CSIR ANNUAL REPORT 2015/16

OUR FUTURE THROUGH SCIENCE

CSIR

our future through science

OUR MANDATE

The Council for Scientific and Industrial Research (CSIR) was established on 5 October 1945. The CSIR's mandate is as stipulated in the Scientific Research Council Act, 1988 (Act 46 of 1988, as amended by Act 71 of 1990), section 3: Objects of CSIR:

"The objects of the CSIR are, through directed and particularly multidisciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act."

The CSIR's Executive Authority is the Minister of the Department of Science and Technology.

science
& technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

CONTENTS

Foreword

by the Minister of Science and Technology

The most demanding target that our country has to meet is the one identified in Vision 2030 of our National Development Plan, which shows that we need to create 11 million jobs in the next 15 years. Science and technology has a critical role to play in ensuring that we meet this and the other goals of Vision 2030. There are two particular areas in which we need to concentrate our efforts – increasing the overall level of investment in science, technology and innovation, as well as improving the productivity and returns that we derive from that investment. In both of these areas, entities like the CSIR can and must play a critical role.

Analysis of our investment in science, technology and innovation suggests that this has been inadequate over the past decade. This not only means an under-investment in the maintenance of our research infrastructure, but also the possible loss of opportunities that may have attracted and retained our scientists, developed new products and made real contributions to growth. While government must play its part, there is also a real need to increase the level of private sector investment in research and development, and the CSIR must continue to make a concerted effort to align its capabilities to attract and collaborate with the private sector. This annual report already contains some examples of how this can be done, such as the Biomanufacturing Industry Development Centre. I look forward to the expansion of this initiative and of other sectors such as photonics, additive manufacturing and nano-manufacturing.

There are never any guarantees in science and we have to accept that many of the ideas and interventions we attempt may not produce tangible benefits. However, one way to improve the chances of our work paying off is to ensure that we use the full power of our National System of Innovation – to minimise the duplication of work and to identify areas in which the weight of our collaborative efforts will exceed the sum of isolated work. The CSIR is mandated to play a special role in this system. The mandate of the CSIR and its range of capabilities ensure that it is ideally placed to play a significant role as the glue that brings our system together.

In meeting our own challenges it is also imperative for us to continue to look beyond our borders. Science is central to sustainable development in Africa and to devising responses to the challenges that we endure over time, that benefit and grow our communities. Although African investment in science research is growing, this is from a very low base. Sub-Saharan Africa contributes about 2.3% of world gross domestic product, but is responsible for only 0.4% of global expenditure in research and development. With 12% of the world's population, it is home to only 1.1% of the world's scientific researchers. In this annual report, there are many pleasing examples of the collaboration of the CSIR with continental partners. These collaborations must now be guided by a solid strategy for engaging with our neighbours, a strategy that identifies the complex challenges we face as a continent and matches these to the opportunities available to us to meet these challenges.

While the CSIR can again be proud of its excellent performance in the past financial year, and for producing value through its scientific work, the challenges that we confront do not allow for any complacency. My congratulations to the Board, leadership and staff of the CSIR, and I hope we will continue to work together to demonstrate the many benefits that are derived from investing in science and technology.

Mrs Naledi Pandor
Minister of Science and Technology

Chairman's overview

The Board is tremendously pleased with the performance and results achieved by the CSIR during the 2015/16 financial year, a performance that is just reward for the effort, commitment and intellect of the staff and leadership of the CSIR. As a Board, we can take very little credit for these successes, particularly since we have only taken up our current positions in early 2015. However, we have used this period to familiarise ourselves with the context within which the CSIR works and the many ways in which it responds to that context and I am confident that we are now well-placed to make a critical contribution to increasing the impact of the organisation.

The CSIR is unlikely, by the force of its size and breadth of its mandate, to be judged only by a single outcome. At a national level, we are guided by the National Development Plan and its focus on the triple challenges of poverty, inequality and unemployment, and I believe that even a brief perusal of the R&D highlights in this annual report will make it clear that we take that guidance very seriously. However, I do believe that in the short-term, the CSIR will largely be judged on its contribution to economic development, and more particularly, on its efforts to grow and transform the economy. If jobs are not created, South Africa runs not only the risk of short-term disruption and instability, but long-term decline as our most skilled people seek their fortunes elsewhere. There are many calls on the CSIR's expertise, many areas where we can use science and technology to make a difference, but few of these will have the immediacy and the urgency of our work to improve economic efficiency and grow our economy.

There is much that we can, and in some cases, must do on our own. However, there is much more that we can and must do with our partners, and in particular, those in the private sector. These private sector linkages need not only be at the level of contracts or bespoke R&D services, although these are certainly important, but need to extend to the conceptualisation of new areas of research and the identification of areas where other forms of collaboration are possible. There are already promising signs of these types of initiatives within the CSIR and we need to build on and extend these to other areas.

Collaboration with the other elements in the National System of Innovation is also of critical importance. Given the constraints on resources, financial and human, within our system, we can ill afford needless competition and the dissipation of our research efforts. However, perhaps as a consequence of these limited resources, the various entities tend to see each other as competitors, in the mistaken belief that individual success will outweigh systemic failure. The CSIR needs to act decisively to counter-act this trend and begin to forge relationships that use the best of its systemic abilities in the national interest.

I wish to thank the staff and leadership of the CSIR for their hard work and for the excellent performance that has resulted from that effort, as well as the Department of Science and Technology for its guidance and oversight. The Board is looking forward to working with all our stakeholders in taking the CSIR to ever-greater achievements.

Prof. T Majozi
CSIR Board Chairperson

CEO's introduction

There are recurring themes in the life of any organisation and after 15 years at the helm of the CSIR, I have become acquainted with some of the rhythms that affect this particular entity. We are asked to deliver value and also to demonstrate this value; to tackle the problems that are of immediate concern and also to prepare the ground for resolving those that threaten our future; all of this while focusing our energies and stretching our mandate to its very limit. We expect nothing less from our partners and stakeholders, and most importantly, we expect the very same from ourselves. The world of technology and innovation is not at a stage where we can rest easily on the laurels of our past achievements, but even if this were not the case, the scale of the developmental challenges we face in South Africa would not permit that luxury.

During the past year, the CSIR celebrated its 70th anniversary. The organisation has come a long way from its origins in the aftermath of the Second World War – our colleagues from those early years would be amazed, not only by the technological developments and the new areas of scientific endeavour we have established, but also by our demographic transformation. However, I am sure they would recognise that what binds us together as scientists is the very human drive to explore, understand and transform the world in which we live. Thirty years from now, our successors will no doubt marvel at the primitive state of the technologies we use now, as well as the many areas of scientific endeavour we are blithely unaware of. However, I believe that they will not only see us as kindred scientific spirits, but will also recognise and value our dedication as active members of a society that sets out to use science and technology for the common good.

We have achieved almost all of our performance targets for the financial year. While this is no small achievement, these results do not reflect the breadth and value of our scientific work. In this report you will find many examples of that work and the immediate difference that the CSIR is making.

I am particularly proud of our work in the area of economic development where we are beginning to see the fruits of many years of investment and effort. For example, the outstanding work of the Biomanufacturing Industry Development Centre, innovations in laser technologies, nano-manufacturing and health technologies are all already contributing to economic development and hold the promise of delivering much more.

However, there is more to the work of the CSIR than I can reasonably summarise here or that can reasonably be covered in an annual report. I urge you to read through the details that are provided, and if that piques your interest in the critical role played by science and technology please do visit our website (www.csir.co.za) and find out more about our work.

Of course all of these achievements are only possible through the hard work of our scientists and those who ensure that there is a sustainable and well-governed environment conducive to learning and innovation, including our Board of Directors, as well as our host department, the Department of Science and Technology.

