knowledge will become broader and more multidisciplinary, you may end up lacking the in-depth knowledge gained by completing a more traditional undergraduate degree, such as Mechanical Engineering, and specialising in Mechatronics later, or simply working on a project as the mechanical engineer in a multi-disciplinary team.

Encouraging individual participation in a groupwork project

Dr Werner Badenhorst, a senior lecturer in the Department of Electrical, Electronic and Computer Engineering, was the recipient of the Faculty's Teaching and Learning Award for 2024. This was in recognition of the success he achieved in overcoming the challenge of evaluating individual participation in a groupwork project.

The motivation for this innovative approach to teaching and learning found its origin in 2020 when the constraints and challenges presented by the COVID-19 pandemic led to the combination of three individual third-year Engineering Design modules for electrical, electronic and computer engineering into a single module. In this combined Design module, students worked in groups of three to develop a line that could be incorporated into the microcontroller-based automated robotic vehicle (MARV) that is developed and built in the first-semester Microprocessors module to take part in the annual Robot Race Day competition.

In 2021, the line to be incorporated into the MARV was again developed and constructed in the first semester as part of the third-year Microprocessors module for the annual Robot Race Day. This left the second-semester Design module without a project to design. Dr Badenhorst therefore decided to use the same structure and plan developed in 2020 and convert the line following the MARV developed in the first-semester Microprocessors module into a maze-navigating MARV. This was named the "A-Maze-Eng MARV".

The Design module has double the practical time compared to a typical 16-credit module to provide sufficient time for the physical implementation of the project. This emphasises the importance of the practical component of the module as the laboratory demonstrations account for 45% of the semester mark. Dr Badenhorst is responsible for the practical elements, while other lecturers present the theoretical content, applying systems engineering concepts to the MARV being developed. It is essentially one project with four different phases taught in class and evaluated in four separate demonstration phases.

GROUPWORK

The Design class typically has between 180 and 200 students, divided into groups of three students from the Department's three disciplines. Each group is required to design and build an A-Maze-Eng MARV that is capable of navigating through a maze. The electrical engineering application involves the design of the motor drive and power subsystem. The electronic engineering perspective focuses on the design of the sensor subsystem, while the computer engineering work entails the design of the state and navigation control subsystem. The three subsystems must be integrated physically, as well as through a given serial communication protocol.

Dr Badenhorst developed a set of quality test procedures to evaluate each subsystem's adherence to the system and subsystem's requirements and specifications. This was done using the HUB graphical user interface. This is a Pygame (Python) emulation of the integrated system with which students and evaluators can test the individual subsystem's quality test procedures as if the subsystem under evaluation were physically integrated with the other two subsystems.

Where possible, the module enforces multidisciplinary groups (from the Department's three disciplines). Once the group has been formed, the members must decide who will design and implement the individual subsystems. The groups have weekly progress and feedback meetings, where they are accountable to each other and to the lecturer. The module's assessment plan requires four evaluation teams, each comprising three evaluators: one for each of the three subsystems. The project is evaluated over four demonstration phases, with specific milestones evaluated in each phase.

EVALUATION

The first phase entails the definition of the concept, together with the design and simulation of the system. Students need to understand the entire system by manually moving a two-dimensional paper model of their MARV on a maze test block. They then need to discuss various scenarios in terms of system and subsystem action and reaction as it is moved. The students must present all their designs and calculations, their simulation or software test bench results and the comparison of the simulation with their theoretical design outcomes. For the first time in their career journey, students are singly responsible for a subsystem's design and implementation, and are required to effectively work in a team because each subsystem's design is dependent on the specifications of the other, and cannot be designed independently.

The second phase involves the individual evaluation of the latest simulations of the components and relevant software flow diagrams within each of the three subsystems. This is followed by the individual demonstration of the system component prototypes using appropriate developmental tests, and a demonstration of the subsystem's communication with the HUB and other subsystems. Students are required to present all their designs and calculations, their simulation or software bench test results and the comparison of their simulations with their prototype outcomes. This phase takes students out of their ever-increasing theoretical, virtual and online reality into the physical and practical reality. They also need to implement the fundamental communication protocols by demonstrating communication between the three subsystems and between each subsystem and the HUB.

The third phase entails a demonstration of the individual subsystem's quality test procedures with the HUB. At this stage, all hardware circuits must effectively be complete, with only minor revisions required for final integration in the final phase of the project. The students' subsystems must be able to demonstrate all their quality test procedures. However, the evaluators select which of the quality test procedures each student will be required to demonstrate for evaluation. This phase prepares the students for their final-year project, where they will be required to develop their own quality test procedures.

The final phase involves a demonstration of a fully integrated system that is capable of navigating through a maze. At this point, group members who did not pass the third phase of the project are excluded from continuing to the final phase. As this sometimes results in incomplete groups, the remaining members may join other incomplete groups to complete the project. The missing subsystem may also be built using off-the-shelf modules or by borrowing the missing subsystem from another group, and integrating and demonstrating it with their remaining subsystems. This phase is concluded with a technical report to detail the design and implementation of their A-Maze-Eng MARVs, in lieu of a traditional written examination.

A VIRTUALLY INTEGRATED CURRICULUM JOURNEY

The Design module's focus on design and implementation enables it to form an integral part of the Department's vertically integrated curriculum, as it encompasses all three of the Department's degree programmes (electrical, electronic and computer engineering). Its inclusion of contributions from several second- and third-year modules turns it into a critical space to prepare students to transition to their final-year capstone project.

The process of developing a fully integrated system, which started in their first-semester Microcontrollers module, is therefore concluded in their final-year project. The capstone project entails a complete system design process, from receiving a user's concept proposal, developing a formal project proposal containing a system requirement, a functional unit diagram and description, specifications and deliverables, and the detailed, iterative design, simulation, implementation, demonstration and writing of a final report.

Dr Badenhorst explains that the students' third-year Design project is a clear indicator of their readiness to successfully complete the capstone project. It is therefore an essential requirement for progressing to the final-year capstone project.

Creating a legacy of sustainable infrastructure

A highlight on South Africa's built environment professionals' calendar took place in the University's Aula Theatre on 25 and 26 July 2024. The annual BIMHarambee Africa was once again hosted by BIMcommUNITY Africa and the University of Pretoria's Department of Architecture, with Dr Calayde Davey as coordinator.

The theme of this year's conference was: "Fit for BIM? People + Business". It attracted industry professionals from all the disciplines within both the private and public built environment industry, from architects to construction managers, quantity surveyors and planners, who were keen to collaborate and learn together about incorporating building information modelling (BIM) into their work to achieve sustainable planning, management, construction and infrastructure development.

In the words of Dr Davey, "BIMHarambee 2024 is not just an event; it is a movement towards embracing innovative technologies and methodologies that will lead us to build for tomorrow today. We are committed to fostering education and skills development to ensure our workforce is equipped to meet the challenges and opportunities that lie ahead." It is of particular interest to built environment professionals keen to reshape the landscape of African cities and infrastructure to create a legacy of built infrastructure for future generations. This includes engineers, contractors and industry professionals. Dr Amanda Flltane of the University of Cape Town's Department of Construction Economics and Management played a big role in opening up the panel discussions.

Setting the tone for the conference, Dr Davey chaired a panel presentation to illustrate the various project work stages of a project that follows a BIM approach. This is an approach in which teams from the different

FIT FOR BIM? PEOPLE + BUSINESS

disciplines involved in a built project embrace technology and collaborate across different workspaces, where each has a unique role to play. This professional workflow is based on the newly developed BIM Standard, SANS 19650. SANS 19650 is the South African National Standard for managing information about buildings and civil engineering works using building information modelling to ensure consistent and effective information exchange throughout an asset's life cycle.

