



CSIR FUTURE PRODUCTION: CHEMICALS

Developing innovative biological and chemical conversion technologies
and products to support a vibrant African chemicals and pharmaceuticals industry



science & innovation

Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA



CSIR

Touching lives through innovation



ABOUT THE CSIR

The Council for Scientific and Industrial Research (CSIR) is a leading scientific and technology research organisation that researches and develops transformative technologies to accelerate socioeconomic prosperity in South Africa.

The organisation's work contributes to industrial development and supports a capable state. The CSIR is an entity of the Department of Science and Innovation.

The organisation plays a key role in supporting the public and private sectors through directed research that is aligned with the country's priorities, the organisation's mandate and its science, engineering and technology competences.

The nine high-impact sectors identified by the CSIR to achieve its aims are:

Industry advancement clusters



Advanced Agriculture and Food



NextGen Health



Future Production: Chemicals



Future Production: Mining



Future Production: Manufacturing



Defence and Security

Industry and society enabling clusters



Smart Places



Smart Mobility



NextGen Enterprises and Institutions



ABOUT CSIR FUTURE PRODUCTION: CHEMICALS

CSIR Future Production: Chemicals has capabilities embedded in biomanufacturing, pharmaceuticals, nanostructures and advanced materials. The cluster's approach to scientific research and development is in line with future trends, and its drive for technology localisation and commercialisation is what gives the cluster an edge and technical lead to provide sustainable and competitive solutions in South Africa and the world.

CSIR Future Production: Chemicals is strategically placed for translational research; to take early stage technologies from academia or any institutions/private sector, develop them at pilot scale and provide competitive solutions to industry through licensing options, contract research, contract manufacturing and/or toll manufacturing.

The cluster has capabilities for technical support to small, medium, and micro enterprises (SMMEs) through its Biorefinery Industrial Development Facility, Biomanufacturing Industrial Development Centre, Nano-Micro Device Manufacturing Facility, Supercritical Encapsulation Facility and Nanomaterial Industrial Development Facility. These centres are supported by the Department of Science and Innovation (DSI) to advance South Africa's industry through SMME development and support.