I am now more confident than ever of the great future that awaits the CSIR – a future in which our intellectual capabilities will prove more than a match for the developmental challenges faced by our nation, a future where scientific endeavour and achievement is valued as highly as cultural and sporting achievements; a future through science.

Dr S Sibisi
CSIR CEO

ISIZULU

Isingeniso seSikhulu esiPhezulu

Kunezingqikithi eziphindaphindekayo empilweni yanoma yiyiphi inhlangano kanti emva kweminyaka eyi-15 ngibambe amatomu kwaCSIR sengize ngakwejwayela okwenzeka kule nhlangano. Simelwe ukubonisa ukubaluleka kwale nhlangano nokukhombisa ukubhekana nezinkinga ezikhona nokucaba indlela ukuxazulula lezo ezibeka ikusasa lethu engcupheni, ikakhulu ekugxileni emsebenzini wethu. Yilokhu kanye esikulindele kwesisebenzisana nabo nabalingani bethu, kanti ikakhulu kithi uqobo. Umkhakha wezobuchwepheshe nokusungula izinto ezintsha awukho esigabeni lapho singazithela ngabandayo khona ngalokho esesikuzuzile kodwa noma ngabe kunjalo, izinselelo zentuthuko esibhekene nazo azisivumeli ukuthi senze njalo.

Ngonyaka odlule iCSIR igubhe iminyaka engama-70 yasungulwa. Lide ibanga eselihanjwe yile nhlangano kusukela yasungulwa ngemva kweMpi Yomhlaba yeSibili, kangangokuthi abalingani bethu kusukela ngaleyo minyaka bangamangala, hhayi kuphela ngezokuthuthukisa ubuchwepheshe bezesayensi namagalelo ethu kepha futhi nangoshintsho ngokwesimo sezisebenzi zethu. Ngiyakholwa wukuthi bangabona ukuthi okusenza sifane njengososayensi yintshisekelo yethu yokucwaninga, ukuqonda nokuletha ushintsho emhlabeni esiphila kuwo. Eminyakeni engamashumi amathathu kusukela manje, abeza ngemva kwethu bayomangala ngesimo sobudala bobuchwepheshe bezesayensi esibusebenzisa manje nangezinto eziningi esingazazi.

Nokho, ngiyakholwa wukuthi ngeke basibone kuphela njengabafowabo kwezesayensi kodwa futhi bayobona bese bazisa ukuzinikela kwethu njengamalungu akhuthele omphakathi wezesayensi nobuchwepheshe ewusizo kuwonkewonke.

Sihlangabezane cishe nayo yonke imigomo ebesihlalele kulo nyaka wezimali. Nakuba lokhu kungeyona into encane, le miphumela ayikhombisi ukujula komsebenzi wethu kwezesayensi kuphela kodwa kulo mbiko nizobona izinto eziningi zomsebenzi nomehluko okwenziwa yi-CSIR. Ngiyaziqhenya kakhulu ngomsebenzi wethu endimeni yezokuthuthukiswa komnotho lapho esesiqala khona sibona izithelo zeminyaka eminingi yesithelo somsebenzi wethu. Isibonelo nje, umsebenzi ovelele wesiKhungo sokuThuthukisa iMboni yoMkhiqizo weMvelo, phecelezi i-Biomanufacturing Industry Development Centre, imikhiqizo emisha yobuchwepheshe bemibani, bamakhemikhali nobezempilo konke osekuvele kuneqhaza ekuthuthukiseni umnotho nokwenza izinto ezinkulu. Nokho kuningi okuwumsebenzi we-CSIR ngaphezu kwalokhu engingakwazi ukukufingqa lapha noma okuqukethwe kulo mbiko wonyaka. Ngiyanxusa ukuthi nifunde imininingwane equkethwe kuthi uma nithatheka wumsebenzi omqoka wesayensi nobuchwepheshe nivakashele i-website ethi (www.csir.co.za) ukuthola eminye imininingwane ngomsebenzi wethu.

Empeleni yonke le mpumelelo ingenxa yomsebenzi wokuzikhandla kososayensi bethu nalabo abaqinisekisa ukuthi kunendawo efanele yokusebenza evumelana nokufunda nokusungula izinto ezintsha, okubalwa kuyo iBhodi yaBaqondisi nomnyango osengamele, umNyango wezeSayensi nezobuChwepheshe.

Ngineqholo elikhulu ngekusasa le-CSIR – ikusasa lapho amakhono okukhalipha kwethu ezohambisana nezinselelo zentuthuko ezibhekene nesizwe, ikusasa lapho umsebenzi nempumelelo kwezesayensi kwaziswa kakhulu njengempumelelo kwezobuciko nezemidlalo; ikusasa ngezesayensi.

Dkt S Sibisi
ISikhulu esiPhezulu kwaCSIR

Matseno a Mohlankedimogolophethiši Ketapelekakanywa

Go na le direrwa tše di ipoeletšago tša mokgatlo wo mongwe le wo mongwe gomme ka morago ga mengwaga ye 15 ka taolo ya CSIR, ke lemogile merethetho ye mengwe yeo e amago lekala le le itšego. Re kgopetšwe go tšweletša mohola le go laetša mohola woo, go šogana le mathata ao go ngongeregwago ka wona ka bjako le go lokišetša thekgo ya go šogana le ao a tšhošetšago bokamoso bja rena, le go nepiša maatla a rena le go katološa taolelo ya rena magomong a mafelelo. Re letetše tše dikgolo go tšwa go badirišani ba rena le batšeakarolo, gomme se bohlokwa kudu, re letetše sa go swana le se go tšwa go rena. Lefase la theknolotši le tšweletšopele ga le legatong leo re ka khutšago bonolo mo go dikatlego tša diphihlelelo tša rena tša go feta, eupša le ge go se bjalo ka se, kelo ya ditlhotlo tša tšweletšopele yeo re lebanego le yona mo Afrika Borwa e ka se dumelele matsaka ao.

Mo ngwageng wa go feta, CSIR e ketikile matswalo a yona a bo 70. Mokgatlo o tšwa kgole go tloga mathomong a wona ka ditlamorago tša Ntwa ya Bobedi ya Lefase – badirišani ba rena go tšwa mengwageng yeo ya pele ba tla makala, e sego fela ka ditšweletšopele tša theknolotši le dikarolo tše mpša tša mešomo ya thuthamahlale ye re e thomilego, eupša le phetogo ya rena ya temokrafi. Le ge go le bjalo, ke na le nnete ya gore ba tla lemoga gore seo se re tlemagantšhago mmogo bjalo ka boramahlale ke kgapeletšo ye kgolo ya motho go utulla, go kwešiša le go fetoša lefase leo re phelago go lona. Mengwaga ye masometharo go tloga gonabjale, bahlatlami ba rena go se nale kgonono ba tla makatšwa ke maemo a theknolotši ao re a šomišago gonabjale, gammogo le dikarolo tše dintši tša mešomo ya saense yeo ka go hloka šedi re sa e lemogego. Le ge go le bjalo, ke kgolwa gore ba ka se re bone fela bjalo ka maikutlo a saense a go amana, eupša ba tla lemoga le go bona bohlokwa bja boikgafo bja rena bjalo ka maloko a mafolofolo a setšhaba ao a beakanyago go šomiša saense le theknolotši ye e holago batho ka moka.

Re fihleletše go batamela ka moka dilebanywa tša rena tša phethagatšo mo ngwageng wa ditšhelete.