The African built environment is increasingly reliant on digital technology for design simulation and management. This is the cornerstone of a BIM approach. As such, industry professionals need to be proficient in the use of digital tools, methodologies and skills to drive innovation and efficiency.

With the overall theme of ensuring that people and business are fit for BIM, the conference thus provided perspectives on navigating the digital transformation space.

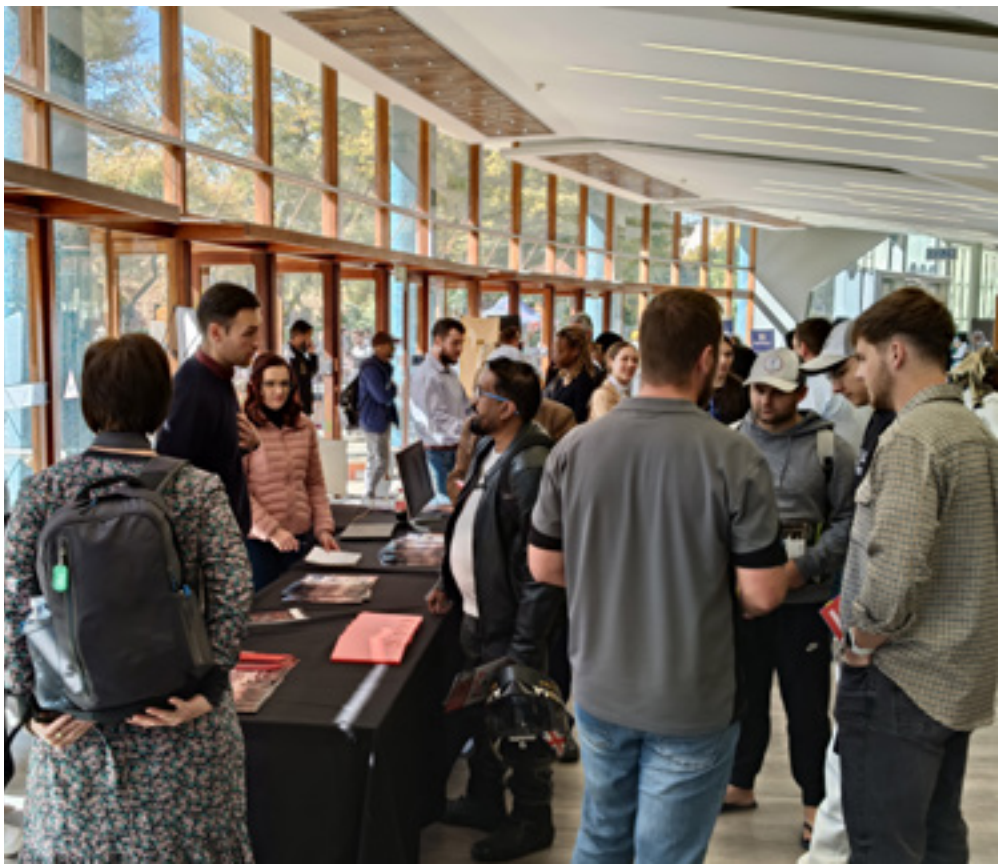
Ensuring that organisations in the built environment are fit for BIM requires them to establish an integrated digital ecosystem that captures the entire infrastructure development process in a real-time virtual collaborative space. This incorporates the full project life cycle – from conceptualisation, through the project's design and development, to its construction and maintenance. BIM-fit organisations are those with an agile and learning mindset, and are open to change.

Transitioning from traditional design and construction practices to digitally integrated environments requires a comprehensive shift in an organisation's practices and approaches. Ideas that provide a good place for an organisation to start transitioning into a BIM-fit organisation include a realisation of the following:

- Digital transformation is a journey, not a destination, which requires planning, care and consideration.
- Change requires patient learning – for everyone. It is not just about adopting new technologies, but about fundamentally reshaping the organisation's operations, self-perception and engagement with partners.
- Transformation must be kept incremental and relevant to the organisation. The organisation's digital transformation must be aligned to its unique needs and objectives.
- BIM managers must prepare and equip their teams with the necessary skills to effectively navigate and utilise digital tools.
- BIM managers must develop reliable digital information delivery processes.
- BIM managers must select digital tools that are aligned with the organisation's needs. Such tools include BIM software, project management platforms, communication tools and AI instruments.

As BIM is focused on people, processes and technology (in that order), the conference was structured according to these essential elements. The presentations on the first day focused on people in BIM. Topics included career paths in BIM, the power of instructor-led training, the roles and responsibilities of the members of a BIM team, and how organisations go about getting their people BIM fit. Delegates were made aware of the fact that the BIM revolution has not led to a shortage of jobs, but a shortage of skills. It was therefore important to emphasise what upskilling and training for a BIM-fit organisation looks like in the short, medium and long term.

The second day focused on the business of BIM, and BIM in action, while some case studies were presented. Topics related to the business of BIM included the BIM organisation, the challenges and opportunities that come with embracing digital transformation in the built environment, establishing a BIM workflow to enhance the design, construction and operation of projects, and determining the critical steps to create a reliable dataset.



Presenting the organisational requirements for BIM-fitness, Dr Davey and Laetitia van der Merwe, a lecturer in the University's Department of Construction Management, explored how a proactive organisational culture is vital for successful digital transformation in the built environment. They highlighted the importance of embracing innovation, fostering digital literacy and encouraging collaboration to seamlessly integrate new technologies.

This was followed by a panel discussion on how to build a BIM-fit organisation. Delegates gained first-hand insights from leading South African digital built environment businesses on their transformative BIM journey. The panellists revealed the pivotal skills they had acquired and the strategic investments they had made to successfully integrate BIM into their operations.

Three case studies were presented on the final day of the conference to illustrate BIM in action. Thomas Fuller, development manager at the JT Ross Property Group, unpacked a project that aimed to achieve a net-zero carbon footprint by following a BIM methodology. Melvern Govender, a quantity surveyor with the City of Cape Town, illustrated the City's evolution towards BIM integration. Dr André Broekman, Astrid van der Laan and James Abrey from the infrastructure, engineering and advisory practice, Zutari, described the integration of computational design practices with BIM to develop customised tools and scalable data pipelines to deliver value-added services across large-scale projects. Their presentation featured a multi-bridge modelling project as an example of adopting a BIM philosophy.

Learning about green infrastructure in Germany

Postgraduate students from the University of Pretoria's Department of Town and Regional Planning had the opportunity to join their peers from the Department of Psychology in the Faculty of Humanities on an international study visit to Germany, including the Technical University (TU) Berlin and Leuphana University in Lüneburg, in June 2024. The purpose of this 10-day visit was to learn more about green infrastructure projects in Germany. The visit came about through funding received from the German Academic Exchange Service (DAAD).

Participants included nine taught master's students in Planning, supervised by Prof Jacques du Toit of the Department of Town and Regional Planning, and six taught master's students in Research Psychology, supervised by Prof Claire Wagner of the Department of Psychology. The students and their supervisors were hosted by Prof Nina Baur, Director at the Global Centre of Spatial Methods for Urban Sustainability (GCSMUS) in the TU Berlin's Department of Sociology.

Prof Du Toit explains that the visit contributed to reinforcing the students' understanding of the global problems of climate change, social inequality and infrastructure challenges at municipal and community level, which require innovative solutions from multiple perspectives. "Within the context of the United Nations' Sustainable Development Goals (SDGs), which aim to achieve a better and more sustainable world for all, the focus of the study visit was to exchange subject-related knowledge about infrastructure (water, green spaces and transport) from an urban sustainability perspective." The emphasis was on the interaction of this knowledge with politics and governance, the economy, social inequality and climate change in relation to urban planning, psychology and sociology. Discussions between the students and lecturers on the use of social research methods to analyse infrastructure arrangements formed an important element of the visit.

The students paid a visit to the Ruhleben wastewater treatment works.