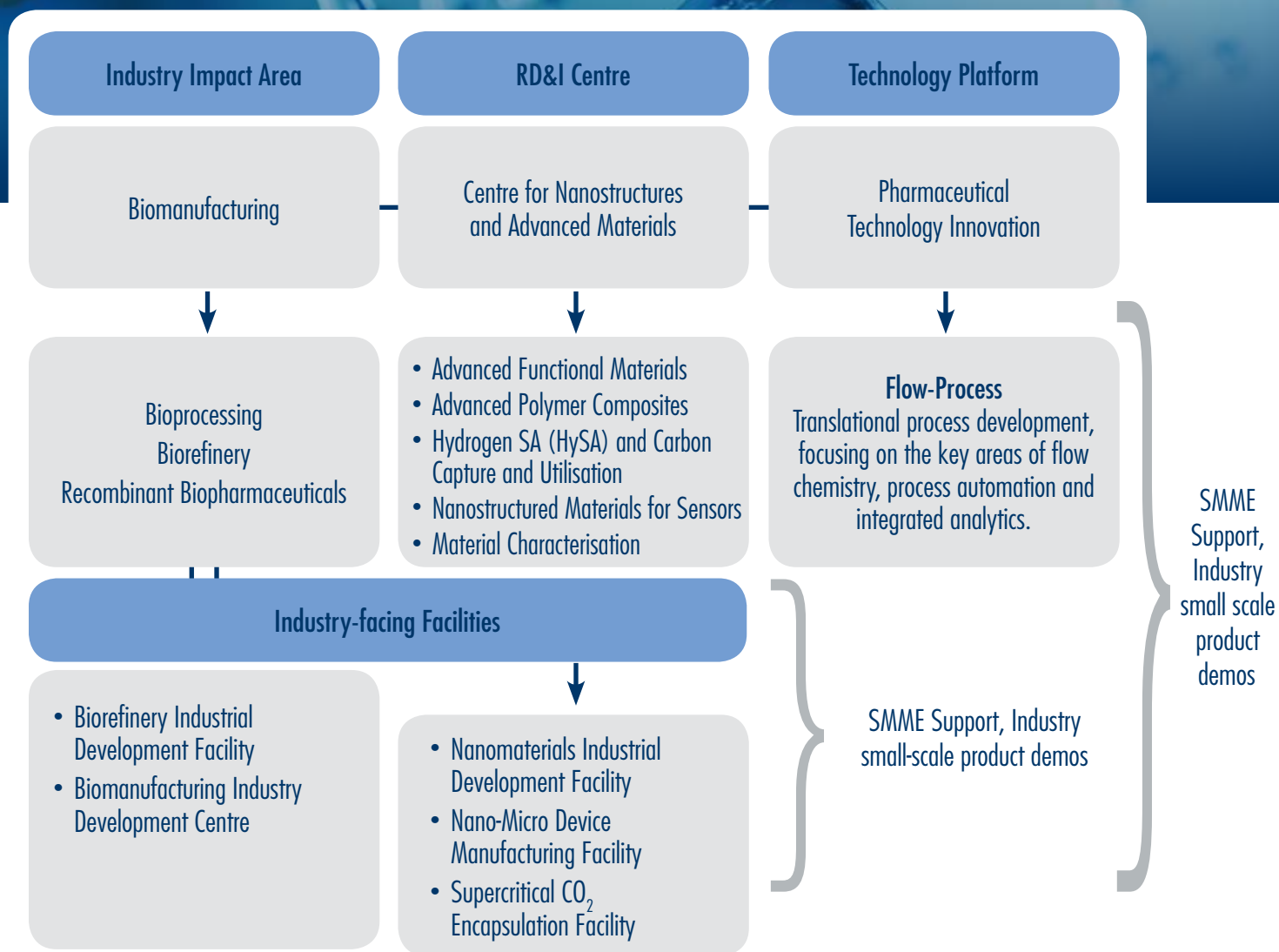


Figure 1: Value offering: CSIR Future Production: Chemicals

An overview of the cluster's research and development (R&D) structure, which is supported by three pillars, namely an industry impact area, R&D centre and technology optimisation platform.



CSIR FUTURE PRODUCTION: CHEMICALS **IMPACT AREAS**



BIOMANUFACTURING TECHNOLOGIES

OFFERINGS

- Localise and validate international technologies – reduces the risk for re-inventing the wheel;
- Collaborate with industry in developing and localising cutting-edge technologies
- Provide industry access to improved and efficient process technology via licensing, contract R&D, toll-manufacturing – de-risks technology before significant capital investment for commercial entities and SMMEs;
- Provide upstream and downstream process development expertise;
- Transfer knowledge and skills in biomanufacturing to SMMEs and industry through technology transfer and training programmes; and
- Support the establishment and commissioning of new bio-based SMMEs.

These offerings are achieved through the work undertaken by two research groups.

➤ THE TECHNOLOGY DEMONSTRATION RESEARCH GROUP

The group develops efficient and cost-effective biomanufacturing-based technologies, processes and products to demonstration phase (in laboratory and relevant environment). The approach is underpinned by sustainable, green technology solutions for the production of efficacious biopharmaceuticals and chemicals.

The research group has expertise in:

- Conventional and plant-based recombinant systems for human health biologics and protein and enzyme reagents.
- Use of enzymes and whole-cell biocatalysis as a green-chemistry approach to manufacturing.

➤ THE BIOPROCESSING TECHNOLOGIES RESEARCH GROUP

This team focuses on the development of disruptive bio-based technologies and products for integration into existing industries or for the establishment of new bio-based small, micro and medium enterprises (SMMEs). Distinctive competencies are found in bioprocess development, optimisation scale-up and scale-down processes using bacteria, yeast, fungi and algae (wild-types and genetically modified organisms).