Le ge se e se phihlelelo ye nnyane, dipoelo tše ga di tšweletše bogolo le mohola wa mošomo wa saense go rena. Mo pegong ye o tla hwetša mehlala ye mentši ya mošomo woo le phapano ya bjako yeo CSIR e e dirago. Ke ikgantšha kudu ka mošomo wa rena mo karolong ya tšweletšopele ya ekonomi moo re thomago go bona dikenywa tša mengwaga ye mentši ya peeletšo le maitapišo. Mohlala, mošomo wo o šaletšego morago wa Biomanufacturing Industry Development Centre (Senthara ya Tšweletšopele ya Intasteri ya Tšweletšo ya Payo), dikaonafatšo ka ditheknolotši tša leisa, tšweletšo ya nano le ditheknolotši tša maphelo ka moka di šetše di tšea karolo tšweletšopeleng ya ekonomi gomme e swere tshepišo ya go tliša tše dintši. Le ge go le bjalo, go sa na le tše dintši go mošomo wa CSIR tšeo nka di akaretšago ka go kwagala mo goba tšeo di ka akaretšwago ka go kwagala ka pegong ya ngwaga le ngwaga. Ke le hlohleletša go bala tshedimošo ye e filwego, gomme ge seo se goka kgahlego ya lema ka tema ye bohlokwa yeo e kgathilwego ke saense le theknolotši, o kgopelwa, go etela wepsaete ya rena (www.csir.co.za) gomme o hwetše tše dintši ka mošomo wa rena.

Ke nnete gore diphihlelelo tše ka moka di kgonagala fela ka go šoma ka maatla ga borasaense ba rena le bao ba kgonthišago gore go na le tikologo ye e swarelelago gape ye e laolwago gabotse ye e loketšego go ithuta le go kaonafatša, go akaretša le Balaodibagolo ba Boto, gammogo le kgoro ya monggae ya rena, Kgoro ya Saense le Theknolotši.

Bjale ke na le boitshepo go feta pele gore CSIR e emetšwe ke bokamoso bja go phadima – bokamoso bjo mabokgoni a monagano a tla bontšhago go feta go nyalana ga ditlhohlo tša tšweletšopele tšeo naga ya rena e lebanego le tšona, bokamoso bjoo mošomo wa saense le phihlelelo o tšewago goba wa mohola wa godimo wa setšo le diphihlelelo tša dipapadi; bokamoso ka saense.

Ngaka S Sibisi
Mohlankedimogolophethiši wa CSIR

PROJECT HIGHLIGHTS

Research, development and implementation

The CSIR is mandated to contribute to the improved quality of life of people in South Africa.

Meeting this mandate requires that the organisation responds to unemployment, inequality and poverty in South Africa. National government addresses these challenges through a broad range of programmes, guided by the National Development Plan (NDP) and further articulated through Government's Programme of Action. The CSIR heeds and responds to these national priorities, in line with its mandate.

The CSIR's research and development programme speaks to seven of the 11 focus areas outlined in the NDP. This section features a selection of the work undertaken in these areas.




A technician observes the laser refurbishment of a generator rotor. Restoring metallic surfaces of components using laser cladding technology has the potential for significant maintenance cost savings for industry.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

The CSIR supports national re-industrialisation initiatives by directing its multidisciplinary skills at the beneficiation of key strategic minerals and the strengthening of sectors such as aerospace and defence. The organisation contributes by improving production processes, supporting local economic development, developing automation solutions for industrial processes, as well as developing and implementing new technologies in nano-manufacturing and agro-processing. Longer-term interventions include the development of large-scale engineering capabilities, industries based on bio-therapeutic manufacture and enterprises using digital media technologies.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

In brief

The Biomanufacturing Industry Development Centre (BIDC) supports small, medium and micro enterprises (SMMEs) involved in biomanufacturing. The centre's early successes are reflected in the achievements of the enterprises it assists and include new products, increased employment and financial growth.

CSIR researcher Ghaneshree Moodley in the BIDC fermentation laboratory, where microbial fermentation processes involving yeast, fungi and bacteria are developed and optimised.

Developing South Africa's biomanufacturing industry through a hub for open innovation

Challenge: Developing South Africa's biomanufacturing industry

Science and technology has a key role to play in developing industries that support economic growth and address unemployment, inequality and poverty.

The development of a South African biomanufacturing sector is contained in several national strategies. In 2013, Cabinet adopted the National Bioeconomy Strategy tabled by the Department of Science and Technology (DST). The vision for South Africa's bioeconomy is to be a significant contributor to the gross domestic product of the South African economy by 2030 through the creation and growth of novel industries that generate and develop bio-based services, products and innovations, with a corresponding increase in new and existing companies that provide and utilise these solutions.

Despite excellent biosciences research and development (R&D) in South Africa, the conversion of outputs into commercialised products and technologies has been extremely limited. In response to this challenge, the CSIR established the BIDC, funded through the DST-led Industrial Innovation Partnership Programme and the Jobs Fund.

Research and development: Supporting SMMEs in the biomanufacturing sector

The BIDC is a hub for innovation in the biomanufacturing sector. It provides the skills and infrastructure to translate R&D into market-ready products and services.

The support for SMMEs is provided through bio-based product development; formulation, labelling and packaging; scale-up; process optimisation; regulatory support; training in manufacturing skills and commercial manufacturing services; and technical incubation. Companies that are supported by the BIDC have access to biomanufacturing infrastructure and have access to scientists, technologists and process engineers.

The companies remain the sole owners of their innovations and retain absolute control over their future regarding value-add and partnerships. The BIDC helps to lower the cost and barriers that inhibit innovative enterprises from translating their inventions into market-ready products.

Job creation, market penetration and enterprise creation

The BIDC implemented support programmes for SMMEs in parallel to the establishment of the infrastructure required within the facility. This allowed the centre to rapidly establish a track record and demonstrate impact. By March 2016, the BIDC had supported 19 enterprises, of which 16 are owned by black entrepreneurs, including 10 black women-owned enterprises.

To date, 42 products with applications in the cosmetics, nutrition, water and sanitation, and biotechnology industries have been developed and transferred to the enterprises. The programme has resulted in 105 new permanent jobs, the majority of which are within the enterprises and their value chains, while an additional 165 temporary jobs have been created. At least 54 interns have received training in the BIDC vocational learning programme to provide the biomanufacturing sector with a skilled workforce.

One of the BIDC-supported enterprises, Elvema Nutritions, distributes its products through several large retail chains, as well as to 10 countries in southern Africa: Botswana, Nigeria, Democratic Republic of Congo, Lesotho, Zimbabwe, Swaziland, Uganda, Malawi, Zambia and Angola. As a result of the support, 500 tons of instant porridge have been exported to southern Africa. Some 250 tons have been sold locally and 300 tons of tea have been produced. The enterprise has also set-up a production facility to undertake its own production and employs 31 employees.

The BIDC has been instrumental in assisting JVS Biotech in providing the infrastructure and technical expertise to develop high-value recombinant proteins used as a raw material for a number of biopharmaceutical products. The protein is being developed locally, but JVS Biotech had to license genetic material and production technology from a UK-based company. The BIDC supported the enterprise to validate the technology and ensure that it is techno-economically feasible to manufacture locally. The company has moved into the first phase of commercial manufacturing.

The programme also inspired one of its interns to establish an enterprise. In 2014, Siyabonga Xaba joined the BIDC as an intern. He received hands-on training in technology and product development activities, as well as being mentored by BIDC staff. In May 2015, he established his own company, GX Insight. The company provides environmentally friendly water and sanitation products to commercial outlets, retail stores, restaurants and filling stations.

Women in science: The CSIR's Londiwe Khumalo, Jane Raphela and Ntombifuthi Shezi with the Minister of Science and Technology, Mrs Naledi Pandor, second from left.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

In brief

Laser cladding technology has the potential to extend the lifetime of high-value components, saving South African industry significant maintenance or replacement costs. The CSIR supports local industries by servicing these components using sophisticated laser technologies and has signed two international licensing agreements with companies in the United States of America and India.

Laser cladding technology is used to build up worn areas on industrial components.

Laser cladding technology benefits local and international industry

Challenge: The cost of damaged components to industry

The refurbishment of high-value industrial components is of special interest to South Africa, as a significant proportion of our infrastructure is ageing. The cost of importing replacement components has become a real concern in the wake of a weakening exchange rate and the loss of production caused by long turn-around times when new components need to be sourced.