The students explored the concepts of water-sensitive planning and urban design to reduce the impact of the urban water cycle, and how understanding human behaviour through social research can encourage sustainable actions within the water cycle. This relationship between pro-environmental behaviour and the built environment is a topic on which Prof Du Toit and Prof Wagner have been conducting interdisciplinary research since 2011. They have also been driving research-led teaching on the topic, which has included mentoring programmes between Planning and Research Psychology students and project-based learning to develop students' research skills.

"The SDGs and the notion of water sensitivity imply specific green infrastructure technologies at the municipal and community level," explains Prof Du Toit. The study visit therefore focused on best-practice examples so that students could learn about both the political and social aspects of green infrastructure, and its planning and implementation.

The combination of the visiting students' backgrounds in Planning and Research Psychology from an interdisciplinary perspective gave rise to several themes that are highly relevant to South African society. These included those that cut across the disciplines of sociology, psychology and urban planning, such as the sociology and psychology of

work and health, climate change, water and wastewater management, and transport infrastructure, as well as methods of social science applied to the built environment. The visit also provided an opportunity to touch on issues of social inequality. "As women in Germany experience high levels of gender equity, the visit gave the young South Africans a chance to experience what it means to live in a country with high gender equity," explains Prof Wagner.

Prof Baur integrated the visit into three courses at TU Berlin for Sociology, Urban Planning and Urban Design students. In response, Prof Wagner integrated the visit into the practical component of her Environmental Psychology course in the master's programme in Research Psychology, and Prof Du Toit integrated the visit into the mini-dissertation module of the master's programme in Town and Regional Planning. Prior to the visit, the South African and German students attended an interdisciplinary, cross-cultural joint online course on global sociology, incorporating spatial arrangements and green infrastructure. This gave them the opportunity to co-learn and intermingle. It also allowed the students to compare their respective countries and to get to know each other before they met in person.

During their seven days in Berlin, the students paid a visit to various green infrastructure sites. They also elected to visit Berlin's city spaces and cultural places, public spaces and urban gardens. A visit to the Beelitzhof water treatment facilities taught them how groundwater becomes drinking water. This provided insights into modern water treatment facilities as green infrastructure, as well as how this infrastructure is embedded in the urban water cycle. They visited an industrial area in Berlin that had been established in the 1920s and 1930s. This gave them insight into industrial design and traffic planning during that era, the role of water and harbours for transport, the role of water for cooling in industrial production and energy production, and social housing and social inequality. Several walks provided the opportunity to explore various applications of green urban infrastructure. This included a walk through a classic allotment garden colony and a walk through the modern urban common gardens. This allowed them to explore the continuities and differences that exist between these two types of community-run gardens. They also visited a former airfield that is now being used as a public park. Another highlight was a visit to historical green infrastructure and the Grünewald Forests, and a visit to the Ökowerk conservation area. This gave the students the opportunity to see how environmental education is conducted in Germany. The historical site had previously been a groundwater extraction plant, and now houses a vegetable garden and wetland.

The German students arranged for their South African guests to attend a match in the UEFA European Soccer Championship. This gave them the opportunity to connect with each other socially and for the South African students to gain a better understanding of German cultural life. Furthermore, the students did joint ethnographic fieldwork in teams of three to five, after which they worked together on course assignments. The students could select one of three topics: Berlin's city spaces and cultural places, Berlin's public spaces, and urban gardening in Berlin. International colleagues from GCSMUS (including those from Botswana, France, Kenya and Thailand) joined some of the excursions, which gave the students exposure to a diversity of viewpoints on urban sustainability.

Their visit to Berlin was concluded with a guided tour of the German Parliament. They also visited the historical legacy of the Berlin Wall and Mauerpark, which is an example of the reuse of urban space.

On their three-day visit to Lüneburg, the UP students attended meetings, tours and excursions. This included a visit to an eco-village to experience a communal sustainable lifestyle in Germany. They also attended a two-hour World Café workshop hosted by Leuphana University's Sustainability Education and Transdisciplinary Research Institute. It enabled the students to reflect on the topics of sustainability education, transdisciplinary approaches to achieving the SDGs and opportunities for future collaboration and postgraduate study. A campus tour of Leuphana University gave them insights into how sustainability measures can be integrated into university infrastructure and everyday life.

Feedback from Veronica Fikiswa Cele, one of the Planning students, illustrated the value of the visit. "It was a life-changing experience. Studying with other students gave me an opportunity to observe urban planning and sustainability infrastructure when travelling. I was able to see how people interact with public transport, waste and spaces." Another student, Nomfundo Mkhize, reflected that it offered new learning moments on the topic of green infrastructure, displaying Germany's innovative and progressive approach to green infrastructure implementation. "It provided practical examples of best practices that have the potential to produce optimal outcomes for planning and implementation in the South African context."

Prof Du Toit concludes that the visit succeeded in strengthening the existing collaboration between UP and TU Berlin, and cultivated new bonds with Leuphana University. "It also gave our students a better understanding of economic, political and cultural life in Germany, while expanding their horizons in terms of green infrastructure planning and design."

Introducing new Heads of Department in the Faculty

The Dean of the Faculty of Engineering, Built Environment and Information Technology congratulates the following senior academics who joined the Faculty's leadership ranks in 2024:

Prof Olufemi Adetunji is Head of the Department of Industrial and Systems Engineering in the School of Engineering. He joined the University as a full-time lecturer in 2007. His research focuses on operations management, supply chain management, operations research, artificial intelligence and enterprise systems.

Prof Natasia Naudé is Head of the Department of Materials Science and Metallurgical Engineering in the School of Engineering. She is an expert in metallurgical engineering and specialises in minerals processing topics related to particle stratification, physical beneficiation processes and advanced computational modelling techniques.

Prof Marlene Holmner is Head of the Department of Information Science in the School of Information Technology. Her research interests include information and communication technology (ICT) for development, information ethics and indigenous knowledge. She is passionate about bridging the digital divide.

Prof Francois Malan is Head of the Department of Mining Engineering in the School of Engineering. He is an internationally renowned specialist in the field of rock engineering. His research interests include numerical modelling, pillar behaviour, geomechanical instrumentation and layout design.

Prof Carin Combrinck is Head of the Department of Architecture in the School for the Built Environment. She is also Director of the Department's Unit for Urban Citizenship. Her research is rooted in the role of architecture in community development, with an interdisciplinary view towards social innovation and urban citizenship.

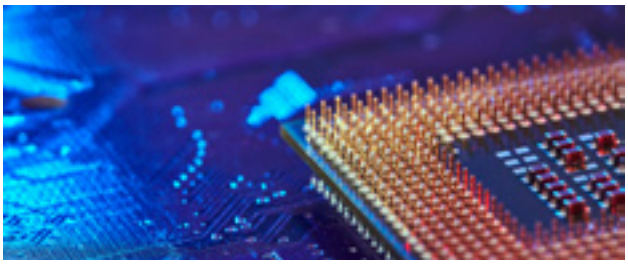
Inaugural addresses

EBIT is home to a team of exceptional researchers. The following academics each delivered a thought-provoking inaugural address in 2024. This marks a highlight in their academic careers.