The research group has expertise in:

- Technology development from proof-of-concept to commercial manufacturing;
- Contract microbial manufacturing capabilities from 30L up to 1 000L scale;
- Product formulations and shelf-life testing;
- External process validation and techno-economic evaluation services;
- Bio-based replacements (agricultural, food and feed industries), bio-materials (bio-surfactants, bio-lubricants); and
- Novel bio-conversions using sustainable feed-stocks for the production of bio-based chemicals.



CSIR FUTURE PRODUCTION: CHEMICALS **IMPACT AREAS**

CENTRE FOR NANOSTRUCTURES AND ADVANCED MATERIALS

OFFERINGS

- Development of innovative advanced materials and their production processes;
- Scale-up and piloting capability in chemical and polymer processing for toll-manufacturing to bridge the R&D industry chasm and for production of market samples; and
- State-of-the art materials characterisation, testing and analytical services.

These offerings are achieved through the work undertaken by four research groups.

► THE ADVANCED FUNCTIONAL MATERIAL RESEARCH GROUP

The group develops local capabilities for the design and development of functional materials, including active particles, biomaterials, nanostructures and functional biopolymers from sustainable raw materials.

The group specialises in:

- Localising biopolymer synthesis;
- Building local expertise in biopolymer modification;
- Building local expertise in technology development for antimicrobial biopolymers – biocidal biopolymers;
- Designing and developing demonstrated technologies for the encapsulation of actives such as: probiotics, nutraceuticals, cosmetics and pharmaceuticals; and
- Designing and developing nanoformulations and drug delivery systems with applications in diseases such as tuberculosis, malaria and diabetes.

► THE ADVANCED POLYMER COMPOSITE RESEARCH GROUP

The CSIR is a leader in the development of high-performance polymer composites and their production processes for downstream beneficiation of conventional polymers and bioplastics.

The group offers:

- Research, development innovation services in bioplastics and bio-composites formulation design (and modification), processing, product development and testing, and characterisation;
- Expertise in material and production process technologies for polymer nanocomposites, including nanoclays and 2D carbon nanomaterials-based composites;
- A world-class polymer characterisation lab, including biodegradation lab;
- Lab-scale polymer processing equipment;
- Technologies in bio-based thermoset, cellulose-based composites, natural fibre composites and nanoclay-based polymer nanocomposites.



> THE HYDROGEN SA (HYSA) AND CARBON CAPTURE AND UTILISATION GROUP

This is a gas-based technology development group, revolutionising the industry through the conversion of carbon dioxide (CO₂) and other gases into fuels and chemicals.

This group provides:

- Expertise in CO₂ gas separation and storage technologies, as well as CO₂ utilisation technologies;
- Expertise in materials development for hydrogen storage;
- Capabilities in the development of CO₂ capture technologies; and
- Dedicated facilities for gas storage research, separation and conversion research – the facilities currently comprise set-ups for gas conversion, materials synthesis, characterisation, powder shaping, testing and small-scale composite cylinder production.



> THE NANOMATERIALS FOR SENSING APPLICATIONS RESEARCH GROUP

The group boasts a proven track record in the design and engineering of novel nano-enabled materials and medical devices for human breath monitoring.

The group offers:

- Capabilities in nano-enabled materials design, engineering, and their fabrication and testing;
- Co-development of gas sensors with local manufacturers for local, regional and global markets;
- Design and development of intermediates with nanoscale features acting as sensing layers for gas sensor, development and demonstration of application in nano-enabled technologies, such as medical devices; and
- Development of electronic device prototypes tailored for gas detection breath analysis, air quality monitoring and food safety applications.