It is estimated that around 70% of metal components that are scrapped only have surface damage while the rest of the component is still fit for service. Any technique that is capable of restoring these metallic surfaces to their original specification has the potential to yield large savings in maintenance costs to industry.

Research and development: Laser welding as a refurbishment technology

CSIR laser welding experts have developed laser cladding technologies to refurbish worn components. Laser cladding is a form of additive manufacturing and entails using a high-power industrial laser to generate a small puddle of molten metal on the surface of a metal component. An inert carrier gas is used to accurately inject fine metallic powder through a specially designed nozzle into the weld pool where the metal powder is also melted by the laser beam. When the laser beam and powder nozzle traverse the surface, the previously molten powder resolidifies on the surface while new powder is melted. The process results in a continuous track of solid metal that is fused to the surface of the component. By depositing parallel tracks with an appropriate overlap, a continuous surface layer of solid metal that is metallurgically bonded to the original surface is produced. Multiple layers can be deposited to build up worn areas. The technology can also be used to 'print' new components or add complex features to components that were produced using more conventional manufacturing processes.

Local success leads to second international agreement

In early 2016, the CSIR signed a second international agreement, this time with a company in India, Sai Surface Coating Technologies, for the roll-out of laser cladding technology used to refurbish casting rolls for the steel industry. The first was an agreement with FW Gartner Thermal Spraying, a business unit of Curtiss Wright Surface Technologies in the United States of America.

The technology that was licensed includes the laser processing parameters, details about a special alloy developed for this application and assistance to set up the technology so that the companies can service steel producers in the countries where the technology was acquired through licensing.

The agreements follow the earlier development of this technology for the cladding of steel processing rolls at ArcelorMittal in South Africa. Laser cladding can extend the lifetime of these components by at least 200%.

The CSIR continues to refurbish rollers for ArcelorMittal and is expanding its research work to apply the technique to other rollers in the steel casting machines. These include the larger bender rollers, which are exposed to a different operating environment needing a different approach to laser cladding.

Supporting Eskom

Over the past year, the CSIR, in partnership with Eskom, has made significant strides in the refurbishment of high-value steam turbine components, including turbine rotor shafts and turbine blades.

Previously, turbine rotors were repaired by the original equipment manufacturers. This was expensive and time-consuming as it implied shipping large, heavy components to Europe. A local repair capability will save costs and time and in the event of unscheduled maintenance, it would significantly reduce the downtime of the power station.

The CSIR developed a laser cladding process for the refurbishment of steam turbine rotor journals. Until now, damaged turbine blades were scrapped in spite of their high value because no repair process was available for these components, which are critical to safety. Sometimes even brand new blades had to be scrapped. This is an inevitable consequence of the way in which certain types of blades are mounted on the rotor. In this case, the tips of the blades are connected by a circular band, known as a shroud. The shroud is fastened to the blade tips by means of protrusions, called tenons, on the end of the tips that fit through holes in the shroud. After the shroud has been fitted over the tenons, the ends of the tenons are peened to keep the shroud in place in a manner similar to a rivet. If any one of the blades that are connected by the shroud has to be removed, for whatever reason, the entire shroud has to be replaced. This implies that all the tenons on all the blades have to be machined off after which none of these blades can be reused, regardless of its condition.

The CSIR and Eskom developed a laser additive manufacturing process to reconstruct the tenons. Near net-shaped tenons are produced on the blade tip after which they are machined to final dimensions. The success of this development was made possible by the ability of the process to deliver the material integrity that is essential for this application.

The CSIR and Eskom developed a laser additive manufacturing process to reconstruct the tenons on damaged steam turbine blades.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

In brief

The use of nanotechnology as an enabling technology that provides industries with materials with improved properties has grown significantly. A facility where research organisations and private sector enterprises can produce and test nanomaterials on an industrial scale was established at the CSIR in 2015. The facility is funded by the Department of Science and Technology (DST) and seeks to support industry competitiveness as part of the Industrial Innovation Partnership Fund.

Inside the nanomaterial industrial development facility: This film blower is capable of creating plastic films with up to five layers of different polymers.

Producing nanomaterials on an industrial scale to make SA industry more competitive

The challenge: Optimising the potential of nanomaterials to support a competitive industry

Nanotechnology has the potential to revolutionise advanced manufacturing industries where lighter, smarter, more efficient and greener materials are needed, for example, for products in the packaging, automotive and personal care markets.

Research and development: Developing and scaling up the production of new nanomaterials

South Africa set out its intention to use nanotechnology to address challenges in energy, health and water provision, while increasing the country's competitiveness in manufacturing, in its 2005 national nanotechnology strategy. In 2007, the DST launched two innovation centres in nanotechnology, one at the CSIR to focus on nanomaterials and the other at Mintek, to focus on water nanotechnology and sensors.

Nano-scale modification

Over the past 10 years, the DST-CSIR National Centre for Nanostructured Materials has undertaken research into the development of nanocomposites that can be used in the plastics, cosmetics and paint industries. For example, researchers have modified nanoclay minerals by attaching various chemicals to their surfaces, which helps to integrate them with polymers and other substrates. Nanoclay minerals are tiny particles just one nanometer wide and 150 nanometers long and they improve the properties of plastics and cosmetic products.

Bridging the gap between laboratory bench and industry

To close the gap between raw nanomaterials produced at laboratory-scale and a commercial product produced at industrial scale, a nanomaterial industrial development facility was constructed. It features a comprehensive set of equipment

and facilities to develop, test and produce enough of a given nanomaterial to be commercially useful. Typically, it involves taking processes that produce 200 g samples in the laboratory and scaling these up to more than 200 kg quantities. One of the industries set to benefit from these resources is the plastics industry.

The plastics industry

The addition of nanomaterials in plastics can significantly enhance their properties, such as increasing strength, dimensional stability and increasing fire and ultraviolet resistance. Addressing the technological development of the plastics industry will enable it to keep up with international trends, at the materials level and in understanding their production processes.

Due to the high cost of importing nanomaterials and the absence of a local manufacturing capability, the plastics industry cannot easily adopt advanced polymers such as nanocomposites on a large scale. If these challenges are not addressed, imports will continue, leading to high-cost products, which will be to the detriment of local manufacturers.

Nanoclays are ideal for use as a nanocomposite in plastics. If these tiny particles are chemically modified and well dispersed in a plastic, they can vastly improve its properties. For instance, nanoclay can improve the oxygen barrier of a plastic used in food and beverage packaging, therefore allowing the use of three-layer films rather than the current seven layers, while also increasing recyclability.

Nanoclay inclusion in plastics can also contribute to stronger plastics that are more stable at high temperatures. The CSIR is attempting to develop such a nanocomposite at industrial scale for agricultural use by partner company, DelaPlast, a manufacturer of irrigation equipment, seed trays and warehouse equipment such as part bins.

Outputs: New skills and new products

Highlights since the establishment of the nanomaterial industrial development facility include the development and installation of a high-pressure reactor system for nanostructure manufacture with industrial partners, Greenfields, a manufacturer of artificial turf, and Amka Products, a manufacturer of health, beauty and homecare products. It has also scaled up new products and techniques that are currently being evaluated by other companies. Three synthetic clays, four cosmetic products, an organically modified South African nanoclay and a number of polyolefin-based nanocomposites have been produced.

The facility plays a crucial role in developing nanotechnology-related skills and transferring such skills to industry. It provides a platform to train interns, graduates and postgraduate students. These individuals are being equipped with practical skills that assist their entry into the chemical industry.

The twin-screw extruder is a crucial instrument in the production of polymer nanocomposites.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

In brief

CSIR-developed technologies that allow for the streaming of mobile videos without buffering and the broadcasting of scheduled content in low- and high-bandwidth environments have progressed to a commercial pilot phase. The technology makes it possible for entrepreneurs to operate their own Internet-based television stations over mobile networks. Five small, medium and micro enterprises (SMMEs) have been given licenses to pilot the technology for a year.