ADVANCES IN STEEL DESIGN AND PROCESSING TO CURB GREENHOUSE EMISSIONS

Prof Charles Siyasiya
Department of Materials Science and Metallurgical Engineering

Iron and steel have been integral to society since about 2000 BC. For the past 150 years, it has been one of the four materials with the most significant global consumption, namely cement, steel, plastics and ammonia, upon which modern civilisation rests. The invention of the Bessemer process revolutionised steel production, ushering in the industrial revolution of the 1800s. In the last six decades, the focus has been on reducing the energy consumption per ton of steel and making steel stronger and tougher to reduce the mass of components, while increasing the payload in pursuit of improved CO_2 emissions to curb climate change. Despite all the recent improvements, iron and steelmaking remains one of the world's most energy- and carbon-intensive industries and contributes about 10% of the total anthropogenic CO_2 emission globally. Prof Siyasiya's presentation shared extracts of his contributions to alloy design, thermomechanical processing and heat treatment of steels vis-à-vis the curbing of CO_2 emissions. He also shared his current research into hydrogen storage and repurposing of the existing storage and transportation systems. Finally, he presented future perspectives on the role of green hydrogen as an alternative to coal in producing green steels, and envisaged technological challenges and opportunities for technological innovations to replace coal in steelmaking to meet the 2050 CO_2 emissions target.



MIXED-MODE MICROELECTRONICS

Prof Trudi Joubert
Department of Electrical, Electronic and Computer Engineering

Microelectronics is undeniably a core driver of the astounding technological developments shaping the world over the last half-century. Prof Joubert's inaugural address presented the microelectronics research that leverages process improvements into cost-effective and innovative integrated circuits, contributing scholarship to the fields of novel electronic components and the mixed-mode integration of analogue and digital functions. Furthermore, she considered key recent research contributions in micrometre-scale electronics devices in the context of digital additive fabrication technologies. State-of-the-art laboratory facilities have been established for research inquiries into printed electronics sensor devices of various modalities. She elucidated the current and future research challenges of integration via heterogeneous technologies into lower-cost and miniaturised continuous monitoring systems at the point of need. The emphasis was on sensor devices in the domains of environmental and agricultural monitoring, as well as diagnostics. Multidisciplinary research teams are vital for progress, whereas the collaborations aim to equip the next generation of microelectronics engineers to meet the challenges of creating translational solutions. She concluded her lecture with a discussion of the impact of these collaborative transdisciplinary application solutions to progressively address the worthy United Nations' Sustainable Development Goals (SDGs), especially SDG 6 (clean water and sanitation) and SDG 3 (good health and wellbeing). A longer-term goal is for the microfabrication processes and developed sensor technologies to contribute to SDG 9 (industry, innovation and infrastructure).

THE FUTURE OF THE MANUFACTURING PLANNING AND CONTROL SYSTEM AND THE SENSOR OF THE INTANGIBLES

Prof Olufemi Adetunji
Department of Industrial and Systems Engineering

Manufacturing Planning and Control (MPC) is the heart of production systems. It reconciles customer demand with the requirements for production resources (inventory and capacity) and guides the necessary trade-off decisions, guided by an appropriate production management philosophy. In his presentation, Prof Adetunji traced the evolution of industrial engineering, starting from basic productivity engineering after the first industrial revolution. He also mentioned some of its prominent subdisciplines today, including MPC. Subsequently, he discussed industrial engineering's role in the competitiveness of nations and the concept of a work system as the operating environment of industrial engineering. He then presented inventory management within the MPC framework, and reviewed models for deteriorating, ameliorating, growing and recoverable inventory items as his main research field. Furthermore, he highlighted some applications of these inventory areas, like food chains and circular manufacturing. He then presented softer issues of production management philosophies and his research in understanding how these affect the efficiency of work systems. He also looked into the future of MPC and anticipated how it will evolve based on Artificial Intelligence and the Industrial Internet of Things (IIoT). He presented the Manufacturing Execution System (MES) layer of the IIoT's five-layer architecture as the digital realisation of the MPC, and discussed his future research direction. Finally, he presented the idea of the sensor of the intangibles (SoI), how it may influence the design of an intelligent MES (IMES) layer of the future IIoT, and how SoI may integrate economic and human factors in the future IMES architecture.

MINDING AND MENDING OUR WAYS

Prof Wynand JvdM Steyn
Dean of the Faculty of Engineering, Built Environment and Information Technology

Roads are essential infrastructure that weave through the fabric of our societies. They are the conduits that connect communities, enabling access to education, healthcare, trade and safety. Beyond this functionality, roads also serve as the threads that bind us and shape our collective journey. Vehicle-pavement interaction lies at the heart of road engineering. It is the intricate dance between vehicle tyres and roads, where physics, materials science and engineering converge. Here, science meets practicality, ensuring that roads endure, vehicles ride smoothly, and our lives move forward. Prof Steyn's lecture took delegates through his 35 years of research on the interrelationships between roads, road users and the ways in which roads affect journeys and users adapt to roads. He reflected on how he has observed and quantified these interactions (minding) and how he has contributed to the construction, maintenance and rehabilitation of roads (mending) to ease the burdens of accessibility and mobility in support of communities. His research journey spans from rudimentary to high-tech data collection and analysis, along with reflections on the meaning of such data and the opportunities to maintain and rehabilitate infrastructure. He also shared his insights into the importance and implications of this research for both users and infrastructure. Looking ahead, he emphasised the need for foresight in vehicle-pavement interaction to ensure sustainable and healthy transportation practices through continuous and automated monitoring and maintenance. He concluded that any successful journey depends on mutual respect between the user and the road, which prevents overstressing and helps maintain smooth road surfaces.

An engineering perspective on the leadership problem: The experience of McDonald's South Africa's CEO

Members of the South African Academy of Engineering were enthusiastic to hear the perspective of Greg Solomon, CEO of McDonald's South Africa, on the topic "We have a leadership problem" at the annual Hendrik van der Bijl Memorial Lecture, held at the University of Pretoria on 10 October 2024.

CHOOSING WISELY, THINKING CAREFULLY AND MAKING WELL-CALCULATED CHOICES ARE THE SECRETS TO SOLOMON'S BUSINESS SUCCESS. TO RUN A RESPONSIBLE BUSINESS, YOU NEED TO THINK AHEAD SO THAT YOU CAN RESPOND TO ANY UNEXPECTED CHALLENGE.

This lecture is an annual event hosted by the South African Academy of Engineering, in collaboration with the University's Faculty of Engineering, Built Environment and Information Technology. It commemorates the contributions of Van der Bijl, a giant in industry, to the industrial and scientific development of South Africa. It has been held since 1963 and has featured many eminent persons whose work illustrates the general theme of the role of engineering in society.

Introducing the guest speaker, the University's new Vice-Chancellor and Principal, Prof Frances Petersen, described Solomon as a successful business leader and humanitarian, who puts people first, and believes in making a difference in terms of inclusivity, equity and diversity. As the master franchise of the American multinational fast food chain, McDonald's South Africa has almost 400 restaurants and employs more than 15 000 people. Important imperatives that have played a role in its development since its entry to the South African marketplace in 1995 include technology, digitisation, modernisation and brand purpose.

Having trained as a civil engineer, Solomon is the epitome of an engineer who has migrated to another industry where he has made an impact with the skills he has acquired. "Losing engineers to other industries represents a gain to the country's economy," he says.

Explaining the topic of his presentation, he reflects, "as engineers, we are leaders, and have to make sure that we contribute a solution to the leadership problem in South Africa".

He described the three aspects that are essential to leadership and management: leading yourself, leading others and leading business. "It is all about doing things differently." He identifies the two prerequisites of a true leader to be the qualities of trust and respect. "It is all about delivering on your promises." His experience with McDonald's South Africa serves as an example of how to manage a business by managing its people and its systems.

Looking back at challenges that have had the potential to impact negatively on South African business, he cited the COVID-19 pandemic, loadshedding and the riots in KwaZulu-Natal. He managed to overcome these challenges by having prepared for future eventualities. "We had already started the digital transformation journey, and our involvement in our communities ensured that we had their continued support." He explains that when the external environment changes faster than the internal environment, it is easy to become irrelevant. His advice is that one should continue to evolve and change, and most importantly, learn. "One needs to focus on scalability and sustainability by paying attention to where transformation needs to take place."