CSIR FUTURE PRODUCTION: CHEMICALS IMPACT AREAS



THE PHARMACEUTICAL TECHNOLOGY INNOVATION PLATFORM

This group supports the local production of critical and modern drugs using automated hybrid processing technologies and incorporates an open facility integrating continuous pharmaceutical manufacturing and biopharmaceutical production for Africa.

The group:

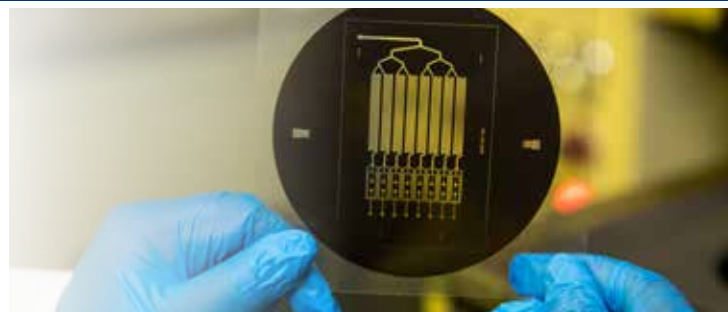
- Improves the performance of the pharmaceutical industry by developing production and processing lines that are more automated, modular and responsive;
- Develops fully scalable automated end-to-end green production processes;
- Supports import replacement through the transformative technology that fosters localisation;
- Uses its capabilities in **small molecule active pharmaceutical ingredient (API) production**, exploiting state-of-the-art chemistry, bio catalysis, emerging green and disruptive continuous flow manufacturing and smart control technologies for production process transformation; and
- Uses its capabilities in **biopharmaceutical production**, applying synthetic biology and industrial biotechnology to develop unique and highly scalable expression systems for production process transformation.

KEY PILOT FACILITIES

> CSIR NANO-MICRO DEVICE MANUFACTURING FACILITY

The objective of this facility is to develop breakthrough technologies that harness micro- and nanofabrication. The focus and capabilities lie in:

- Research, design, development and prototyping;
- Assisting researchers from academia and industry to apply microfluidics, advanced materials and additive manufacturing in developing lab-on-chip point-of-care prototypes – impacting in human and animal health, as well as the environment;
- Strengthening capacity building of the lab-on-chip point-of-care technology platform for veterinary, and human and environmental applications to encourage interdisciplinary collaboration and communication on health at the human-animal-environmental interface, popularly referred to as the One Health approach; and
- Offering clients access to specialised world-class equipment, such as a polydimethylsiloxane soft-lithography manufacturing unit; mask aligner; an automated dispensing system, a sputter deposition system, advanced substrate printer, a clean room facility; chemical laboratories, and equipment for cell culturing/incubation and cell counting.



> CSIR SUPERCRITICAL CO₂ ENCAPSULATION FACILITY

The CSIR hosts Africa's first supercritical CO₂ encapsulation technology with imminent implementation of a pilot facility that will be accessible to industry and SMMEs.

The facility is designed according to SANS 10330: 2020 and SANS 10049: 2019 Guidelines for food safety management, and will have the following functions:

- Encapsulation of actives in an inert and environmentally benign atmosphere – overall improved stability and efficacy of the actives;
- Up to 100kg/product per day production capacity.

Furthermore, the facility:

- Houses a reactor that accommodates a wide range of materials without the risk of cross contamination;
- Allows industry partners access to CSIR scientists for training and skills transfer, as well as technology development and transfer to industry; and
- Provides toll-manufacturing opportunity for industry once the pilot plant is implemented – de-risking the technology before significant capital investment in pilot phase.



KEY PILOT FACILITIES

> MATERIALS CHARACTERISATION, TESTING AND ANALYTICAL FACILITY

This facility is a one-stop shop that provides a wide range of instrumentation for use by the nanotechnology community to characterise their research samples. Researchers from universities and other public institutions, as well as from industry, are welcome to book time on the available instruments.