Dr Keith Ferguson of the CSIR and Dr Melanie Chait, CEO: Big Fish School of Digital Filmmaking, at the signing of a collaboration agreement in terms of which students at the film school will use CSIR-developed technology.

Technology aimed at creating a new mobile media industry licensed for commercial piloting

The challenge: Creating new opportunities for media entrepreneurs through technology

Traditional television broadcasting is expensive and is dominated by large companies that own the content delivery mechanisms. The prohibitive cost to enter this industry means that content creators have limited avenues to distribute their content.

The mobile segment of the telecommunications market has seen enormous growth globally and the ability to reach the mobile-phone audience offers significant opportunities for content producers and advertisers. The two main technological problems that need to be solved to allow media entrepreneurs to begin mobile broadcasting, relate to the availability of bandwidth and the speed at which content can reach the audience's devices (often experienced as buffering), and an open-collaboration platform to allow broadcasters to commission; upload and schedule content for broadcast.

If these barriers could be surmounted, there is a potential for entrepreneurs to innovate, create jobs and build a new mobile media industry in South Africa. The CSIR is using its expertise to solve these technology problems.

Research and development: Scalable digital media technology platform for mobile broadcasters

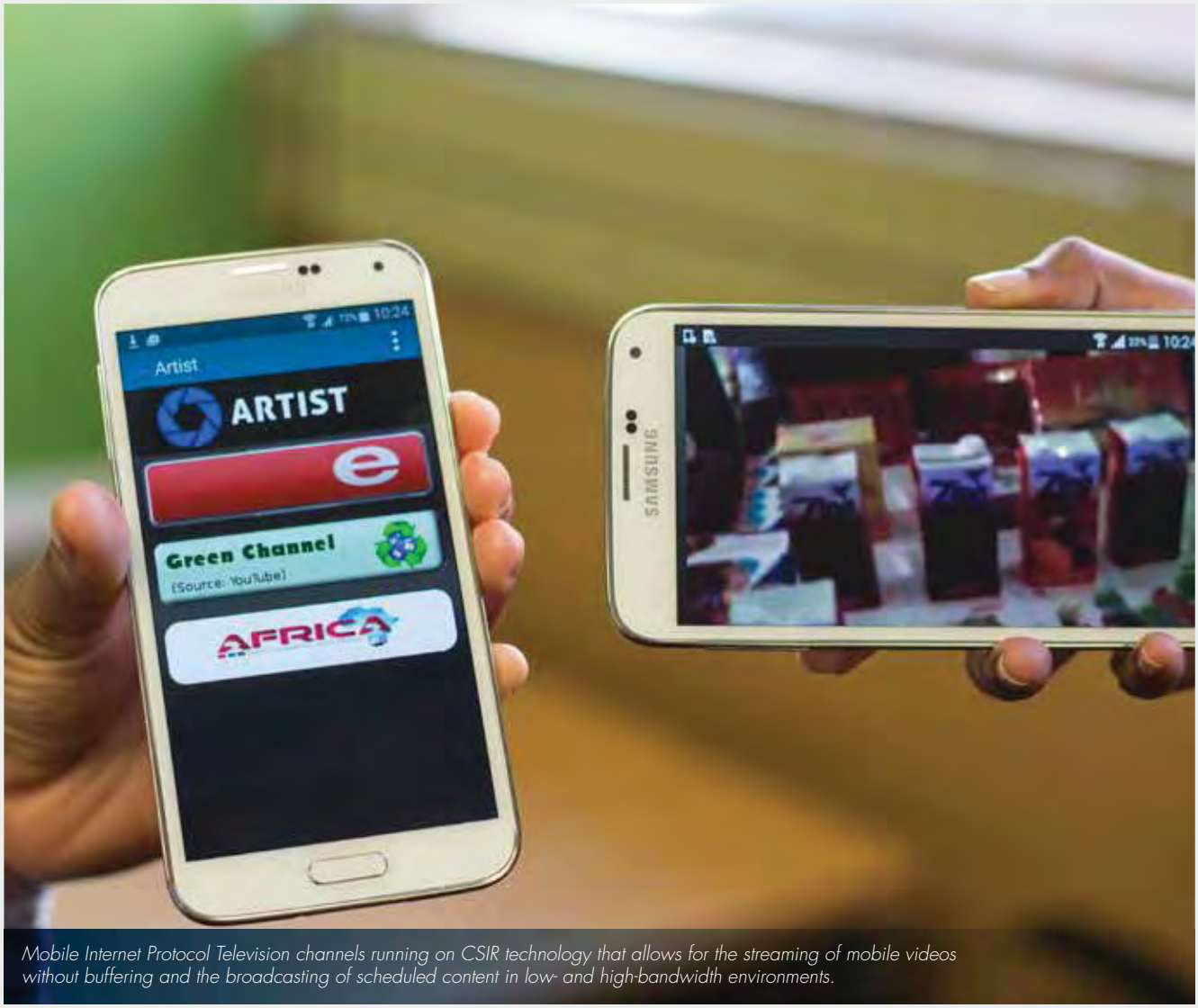
The CSIR has developed a platform that allows entrepreneurs to operate their own television stations over the mobile Internet. The platform is made up of two main components. The first component, called Adaptive Real-Time Internet Streaming Technology (Artist), addresses bandwidth constraints. Using novel compression algorithms developed by researchers at the CSIR, this solution compresses streams of data to match available bandwidth so that the viewer at no point experiences buffering. This means that content can reach audiences effectively and efficiently without the need to make changes to hardware and infrastructure.

The second component, called Micro-Enterprise Media Engine (Meme), addresses station management. To deliver content to audiences, a broadcast station must be able to commission, upload and schedule content. Meme enables a broadcast manager to commission work from other media professionals, and to then upload, schedule and broadcast to audiences, while also connecting audiences to advertisers.

These technology components enable broadcasting over the mobile Internet, known as mobile Internet Protocol Television (IPTV). This type of broadcasting is in its infancy in South Africa with no sustainable commercial offerings on the market. Unlike video-on-demand platforms like YouTube or Netflix, which only have hosted content, mobile IPTV allows for scheduled programming.

Outcomes: Technology piloted by small business

The Artist/Meme solution is now in the commercial pilot phase. The solution has been patented in China, Russia, Nigeria, Africa, the United States of America and the United Kingdom. Five SMMEs have been licensed to pilot the technology for a year. During the pilot phase it has resulted in employment for four film students, four full-time media employees, seven full-time technology employees and approximately 25 workers across the five SMMEs. The platform is also being integrated into the curriculum of a local film school.



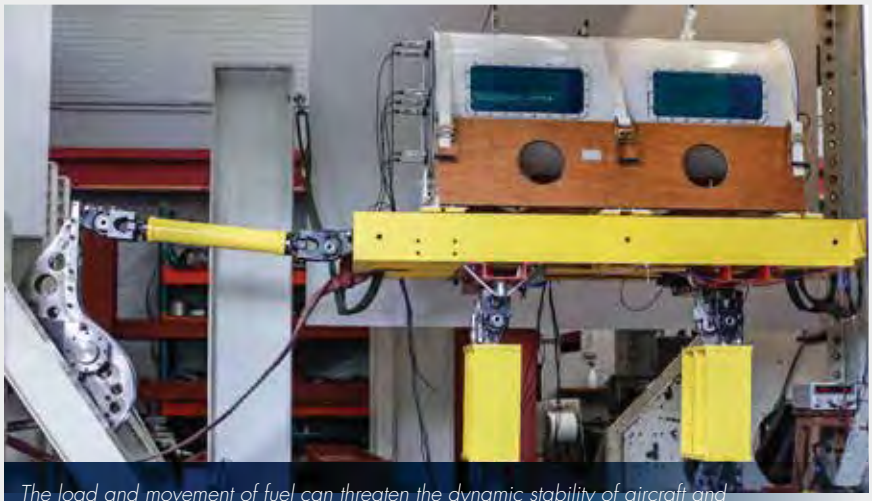
Mobile Internet Protocol Television channels running on CSIR technology that allows for the streaming of mobile videos without buffering and the broadcasting of scheduled content in low- and high-bandwidth environments.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

In brief

The South African aerospace industry is benefitting from a number of interventions by the CSIR-hosted Aerospace Industry Support Initiative (AISI) aimed at improving the competitiveness of the industry.