Solomon places great emphasis on the choices one makes: both in business and in one's personal life. "In South African business, and particularly in the retail industry, we are standing at a crossroads, where we need to find solutions to two important challenges: youth unemployment and purchasing power." He believes that one's decisions have the power to transform business, to transform the youth, and to transform the country.

Choosing wisely, thinking carefully and making well-calculated choices are the secrets to his business success. "To run a responsible business, you need to think ahead so that you can respond to any unexpected challenge," he says. He believes in nurturing a culture of innovation, and the importance of continuing the education journey. Highlighting milestones in the development of MacDonald's South Africa since its inception in 1995, he illustrates how many of the innovations were based on listening to the people who work for him, and recognising when something needs to change. He also explained the significance of launching the new flagship Sammy Marks branch in the city centre of Pretoria, rather than in the more prestigious precincts of Brooklyn or Menlyn. "This is where we can make the biggest difference in the lives of an important demographic in our client base," he says.

Other important elements of a successful business include having contingency plans in place, being a nimble business leader with an analytical mindset and playing out different scenarios for any future situation. "When something changes by the power of 10, something needs to change fundamentally," he explains. This recognition drives his operational excellence.

"I believe our power lies in our differences, and that it is our values that bring us together." He therefore subscribes to the values of service, inclusion, integrity, community and

family, where he puts his staff and his customers first. He also believes that it is the smallest things that make the biggest difference. For that reason, he ensures that the focus of every single store in the chain is characterised by quality, service, cleanliness and value. He also believes in the importance of balancing relationships, and holding people accountable, which is why the tripartite relationship between the franchisees, the corporation and the company's suppliers form a key part of the brand's strategic plan, with the customer and staff members as the ultimate beneficiaries.

Solomon concluded his presentation by responding to a wide range of questions about the firm, business in general, tips for future entrepreneurs and his personal priorities. The consensus was that it was a very insightful talk, with a good mix of finance, passion for people and the willingness to take a risk. By following his example, South Africa's leadership problem may have found its solution.

Space explorer inspires students to change the world for all humanity

The Faculty of Engineering, Built Environment and Information Technology, in collaboration with the US Embassy, hosted Dr Sian Proctor, mission pilot of the first all-civilian orbital mission, SpaceX Inspiration4, on the University's Hatfield Campus on 31 July 2023. She shared her experience with an enthusiastic audience fascinated by space travel. The event was organised by the UP Aerospace Society.

Dr Proctor is the first African American woman to pilot a spacecraft, and the first African American commercial astronaut. She is a geoscientist, who is a full-time professor at the South Mountain Community College (SMCC) in Phoenix, Arizona, where she teaches geology, sustainability and planetary science. Her academic qualifications include a BSc in Environmental Science, an MSc in Geology and a PhD in Curriculum and Instruction: Science Communication. She is also one of The Explorer's Club 50: Fifty people changing the world.

She sought to encourage the members of the audience to dream that anything is possible, and not to be discouraged when they do not succeed at their first attempt. She explained that travelling in space had been a childhood dream, and despite being shortlisted in the final round of applications in NASA's selection process to travel to space in 2009, she did not make the final cut. However, she explains that she would never have known how far she could have gone if she had not applied.

Taking what she could learn about herself from this experience, she continued to express her passion for exploration through her work as a science communicator. She articulated her belief that education is the roadmap to opportunity. "You need to understand the value you can bring to a situation by being dedicated to continually developing your knowledge and skills." She explained that one needs to be a perpetual explorer. "It's all about discovering something new about yourself through lifelong learning."

A second opportunity to explore space presented itself when she was recognised for her talents as an artist and a poet. She became one of only four civilian crew members to be selected to orbit the earth for three days in the SpaceX Inspiration4 space capsule in September 2021. This spaceflight formed part of a charitable effort on behalf of the St Jude Children's Research Hospital in Memphis, Tennessee.

Each of the crew members represented one of the mission's four pillars of hope, prosperity, leadership and generosity. Dr Proctor was awarded the prosperity seat on the basis of her submission of a poem, "Space to inspire", which she had penned during the COVID-19 pandemic to inspire people to change the world for all humanity.

Her presentation, titled "Packing for space", focused on ensuring a just, equitable, diverse and inclusive space. She emphasised the fact that when we solve for space, we also solve issues on earth. Asking the audience what they would "pack" for a trip in a spacecraft, she explained that one's mental resources are often just as important – if not more so – than the physical items one would pack; whether it is for a metaphorical life journey or an actual space flight.

She continued to elaborate on the six characteristics one should strive to develop to prepare oneself for future success: persistence, determination, creativity, inspiration, teamwork and responsibility. In the process, she encouraged the members of the audience to believe in their ability to do amazing things to make a difference to life on earth by finding sustainable solutions to the challenges facing mankind.

Her message reinforced the vision of the Faculty of Engineering, Built Environment and Information Technology: Innovating our tomorrow, and the members of the audience left the auditorium inspired by what they can achieve if they let their "earthlight" shine.

THE FREQUENCIES AROUND US

Frequency is more than just a numerical value; it is a universal language that binds together the realms of engineering, architecture and information technology. It is the rhythm of innovation, the harmony of design and the melody of progress. It was also the theme of the **2024 EBIT Concert**. This event took the audience on a musical exploration of the frequencies that surround us, in which lie the key to unlocking the true potential of humanity – a harmony that knows no bounds and a melody that echoes through eternity. It was a collaborative showcase between the Dean's Office and the University of Pretoria Symphony Orchestra (UPSO), under the guidance of conductor Schalk van der Merwe. Its purpose was to thank the Faculty's alumni and partners for their continued support.

NEW ARTS FESTIVAL BLENDS THE ARTS AND ENGINEERING

The Faculty is the proud sponsor of a brand-new event on Pretoria's youth arts scene. The ShowUP Arts Festival, which was held in the University's iconic Aula Theatre on 13 July 2024, was the brainchild of David Brink, CEO of the Stage Alive production company. The aim of the festival was to foster cultural exchange, inspire artistic expression and provide a platform for emerging artists to display their talents. The event proved to be a celebration of creativity, diversity and community engagement through various forms of the performing arts. It offered school learners and students the opportunity to compete in various genres.

The format was based on the popular "America's Got Talent" programme, with three judges offering comments to the artists after each performance. Artists were drawn from 65 of the University's feeder schools, with 250 artists from these schools, as well as the University's student community, participating in the event. The event was concluded with a gala evening in the Aula. First place went to vocalist Reneésha Kruger from Hoëskool Die Wilgers, who performed the song "Never enough" from the musical "The Greatest Showman". Second place went to another talented vocalist from the same school, Zarko van Niekerk, who performed Michael Bublé's popular song "Sway". Third place went to Freddy Swarts from Hoërskool Linden, who performed a contemporary dance item to the lyrics of Tate McCrea's "That way".

BOOK LAUNCH

Prof Hendrik Brink, an associate professor in the Department of Chemical Engineering, is a co-author of a Special Issue Reprint of *Sustainable mining as the key for the ecological transition: Current trends and future perspectives*. His co-authors are Pierfranco Lattanzi from the Institute of Geosciences and Earth Resources of the Italian National Research Council, Elisabetta Dore from the Department of Chemical and Geological Sciences, University of Cagliari, Italy, and Fabio Perlatti from the National Mining Agency, University of São Paulo, Brazil. This publication reproduces 11 articles that had previously been published in the journal *Minerals*. The reprint contains an editorial, an introductory paper dealing with general issues, and nine papers dealing with resource exploration, the impact of mining activities and waste recovery.

Celebrating Arbour Day

Ketla Madileng

The University of Pretoria's Department of Architecture joined hands with the landscape industry and the City of Tshwane's Department of Environment and Agriculture Management at the Fountains Valley Resort on 13 September 2024 to celebrate Arbour Day.