Some of the facility's instruments include:

Electron Microscope Techniques

- Zeiss Auriga Crossbeam Workstation with Field Emission Scanning Electron Microscope (FESEM) and Focused Ion Beam (FIB) columns
- JEOL JSM-7500F Field Emission Scanning Electron Microscope (FE-SEM) Equipped with Energy Dispersive X-ray spectroscopy (EDX)
- JEOL-JEM 2100 High Resolution Transmission Electron Microscope (HRTEM)

Oxygen and Water Permeation Analysis Techniques

- Mocon Permatran (3/33) – Water Vapour Permeability
- Mocon Oxtran (2/21) – Oxygen Permeability
- Mocon Oxtran (2/22) – Oxygen Permeability

X-Ray Techniques

- PANalytical X'Pert PRO X-ray Diffraction (XRD)
- Jobin Yvon LabRAM HR 800 UV-VIS-NIR- Raman Spectrometer

Optical Techniques

- Perkin Elmer Spectrum 100 FTIR spectrometer - Fourier Transform Infrared Spectroscopy
- Perkin Elmer LS55 Fluorescence (Photoluminescence Spectrometer)
- Perkin Elmer Lambda 750s Ultraviolet (UV)-visible (VIS) Spectrometer

Mechanical Analysis Techniques

- Instron Tensile Tester (5966, K883)
- Ceast Resil Impactor & Ceast Notch-vis
- IDM Instruments Gelbo Flex Tester (G0002) – Resistance of flexible barrier materials to Pin holing.

Thermal Techniques

- TA Instruments DSC (Q2000) – Differential Scanning Calorimeter
- PerkinElmer DSC 8500 Differential Scanning Calorimeter
- Ceast HDT6 Vicat – Heat Distortion Temperature
- Ceast Melt Flow Meter
- Anton Paar Physica Rheometer (MCR 501) and Compact Rheometer (MCR 302) – DRD (Dielectric)
- TGA-FTIR-GC-MS (Hyphenated Technology)
- TGA Q500 and TGA 5500 Thermogravimetric Analysers
- Perkin Elmer DMA 8000 Dynamic Mechanical Analyser



CSIR INDUSTRY INNOVATION SUPPORT PROGRAMMES

The CSIR is helping local industry to improve its competitiveness by providing access to specialised facilities and skills. Funding to support this initiative is sourced from a variety of stakeholders, including the Department of Science and Innovation. Participants have access to large-scale prototyping and pre-commercial manufacturing infrastructure, equipment, expertise, as well as business and technical networks. Research, development and innovation (RD&I) activities range from laboratory-scale validation to technology prototyping and pilot manufacture. The Future Production: Chemicals cluster hosts three industry-facing programmes, namely the Biomanufacturing Industry Development Centre, Biorefinery Industrial Development Facility and the Nanomaterials Industrial Development Facility.

Fire Testing Techniques

- Fire Testing Technology, i series (I – Cone Calorimeter)
- Fire Testing Technologist (UL 94) – Confirmation of test flames for burning test on plastic materials.

Analytical Techniques

- Ion Chromatography (IC)
- Inductively Coupled Plasma Mass Spectrometry
- Malvern Viscotek GPC max (VE 2001) – Gel Permeation Chromatography

Surface Analysis Techniques

- Micromeritics Tristar II BET analyser
- Micromeritics AccuPyc II 1340 Helium pycnometer – Gas Pycnometer

➤ THE CSIR BIOMANUFACTURING INDUSTRY DEVELOPMENT CENTRE

This programme was established to translate biotechnology-based R&D into market-ready products and services for SMMEs.

The BIDC:

- Supports start-up SMMEs with the development of new technologies and products;
- Provides incubated companies with access to ready-to-use biomanufacturing facilities and supporting R&D laboratories;
- Gives access to in-house expertise in bioprocess development, prototyping, pilot manufacturing and scale-up activities; and
- Offers laboratories for molecular biology, applied biochemistry, biocatalysis and fermentation, as well as laboratory and pilot-scale process development for our clients – these facilities are complemented by high-end analytical infrastructure.