The load and movement of fuel can threaten the dynamic stability of aircraft and is therefore a crucial safety consideration. The CSIR, the University of Pretoria and Denel Aerostructures are undertaking an extensive range of large-scale laboratory tests on realistic fuel tanks as well as the numerical simulation of the experiments for validation of the laboratory results.

Supporting the industrialisation of aerospace technologies to create a vibrant industry

The challenge: Improving the competitiveness of the South African aerospace and defence industry

The South African aerospace and defence industry, with its advanced manufacturing capability, has the potential to help grow the South African economy and create sustainable jobs. The AISI, which is managed and hosted by the CSIR, was established by the Department of Trade and Industry to improve the competitiveness of this industry through focused interventions in technology advancement, productivity improvement and supplier development.

Research, development and implementation: Improved fuel tanks, components and supply processes

Interventions implemented by the AISI include research, development and innovation in the design and manufacture of aerospace and fuel tank structures, the use of additive technologies to manufacture aerospace components, and streamlining supply chain processes to improve productivity and realise cost savings.

Design and manufacture of aerospace fuel tank structures

The CSIR, through the AISI, Denel Aerostructures and the University of Pretoria (UP), are collaborating to establish a local expert capability in the analysis and design of aerospace fuel tanks. The movement of a liquid inside another moving object, known as sloshing, is an important aspect of aerospace fuel tank design. Sloshing in large fuel tanks causes impact loading on structures and can threaten the dynamic stability of the vehicle in which they are contained, typically airliners and space launch rockets.

The collaborative research team investigates the dynamic loading of fuel and how to accurately predict these loads for design purposes. It encompasses laboratory tests on actual fuel tanks, as well as numerical simulations of the experiments for validation of the laboratory results.

This specialised capability in analysing sloshing will provide critical design information to the local industry and when combined with local breakthroughs in advanced manufacturing, will provide a competitive edge to the aerospace sector.

The CSIR's research contribution focuses on the development of software to model the fuel movement and predicting the loading on tank walls and baffles (used to restrain the flow of a fluid). This high-fidelity simulation approach provides design engineers with greater insight into the operating conditions of tanks during the design process and allows them to improve the safety and efficiency of the system.

UP undertakes the tests to validate the numerical algorithms used in the analysis of fuel sloshing. These tests are critical in establishing confidence in the simulation software for it to be adapted by industry. Although a number of simulation algorithms exist, there are very few instances of these algorithms being published with experimental validation data.

The second part of the project investigates the application of the new technology to a system under design. Denel is developing a rotatory wing unmanned aerial vehicle (UAV) carrying approximately 180 L of fuel. It is estimated that the weight of the airframe will only be 20% of the fuel weight, making the structure highly sensitive to the dynamic behaviour of the fuel.

The design, analysis and testing of the fuel tank structure will provide design engineers with better insights into the system dynamics, reduce risks during the development stage and improve the efficiency of the system.

Developing additive manufacturing build and qualification strategies for aerospace components

CSIR researchers are developing additive manufacturing build and qualification strategies for aerodynamic and structural components.

Additive manufacturing is an emerging technology that has not been fully adopted by industry due to limitations in commercially available technology.

In traditional manufacturing technologies, materials are removed through a cutting or milling process, resulting in significant material waste and reduced tool life. In additive manufacturing, material is only used on demand and no contact tooling is involved. It relies on various energy depositing technologies to fuse materials into near-shape parts.

However, defects associated with this type of manufacturing include cracks. Cracks typically form due to residual stresses in the structure during the build or subsequent cooling process. In the aerospace environment, components with such defects cannot be used.

Researchers have identified areas with relatively high risk for defect formation and further research is being done before final additive manufacturing building specifications are formalised.

Supplier development for industry competitiveness

One of the aims of the AISI is to broaden economic participation in this sector by developing small, medium and micro enterprises (SMMEs), particularly black-owned SMMEs. This is achieved by transferring technologies and skills to improve capabilities.

Sinjana Engineering, a 100% black-owned, Gauteng-based supplier in the defence and aerospace industry is one such beneficiary. The company manufactures ferrous, non-ferrous and non-metallic materials using precision equipment and tools.

The CSIR assisted the company to improve its production planning system as well as quality management and production processes.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

In brief

The CSIR plays a leading role in developing and implementing innovative and sustainable solutions to boost local economic development and increase opportunities for employment, particularly in rural areas. The CSIR has helped create opportunities in agro-processing in the Eastern Cape, botanical extracts in Limpopo and business process outsourcing in Gauteng.

A model of the Tshwane Business Process Outsourcing Park in Hammanskraal, Pretoria.

Implementing innovative solutions to boost local economic development

The challenge: Unemployment and poverty

South Africa faces the challenge of broadening economic participation, especially in rural areas, which typically have higher levels of unemployment and poverty. The CSIR addresses these challenges by packaging, implementing and facilitating science, engineering and technology solutions.

Research, development and implementation: Innovative solution to create employment

The CSIR has contributed to finding solutions to help broaden economic development and alleviate the scarcity of employment opportunities in the Eastern Cape, Limpopo and Gauteng.

Agri-parks to stimulate economic growth in the Eastern Cape

The CSIR has developed innovative methods for large-scale agricultural processing using industry standards at agri-parks in the Eastern Cape. Agri-parks can provide a means of enhancing agricultural productivity and establishing an agricultural value chain that benefits community members across the province.

The Department of Rural Development and Land Reform, in conjunction with the University of Fort Hare, the Eastern Cape Provincial Government, the Agricultural Research Council and other stakeholders, had established two agri-parks in Dutywa and Alice. The CSIR contributed its expertise to help establish successful processing facilities.

In 2012 and 2013, the CSIR conducted a study to assess the feasibility of these two sites in producing good quality agricultural products using industrial standards.

For several years, the CSIR had collaborated with Nestlé and the Agricultural Research Council to conduct research on indigenous South African biodiversity to evaluate the potential for nutraceuticals and functional foods with proven health benefits.

Nestlé conducted an audit on the processing facilities to determine whether they meet the industry standard and whether the facilities would be able to supply Nestlé with high-quality dried vegetables that could be used in a two-minute noodle product. Both processing facilities were deemed to meet the industry standard and quality.

The CSIR trained eight agro-processors at the University of Fort Hare and cooperatives in the agri-park in Alice to ensure the production of a safe and high-quality dried vegetable product. The processors were able to produce a ton of dried morogo for Nestlé in 2015. The facility also supplies morogo for a CSIR nutri-drink project in Cofimvaba.

In Dutywa, 30 community members benefitted from this project, with five members employed in agriculture and trained in agronomy – the science and technology of producing and using plants for food – and harvesting techniques of leaves. Twenty-five community members were employed in agro-processing, which includes washing, blanching, oven drying, milling and the packaging of morogo.

Approximately three tons of the dried leafy vegetables were produced during the commissioning stages of the facility in Dutywa. Six hectares of morogo were planted, but due to drought, only three tons of dried processed morogo powder were produced.

Tshwane business process outsourcing to revitalise Hammanskraal

The CSIR conducted pre-feasibility and feasibility studies and produced a business plan for the establishment of the Tshwane Business Process Outsourcing Park (BPO) in Hammanskraal, Pretoria.