The aim of the initiative was to plant 50 white stinkwood *(Celtis africana)* trees to replace the old and dead trees and to restore the forest area that naturally occurred in Fountains Valley. This is the perfect location for the white stinkwood as it thrives where there are streams and underground water. The city is in the process of reforesting the Groenkloof Nature Reserve and the Fountains Valley Resort. Over and above the heritage and ecological importance the urban forest renders, it further serves as a green lung to mitigate against the pollution that results from the daily traffic congestion in the inner city. Trees are also the most effective means of carbon sequestration. The organisers hope that future nature relationships will be as strong as the trees that were planted as visitors come and enjoy this natural area in the city and find the trees growing strong.

A leader in Green Sustainability Trends

Dr Karen Botes, a lecturer in the Department of Architecture, has been awarded first place in the second annual Green Sustainability Trends competition. This prestigious event draws participants from the Mid-East, Africa and Asia. It recognises innovative solutions in environmental engineering and organic architecture. Dr Botes's project on modular living wall systems and African vegetables has set a new benchmark in sustainable urban design.

The Green Sustainability Trends competition fosters collaboration among researchers and practitioners who tackle pressing environmental challenges. This year's competition saw a diverse range of projects, each highlighting novel approaches to sustainability. Dr Botes's project stood out for its comprehensive and practical approach to integrating edible plants into urban green infrastructure. Her research proposes guidelines for implementing outdoor modular living wall systems specifically designed for urban environments. By incorporating African vegetables, these living walls serve dual purposes: enhancing the aesthetic and functional aspects of urban spaces, while providing a sustainable source of nutrition. The benefits of these living wall systems extend beyond mere decoration; they contribute to air purification, temperature regulation and community wellbeing. The emphasis of her project on community involvement is particularly noteworthy. She highlighted the importance of selecting appropriate plant species, ensuring proper irrigation and optimising structural design. By engaging local communities in maintaining and utilising these living walls, her project promotes a sense of ownership and environmental stewardship. Her achievement in this competition is a testament to her dedication, expertise and innovative spirit. Her work addresses the urgent need for sustainable urban solutions. It bridges the gap between traditional agricultural practices and modern environmental engineering. She serves as an inspiration for all aspiring landscape architects by encouraging the exploration of sustainable and community-focused design solutions.

University's railway engineering researchers earn national recognition

The University of Pretoria (UP)'s Chair in Railway Engineering was the winner in the category Pioneering Applied Rail Research at the inaugural South African Rail Industry Awards ceremony, instituted to celebrate 21 years of excellence by the Railway Safety Regulator (RSR). In addition, Dr Willem Sprong, the Programme Manager in the University's Chair in Railway Safety, received the Regulator's Lifetime Achievement Award. UP was also a finalist in the category Excellence in Training. The awards ceremony was held in Johannesburg on 24 October 2024.

Prof Hannes Gräbe, the University's Chair in Railway Engineering, explains that railways around the world are currently undergoing a digital revolution that is fundamentally reshaping traditional practices and is challenging the long-established technologies that emerged during the eras of automated production, electronics and computing. "This shift towards digitalisation offers unprecedented opportunities to enhance the efficiency, safety and performance of railway systems." By integrating advanced systems and processes, railway operators can extract greater capability from existing assets, leading to significant improvements in capacity, operational performance and connectivity across the network.

He emphasises that the concept of smart infrastructure is at the core of this transformation. This concept involves the deployment of sensors and integrated digital communication networks to continuously monitor the current state and performance of railway assets. These sensors, which are often part of the rapidly expanding Internet of Things (IoT), range from devices that measure simple parameters such as temperature, to advanced systems to capture high-frequency, three-dimensional acceleration data.

Presenting the award to the University of Pretoria (from left): Sisa Mtwa (RSR Deputy Board Chairperson), Dr Willem Sprong, Dr David Mpye and Prof Hannes Gräbe (UP Chair in Railway Safety) and Rirhandzu Mashava (RSR Executive).

This rich dataset provides real-time insights into track conditions, asset health and potential risks, allowing for more informed and timely decision making.

"The ability to collect vast amounts of data is only part of the equation," he explains. The advent of big data analytics, combined with cutting-edge machine learning algorithms, enables railway engineers to move away from traditional, cyclical maintenance practices. Instead, these technologies support the implementation of condition-based and predictive maintenance strategies, where interventions are based on actual asset conditions rather than fixed time intervals. This shift not only optimises maintenance schedules, but reduces downtime, improves safety and extends the life cycle of critical infrastructure components.

The research of the Chair in Railway Engineering focuses on track infrastructure, with a particular emphasis on the use of advanced digital technologies to monitor and assess the condition of bridges, track transitions, rails, ballast and formation layers. It highlights industry-ready solutions for track infrastructure that are designed to increase capacity, enhance predictive maintenance capabilities, and extend the life cycles of various track components.

LAST
WORD

Wilhelm Haupt

Wernher von Braun and the innovation conundrum

Human inventions can be used for the common good and for evil purposes alike. The results of the work of aerospace engineer and pioneer of rocket and space technology in the USA, Dr Wernher von Braun, bears this observation out with exclamation.

Wernher Magnus Maximilian Freiherr von Braun was the son of Magnus Freiherr von Braun and Emmy Melitta Cécile von Quistorp. He was born on 23 March 1912 in Wirsitz, in Prussian Germany. (The town now forms part of Poland and is named Wyrzysk.) Wernher's family were of noble descent.

Philip III of France, Valdemar of Denmark, Robert III of Scotland and Edward III of England mark his mother's ancestry. His father served in the Ministry of the Interior. He was Minister of Agriculture during the era of the Weimar Republic. His older brother, Sigismund, became a West German diplomat and Secretary of State in the 1970s. His younger brother, Magnus, was a rocket scientist and later senior executive of Chrysler. The family attended the Lutheran Church.

THE EARLY YEARS

Wernher grew up in Wirsitz and, later, on the family's estate near Anklam in Greifswald. The family relocated to Berlin in 1920 when he was eight years old. He was an inquisitive lad and ardent reader.

The motion picture "I aim at the stars" was regularly screened by the Early Show of WCAU during the 1960s. It contained a scene showing the young Wernher launching a rocket from their house's balcony to see where it would land. The rocket crashed through a neighbour's hothouse, setting it alight.

This scene may be an ambitious dramatisation of an actual incident when the 12-year-old Wernher strapped six firework rockets to a small wagon and set them on fire in the street. The wagon accelerated around a wildly snaking route, leaving a trail of fire until the rockets burnt out. Someone forewarned the police and they arrived for the final movements of the wagon. As the smoke cleared, he was apprehended and shepherded to his father, Baron von Braun.

Wernher later stated: "Basic research is what I am doing when I do not know what I am doing." That experiment launched Wernher's drama-laden career of designing, building and firing rockets.

Rockets were not the only things Wernher built.

While attending the French Gymnasium School in Berlin, he spent much more of his time in the Von Braun garage building an automobile than in his study attending to schoolwork. He did not perform according to expectations and was placed in the Hermann Lietz boarding school in Ettersburg, where he fared better.

In boarding school, Wernher received permission to study the stars, using a small telescope his mother had given him as a rather uncustomary confirmation present. He noticed an advertisement in an astronomy magazine and ordered *Die Rakete zu den Planetenräumen* by Hermann Orbeth, physicist and pioneering rocket scientist.

The 13-year-old Wernher could not make head or tail of the overwhelming mathematical symbols and formulae, and consulted his teacher who urged him to study harder in Mathematics and Physics (his weakest subjects). As he was "aiming at the stars", he obliged, burying himself in their mysteries and complexities.

This elevated his marks to such an extent that he graduated in April 1930,

a year before his peers. His senior school years (1928–1930) were spent at the Lietz School on the Frisian islet of Spiekeroog in the North Sea.