CSIR INDUSTRY INNOVATION SUPPORT PROGRAMMES

➤ THE NANOMATERIALS INDUSTRIAL DEVELOPMENT FACILITY

This facility bridges the gap between bench-scale developments and commercially ready products such as polymer composites and chemical processes related to nanotechnology. It offers integrated access to three key R&D components, namely scale-up facilities, well equipped characterisation laboratories and multidisciplinary researchers (comprehensive technical support).

The NIDF:

- Supports SMMEs and large entities with product/process development needs, as well as extensive chemical/materials characterisation using state-of-the-art equipment;
- Offers toll production services for polymer composites, nano-powders and general chemicals; and
- Works with technologies developed locally or internationally that require localisation.

➤ THE BIOREFINERY INDUSTRIAL DEVELOPMENT FACILITY

The facility develops and implements innovative biorefinery technologies for the industry and SMMEs.

The BIDF:

- Has proven capabilities in lignocellulosic waste beneficiation into chemicals, biomaterials and fuels – value-added product diversification to traditional wood, pulp and paper products;
- Establishes proof of concept for new biorefinery feed stocks and products for industry;
- Enjoys strong R&D collaborations with industry, industry associations, universities, research and technology organisations, as well as partnerships with international entities;
- Offers equipment and pilot amenities that enable the testing and implementation of technologies for the benefit of industry;
- Provides technological support that improves the efficiency, sustainability and competitiveness of forest products and biomass industrial processes; and
- Can process other waste biomass into high-value products such as feathers into keratin; shellfish wastes into chitosan, snail shells into calcium carbonate nano materials.

NOTABLE MILESTONES OF THE CSIR INDUSTRY INNOVATION PROGRAMMES

Biomanufacturing Industrial Development Centre

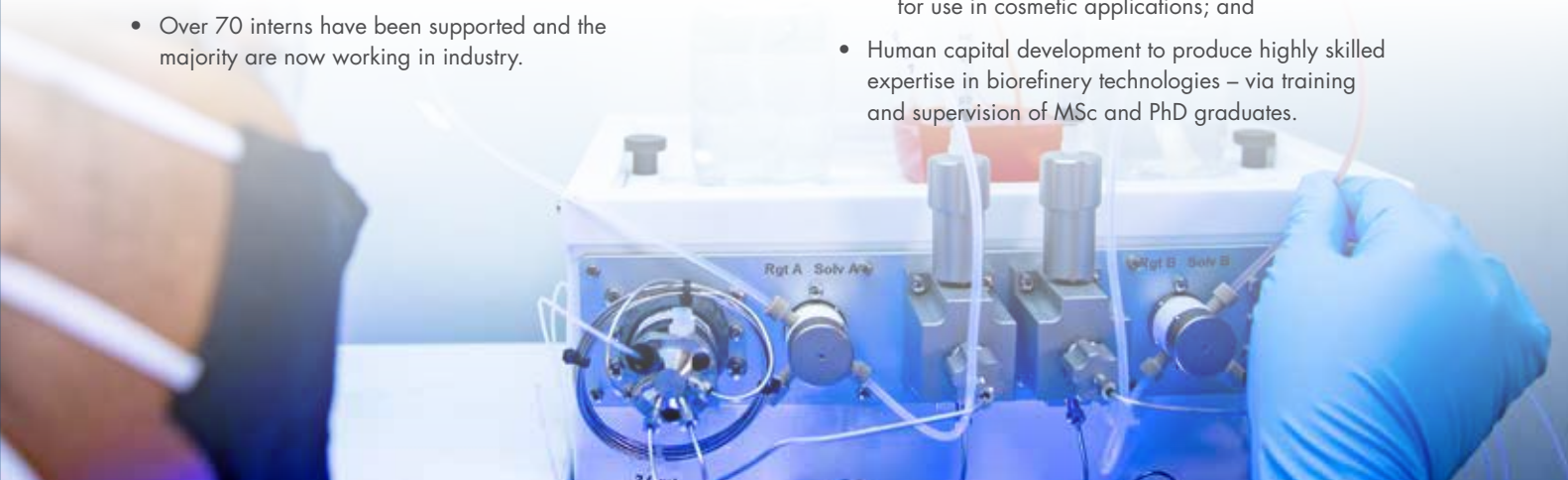
- 37 enterprises contracted and supported since inception;
- 108 products in market evaluation stage, in the market or transferred to SMMEs;
- 183 new permanent jobs recorded;
- More than a 100 interns equipped with vocational skills; and
- 26 licences signed, seven technology demonstrators.