The Tshwane BPO Park is a project of the City of Tshwane Metropolitan Municipality and aims to broaden economic participation among Tshwane residents, particularly those from the Hammanskraal area. The BPO is expected to create about 3 000 jobs. The BPO sector is seen as a viable mechanism to help resolve youth unemployment in the area.

The park will offer on-site training, technical support and incubators for small, medium and micro enterprises. It will also have a contact centre with the capacity to seat 3 000 people and an academy offering a national training programme.

Creating new value-add products from tea extract produced on the Tshivhase Tea Estate in Limpopo

The CSIR has investigated and piloted the production of additional value-added products based on the tea crops of the Tshivhase Tea Estate in Limpopo. The estate employs 2 000 people from the surrounding areas.

The project, which was co-funded by the Limpopo Department of Agriculture and the Department of Science and Technology, included investigating the feasibility of diversifying the estate's products to include value-added products based on the tea crop *Camellia sinensis* – in addition to the current packaged black tea products. The initiative formed part of efforts to ensure the sustainability of the estate.

The additional products included black and green tea extracts, as well as a hand cream produced from green tea and other natural ingredients such as avocado and lavender oils. The extracts and hand cream were tested in local and international markets. The production and market tests were used to assess the viability of industrial-scale production of botanical extracts as a commercial enterprise.

The pilot extract facility includes four main processing steps, namely tea brewing, filtration, concentration and drying. Technical challenges that had to be addressed in setting up the plant included the need to produce extracts without damaging the active ingredients and led to the inclusion of ultrafiltration and reverse osmosis technologies in the production line design.

The CSIR team also developed a business plan for the industrial-scale production of the botanical extracts, which was accepted by the owners. This business plan is being used to approach potential funders for the investment needed to set up an enterprise based on the production of botanical extracts.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

Support to technology entrepreneurs in the defence sector

The CSIR and the Department of Defence (DoD) have joined forces to support black-owned enterprises in the defence sector with technology development, enterprise development and technical human capital development.

The Defence Transformative Enterprise Development programme is funded by the DoD and implemented by the CSIR. The primary goal of the programme is to create and support sustainable and competitive black-owned small, medium and micro enterprises in line with objectives of the 2014 Defence Review, the National Development Plan and the Department of Trade and Industry Black Industrialist Policy.

In the first phase of the programme, three businesses, established by entrepreneurs in the defence sector, were identified. Engineers from these companies were integrated in the CSIR's radar and electronic warfare activities to expose them to technology development and the latest innovation trends.

In addition to the direct economic benefit, the programme will also contribute to the development of technical skills, particularly in highly specialised domains. The programme is an outcome of a memorandum of agreement signed between the CSIR and the DoD in 2015 that provides the strategic framework for a number of joint projects focused on capability development in national defence and security.

Mcebisi Solilo, engineer at Sovereignty Systems, at work in the CSIR's electronic warfare laboratory.

Boost to radar and electronic warfare industry: From left are Sujo Mulamattathil, Director of Protea Mechatronics Systems; Bernad Mangwane, Manager of the Defence Transformative Enterprise Development (DEFTED) Programme at the CSIR; Florence Musengi, Director of Floida Engineering Services and Madodana Mfana, Director of Sovereignty Systems. The three companies are SMME participants of the DEFTED programme undertaken by the CSIR and the Department of Defence.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

Assisting emerging and small-scale entrepreneurs with environmental impact assessments

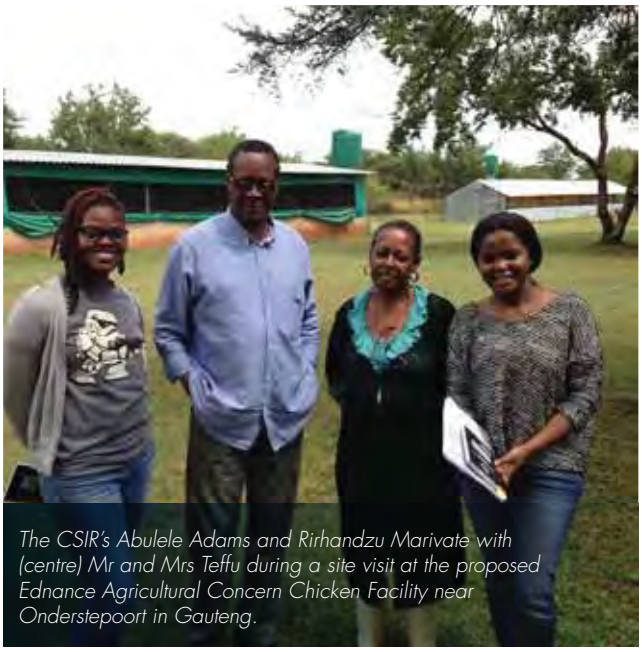
Many business opportunities are linked to securing environmental authorisation and a lack of knowledge on these aspects limits emerging entrepreneurs from exploring such opportunities. The CSIR is helping 18 emerging and small-scale entrepreneurs with Environmental Impact Assessment (EIA) services as part of the Special Needs and Skills Development Programme of the Department of Environmental Affairs.

The primary goal of the programme is to assist emerging or small-scale entrepreneurs, companies and community trusts in the mining, waste and agricultural sectors to meet the regulatory requirements of the National Environment Act, 1998 (Act 107 of 1998). Many such entrepreneurs, companies and community trusts do not understand or have the funds to comply with EIA regulations.

To build critical skills in environmental management, the CSIR, through the programme, employs four young postgraduates and two interns who work under the management of senior CSIR staff to support entrepreneurs and rural communities.

To date, 28 applications have been received, mostly from the agricultural sector and mostly small-scale agriculture, which includes poultry farming, piggeries, beef lots and crops farming. An application has also been received from a diamond mine. The CSIR is assisting 18 of the applicants with their basic assessments.

The CSIR's Kelly Stroebel places site notices at the proposed Legae La Tlhago pig production facility in Winterveld, Gauteng, with client Thabo Mokwena looking on.



The CSIR's Abulele Adams and Rirhandzu Marivate with (centre) Mr and Mrs Teffu during a site visit at the proposed Ednance Agricultural Concern Chicken Facility near Onderstepoort in Gauteng.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

Robotic system for horticultural crop monitoring tested in Western Cape vineyards

The CSIR has developed a cost-effective platform to inspect and monitor horticultural crops on local farms. This automated, intelligent robotic system has significant potential to improve the monitoring, production, harvesting and processing of produce.

Following the successful development of a prototype that was tested in laboratory conditions, field trials of this precision-farming tool were undertaken to monitor vineyards in collaboration with the Department of Viticulture and Oenology and the Institute for Wine Biotechnology at the Stellenbosch University.

The sensors of the robotic system have been configured to estimate grape yield and to monitor plant growth and canopy health. The data provided will help farmers in the early identification of anomalies and potential hazards, allowing them to mitigate factors that could potentially cost millions in yield loss.

One of the key considerations in developing the technology was durability, as the harsh South African climate and landscape have in the past prevented advanced robotic technologies of this nature from being utilised. The researchers developed a platform that was capable and durable by ensuring that it had more than the required weight carrying capacity and energy to drive the machinery. Computer-aided design allowed for the simulation of performance before construction and deployment of the platform.

The robot is able to navigate autonomously through the vineyard, using CSIR-developed data-sensor fusion techniques to combine the data from the different sensors. Using the CSIR-designed data-fusion algorithm, it is also able to perform path planning, obstacle avoidance and lane following. The robot development is part of a three-year programme evaluating and demonstrating robotics, automation and sensors in viticulture.

Work undertaken in this project is part of a broader initiative focusing on automation solutions to improve the competitiveness of horticulture in South Africa.

The automated robotic system developed to inspect and monitor horticultural crops on local farms.

Research, development and implementation for

ECONOMY AND EMPLOYMENT

Extracting value from chicken feather waste

The CSIR is investigating the smart use of chicken feather waste by extracting keratin protein from the feathers.