Despite his dedication to astronomy and machines, Wernher's talents and activities were not limited to that.

He played the piano and cello and was an amateur composer, who took lessons from Paul Hindemith. He produced some youthful pieces that are still around and reminiscent of the Hindemith style.

RESEARCH IN GERMANY

Later, in 1930, Wernher enrolled at the Berlin Institute of Technology, where Hermann Oberth was a professor. Wernher and two friends became Oberth's assistants at the German Society for Space Travel. Oberth was studying the viability of using liquid fuels to replace solid fuels for enhanced rocket propulsion. Their equipment and ignition systems were crude and the ignition system was perilous. At the Raketenflugplatz, an assistant dropped a burning fuel-soaked rag over the rocket motor. He then dived for cover as Oberth opened the fuel valves full throttle to fire the motor up with a glowing hot roar. This exuberance was reflected by the habit Wernher had reportedly assumed of arriving at social gatherings with two ladies – one on each arm.

Bone arrow points, dating back 61 millennia, have been found at Sibudu Cave near KwaDukuza in KwaZulu-Natal; the Assyrians and Judeans used oil- and resin-soaked burning arrows during the siege of Lachish in 701 BC; and the medieval solid propellant rockets from China followed, but liquid propulsion was new at the start of the 20th century. Oberth in Berlin and Robert Goddard at the Smithsonian Institute in the USA independently performed some experiments using liquid oxygen and alcohol combinations as propellants to fire relatively tiny rocket motors.

After one semester in Berlin, Wernher diverted to the Swiss Technical Institute in Zurich for one more semester. From 1931, Wernher received private flying lessons in Grunau and eventually became a skilled pilot of gliders, light aircraft, fighters and helicopters.

Wernher von Braun, the student, wanted to understand the complex interactions when atomisation, combustion and gas expansion take place. To his delight, he succeeded in securing funding and permission to do the expensive and dangerous research at the Kummersdorf proofing site of the Deutsche Wehrmacht.

In 1932, he was back in Berlin studying Physics and doing a classified government-funded doctorate under the tutelage of Walter Dornberger. Dornberger appointed Von Braun as Head of Rocket Development. Wernher led the team that built the A1 and A2 liquid fuel rockets in Kummersdorf, south of Berlin. Only the two A2 rockets named Max and Moritz were successful and contributed to Von Braun graduating with a doctorate in Physics in 1934.

To build and test larger rockets, Von Braun established the Peenemünde test site on the Baltic island of Usedom, where his grandfather had once liked to hunt ducks. He joined the Schutzstaffel (SS), the elite guard of the Nazi regime, with the rank of Sturmbahnführer (major) to pave the way for his quest to build rockets to eventually reach the moon and stars.

In Russia, Dr Konstantin Tsiolkovsky had set down many principles for space flight before passing away in 1935.

Wernher von Braun with his family.

Also in 1935, Dr Robert Goddard fired rockets (at Roswell, USA), reaching heights of up to 2.5 km. By 1941, Von Braun's team had, however, and unbeknown to the others, built the A3 and A4 rockets.

The former reached a height of 13 km and the latter – a 13-ton beast, 14 m in length and providing thrust of 250 KN – surpassed it. It was the first rocket ever to perform like that. It used alcohol rather than gasoline as its main propellent. Two turbopumps injected liquid oxygen into the propellent mix.

In March 1944, it was reported to the Gestapo (the official secret police of Nazi Germany) that Von Braun was more interested in reaching the moon than in assisting their political ambitions.

He was arrested, accused of treason and threatened with summary execution. Walter Dornberger and Minister Albert Speer intervened speedily to get him back to Peenemünde to continue his work. When Peenemünde came under hostile fire, the research was continued underground near Nordhausen in the Harz Mountains.

They built the V2, an A4 rocket with some modifications, the world's first liquid-fuelled ballistic rocket. Carrying a 980 kg warhead, it had an operational range of 320 km, which it could traverse in five minutes.

RACE TO THE MOON

The launch of the first A4 rocket was also the launch of the space race and the race to the moon.

After World War II, both the Soviets and the Americans came into possession of V2 rockets, V2 remnants and components, V2 documents and manufacturing information. They started exploiting these windfalls for their competing space programmes. Without the V2, rocket research in the third semester of the 20th century would have been much more subdued. Inventions and knowledge emanating from the space programmes (like satellite communications and cosmic mirrors) would have come much later.

As a rocket, the V2 was a major success; as a military weapon, less so. More people died in manufacturing the V2 than in V2 attacks. The death toll was, however, very disturbing, especially in hindsight. Wernher von Braun, who wished to land on the moon, said: "The rocket worked perfectly, except for landing on the wrong planet."

Fortunately, the war ended in 1945. Von Braun was instructed to destroy all records and blueprints, which he did not do. To prevent being captured by the Russians, Von Braun and 500 members of his team travelled to Bavaria with their documentation. On 3 May 1945, in Reutte, Austria, they surrendered to US army officers. Some 117 members of this contingent were whisked off to Fort Bliss, Texas, during Operation Paperclip.

The Operation Paperclip team en route to Fort Bliss.

MARRIAGE

During his stay at Fort Bliss, prior to his official emigration to the USA, Von Braun undertook a sea voyage from New York to Berlin to marry his first cousin, Maria Luise von Quistorp, whom he had met in Peenemünde.

When they married in a Lutheran church in Landshut, Bavaria, on 1 March 1947, Wernher was 34 years old, while Maria was not yet 19. Their honeymoon was characterised by the American military police shadowing them, only women being allowed in cabins on the troop ship to the USA, which predominately carried returning GIs, and Von Braun's parents, who emigrated with them and were also present on the end-of-March train journey to El Paso.

They were naturalised as American citizens (with other Paperclip participants) in 1955. They had three children, Iris (born in 1948), Margrit (born in 1952) and Peter (born in 1960).

RESEARCH IN THE USA

From 1947 to 1949, Von Braun was assigned to salvage the abortive Hermes II cruise missile. He became frustrated by the low priority the Eisenhower administration awarded to rocketry, allowing interservice rivalry to delay Von Braun's plans. While the US navy's Vanguard rocket exploded spectacularly and on television, the Soviet Union utilised their German scientists with more urgency, enabling them to get Sputnik into orbit in 1957, with America left behind.

The Korean War put paid to America's laxity. Von Braun was reassigned to Alabama, and ballistic missile design, based on the V2, was supported and funded. A crucial challenge was guidance systems, as a V2 could land anywhere within 25 km of the target. Von Braun's team grew to almost 4 000 people and he was back in his forte of running large-scale projects. America's first orbiting satellite was put into space using his Jupiter rocket Juno 1 in January 1958, just months after Sputnik. The Soviets launched a much larger satellite into space in November. The technology for that was sufficient for spy satellites and intercontinental ballistic missiles, constituting threats to the Free World.

Von Braun became a household name in the USA through news and magazine articles, television appearances and shows. He expressed his goals for space travel, including space stations, and flights to Mars. From then, things heated up.

On 26 March 1958, Explorer 3 was launched to study the Van Allen Belt that Explorer 1 had discovered. In Huntsville, Von Braun appointed project managers for the Pershing, Redstone and Jupiter rockets, and developed more potent rocket fuel. The result was a rocket named Saturn.

In 1960, Von Braun left the US Army to head NASA's new Marshall Space Flight Centre. His team developed the powerful Saturn V rocket that put six teams of American astronauts on the moon between 1969 and 1972. He orchestrated the moon programme, while continuing with earth orbit and deep space endeavours.

In 1970, he joined NASA headquarters in Washington DC, where he was further frustrated by red tape. After the final Apollo (17) moon landing, he joined the private sector as R&D Vice President of Fairchild Industries in Germantown, Maryland.