Nanomaterials Industrial Development Facility

- 15 entities have been supported, both SMMEs and established companies;
- Four products have been licensed;
- 15 technology demonstrators at technology readiness level 6 and above have been developed; and
- Over 70 interns have been supported and the majority are now working in industry.

Biorefinery Industrial Development Facility

- Demonstrated that fractionation of chemical pulps to remove fines has the potential to save R20 million per annum;
- Developed a low-cost technology for extracting a high-value material, cellulose nanocrystals, from sawdust waste at high yield (>40%);
- Demonstrated production of high-quality starch from waste avocado and mango seeds;
- Is working with 15 SMMEs to implement biorefinery technologies and initiatives, such as:
 - beneficiation of waste biomass into wood vinegar and biochar;
 - development of special economic zones for processing biomass;
 - extraction of keratin from waste chicken feathers for use in cosmetic applications; and
- Human capital development to produce highly skilled expertise in biorefinery technologies – via training and supervision of MSc and PhD graduates.



KEY SUCCESSES OF OUR RD&I

"One of our key highlights has been the **recycling of lithium-ion batteries** and multi-layered 'Tetra Pak' packaging materials and valorisation of the coal-combustion by-products, coal fly ash, to produce high-value porous materials, such as zeolites and metal-organic frameworks and applying them for gas storage and separation of gases.

We have also collaboratively **tested their use in designing new battery cells and supercapacitors.**"

– **Dr Nicholas Musyoka**, *CSIR research group leader, The HySA and Carbon Capture and Utilisation Group.*

In 2019, the **CSIR developed a test kit that could be locally manufactured and distributed** as a cost-competitive import replacement strategy for South African small, medium and micro enterprise, Professional Laboratory Services. The chemical oxygen demand detection kits are **compatible for use across all makes of photometers** in the market and grant users the freedom to use alternative kits, irrespective of the brand of photometer purchased, **and at a lower cost.**"

– **Dr Santosh Ramchuran**, *CSIR research group leader for bioprocessing development*

"We licensed and commercialised a probiotic encapsulation **technology for human health** and the DSI recently awarded high-end infrastructure funding for a pilot-scale supercritical CO₂ encapsulation facility to be established at the CSIR."

– **Dr Philip Labuschagne**, *CSIR principal researcher*

"The team has **successfully transferred** more than six enzyme reagent technologies to industry to **effect real-world impact**. We recently licensed four technologies to a spin-out company, CapeBio Technologies. The SMME employs 13 staff members and **plays a leading role in the local response to Covid-19** by developing reagent enzyme kits for diagnosing the disease."

– **Dr Tsepo Tsekoa**, *CSIR research group leader for biomanufacturing technology*

"We have recently developed a composite material for steel pipe coating for an industrial partner. Nine tons of this material have since been produced in an industrial facility and **the coating trials successfully carried out at the industry partner's fluidised bed facility**. The client has since started local production of the material at a third-party premise."

– **Dr Vincent Ojijo**, *CSIR research group leader for advanced polymers and composites*

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