Despite contracting liver cancer with all its horrendous ramifications, he continued to work until, by December 1976, it was no longer possible. On 16 June 1977, Von Braun passed away at the age of 65. He was laid to rest in the Ivy Hill Cemetery in Alexandria, Virginia.

THE VON BRAUN PHILOSOPHY

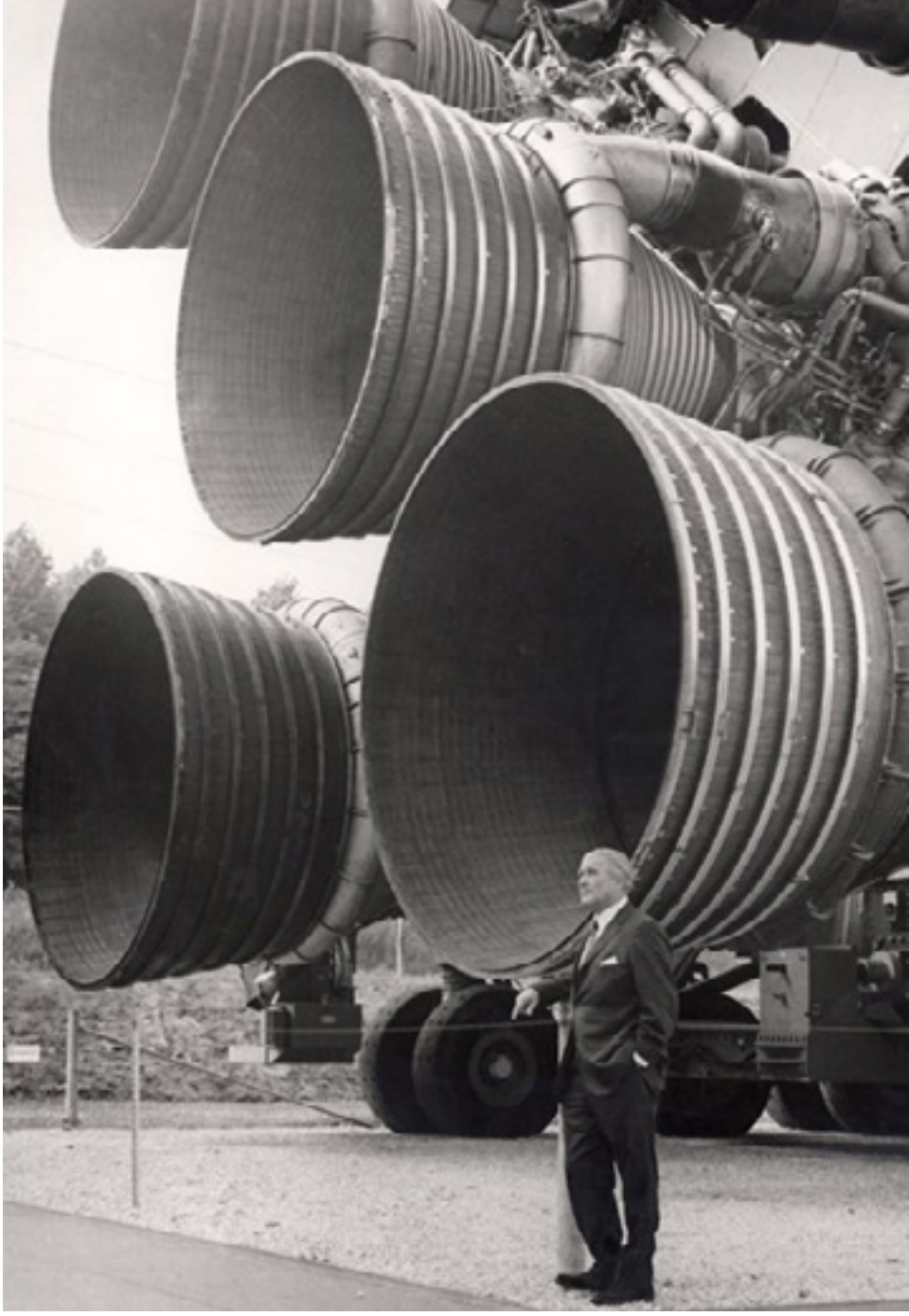
In order to understand and learn from Von Braun's dedication and success, it is necessary to have at least a glimpse of his life philosophy.

While in Germany, Von Braun did not display his faith habitually, but became an Evangelical Christian shortly after his marriage, while living in Texas.

He proclaimed: "Everything science has taught me strengthens my belief in the continuity of our spiritual existence after death. I believe in an immortal soul. Science has proved that nothing disintegrates into nothingness. Life and soul, therefore, cannot disintegrate into nothingness, and so are immortal."

Von Braun also said: "We should remember that science exists only because there are people, and its concepts exist only in the minds of men. Behind these concepts lies the reality that is being revealed to us, but only by the grace of God."

On another occasion he declared: "For me, the idea of a creation is not conceivable without invoking the necessity of design. One cannot be exposed to the law and order of the universe without concluding that there must be design and purpose behind it all." He believed: "To simply dismiss the concept of God as being unscientific is to violate the very objectivity of science itself."



Von Braun with the Rocketdyne F1 engines of Saturn V. Photo: NASA

RELENTLESS PURSUIT OF PROGRESS

Von Braun was the product of an aristocratic, conservative upbringing. As a youngster, he generally accepted the authority of the state and its institutions without question. Later on, when politics and administration hampered the progress of his work, he once quipped: "Conquering the universe one has to solve two problems: gravity and red tape. We could have mastered gravity."

Von Braun believed research requirements, not political and administrative concerns, should dictate resource allocation for projects. Regarding managerial attempts to speed up research by injecting cash and resources into urgent projects, Von Braun declared: "Crash programmes fail because they are based on the theory that, with nine women pregnant, a baby can be born in a month." These words may seem to belie his extreme sense of urgency, but he also warned: "If we continue at this leisurely pace, we will have to pass Russian customs when we land on the moon."

POSTSCRIPT

The dedication and mastery Wernher von Braun expended on research and development in rocket science and further applied and enhanced in advanced aerospace engineering has undoubtedly advanced these fields much more rapidly than would have been the case without him.

His work serves as a springboard for current and potential research in the space arena – with unimaginable future applications. Simultaneously, it has been a catalyst for the development of destructive nuclear weapons that, in the hands of nefarious players, have the potential to start an uncontrollable war that can destroy mankind and other life forms on earth.

This highlights an uncomfortable ethical conundrum regarding the duality of scientific progress. After all, Von Braun said: "The same forces of nature that enable us to fly to the stars, enable us also to destroy our star."

References

Columbia Pictures 1960. I aim at the stars (Wernher von Braun)

Cooney, TJ. X-Post @TJ_Cooney 12:17 AM Oct 18 2021

Coppedge, D.F. Wernher von Braun. Available at: https://crev.info/scientists/wernher-von-braun/.

Fandom. Wernher von Braun. Available at: https://nasa.fandom.com › wiki › Wernher von Braun.

Frebault Geneanet (Genealogic Database). Emmy von Quistorp. Available at: https://gw.geneanet.org/.

Frebault Geneanet (Genealogic Database). Wernher von Braun. Available at: https://gw.geneanet.org/.

The German Way & More: Wernher von Braun – Parts1, 2 and 3. Available at: https://german-way.com October 2024.

Hernandez, J. The explosive history of fireworks, from ancient China to Revolutionary America. Available at: https://www.npr.org/2024/07/04/nx-s1-5027826/fireworks-history-ancient-china-revolutionary-america.

Kerrod, R. 1989. The illustrated history of man in space. Mallard Press.

NASA Earth Observatory. Wernher von Braun (1912–1977). Available at: https://earthobservatory.nasa.gov/features/vonBraun/vonbraun_3.php.

Wikipedia. History of archery. Available at: https://en.wikipedia.org/wiki/history_of_archery viewed 20/10/2024.

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