While chicken feathers are currently viewed as waste, they are rich in keratin proteins and amino acids. This potentially valuable resource is currently mostly disposed of as waste or used for livestock feed. Keratin is used worldwide in the production of various high-value products such as nanostructured materials for biomedical applications, regenerated fibres for textiles, composite materials and as ingredients for use in the cosmetic industry.

The extraction of usable proteins from chicken feathers will solve the disposal problem and generate additional income for the poultry industry, resulting in the creation of new industries specialising in the processing of feathers. However, using the feathers directly in any process is difficult because of their rigid protein structure.

CSIR researchers are investigating options for the use of the extracted proteins. They pre-treat the feathers to ensure decontamination from bacteria and viruses, whereafter keratin protein is extracted and characterised for its physical, mechanical, chemical, optical, dielectric and thermal properties. These results determine what the extracted keratin is used for.

The researchers have successfully produced nanostructured materials using the extracted proteins and continue to investigate other applications. For example, after the regeneration of the keratin-based fibre via electro-spinning, the fibres can be used to replace synthetic fibres in textile production, leading to the development of textile materials based on environmentally sustainable materials that could replace petroleum-based synthetic fibres.

The research is currently at the laboratory stage and is being conducted in collaboration with the University of KwaZulu-Natal with funding from the Department of Science and Technology. The project followed collaboration on a PhD programme with the Ethiopian Government.

Pre-treated and decontaminated chicken feathers, ready for keratin protein extraction.

One of the challenges associated with the growth in data availability, is how to draw insights, forecast and act on these massive datasets. This capability is required for sound decision-making by government officials. A CSIR-managed programme introduces students in the fields of engineering, computer science, business informatics, mathematics and statistics to machine-learning topics, tools and theories. The CSIR's Dr Quentin Williams engages with a group of students in the programme. Also see page 36.

Research, development and implementation for

A CAPABLE STATE

A capable state relies on efficient service delivery processes to support its citizens. The CSIR addresses various challenges related to this, including a shortage of skills and the lack of organisational capacity, the absence of an integrated decision-support capability and poor uptake of potential technology-based service-delivery solutions.

Research, development and implementation for

A CAPABLE STATE

Developing a smart complaints management system for municipalities

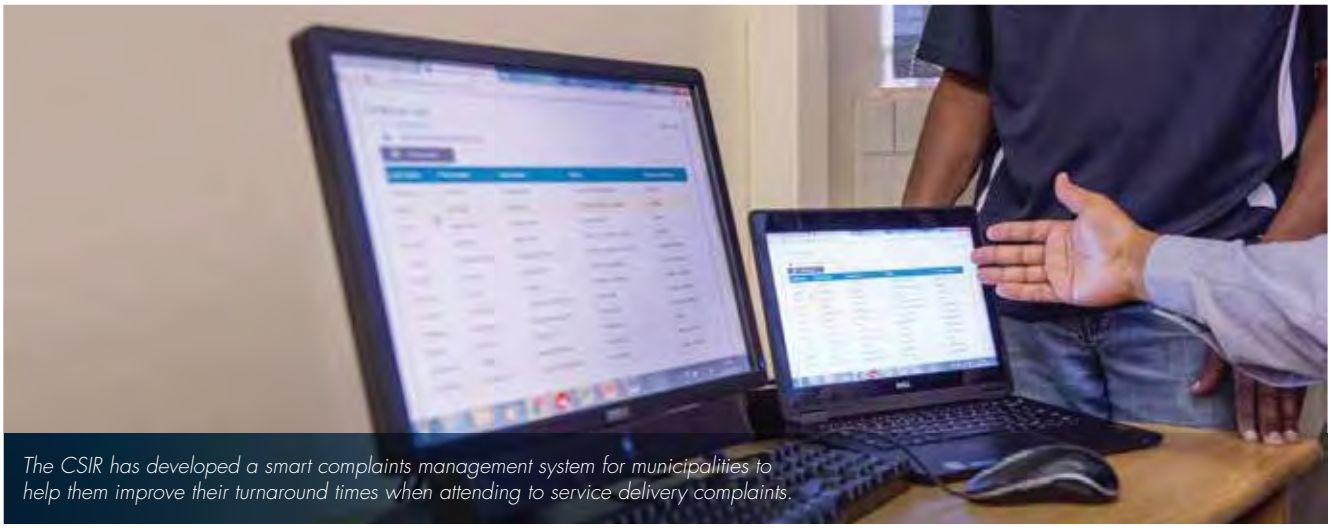
The CSIR has designed and developed a web-based technology, the Municipal Services Corrective Action Request and Report System, to help municipalities improve their turnaround times when attending to service delivery complaints.

The system aims to improve the ability of municipalities to monitor service delivery and contribute to a culture of accountability.

The system is similar to a workflow system in that complaints are automatically escalated and complainants are informed on progress relating to the complaint. The system provides feedback to the complainant at all stages of the complaint escalation.

When it comes to water service delivery, the average non-revenue water, which is water lost in the system, is 36.8%. With this technology, municipalities can monitor and ensure that responses to incidents such as leakages in the water distribution network system are executed timeously.

The system was piloted in the Amathole District Municipality in the Eastern Cape, with incidents reported and resolved at the four pilot sites.



The CSIR has developed a smart complaints management system for municipalities to help them improve their turnaround times when attending to service delivery complaints.

Research, development and implementation for

A CAPABLE STATE

Preventing fraud and identity theft by improving a municipality's network security

Cyber security experts at the CSIR supported a municipality that had experienced an information network security breach.

Cyber criminals, who obtain access to confidential information stored on a municipality's system, may use that data to commit identity theft or financial crimes.

The municipality approached the CSIR to assist it with the investigation and to find ways to avoid a repeat of the incident. CSIR cybersecurity experts performed a digital forensic investigation on the municipality's network and servers to determine the extent of the breach and the damage that it had caused.

They also assessed the state of the security of the municipality's cyber infrastructure by performing a penetration testing activity. Penetration testing is a form of 'ethical hacking' where the investigators try to exploit the vulnerabilities of a network, just like real hackers would, to see how these attackers gain access to a system.

The penetration test allowed the CSIR to identify several vulnerabilities in the municipality's cyber infrastructure and the team helped them to improve their network security.

The CSIR continues to work with this municipality to avoid a repeat breach of security.

Cyber criminals obtain access to confidential information to commit identity theft or financial crimes.

Research, development and implementation for

A CAPABLE STATE

Strengthening a national data visualisation and analytics capability to support government and industry

The CSIR has developed and is implementing a programme to strengthen the national capability in data visualisation and analytics.

The need for the Data Science for Impact and Decision Enhancement (DSIDE) Programme stems from the exponential growth in the volume of data that have become available from sensors, satellites, social media and other sources. One of the challenges associated with this growth in data is how to draw insights, forecast and act on these massive datasets. The cabinet-approved ICT RDI Roadmap highlighted that such a capability is required for sound decision-making by government officials. Research conducted for the roadmap also revealed a need for this capability in the private sector with potential as an export capability related to data analytics.

The DSIDE programme targets third-year and final-year students in the fields of engineering, computer science, business informatics, mathematics and statistics. Students spend a total of 12 weeks at the CSIR, where they are allocated to mentors. The mentors introduce the students to machine-learning topics, tools, theories and provide them with datasets on which to apply these techniques. The students are then required to work on real-world projects, develop prototypes and present their understanding of the dataset with new insights acquired through interactive visual exploration, analytics and model development. Projects included, among others, preventative maintenance analyses for the Gauteng Department of Infrastructure Development and Transnet Engineering, evidence-based policy models for the National Department of Health and the Department of Transport and financial tracking of programmes related to the National Development Plan for the Department of Planning, Monitoring and Evaluation.

In 2015, 32 students were selected from 11 tertiary institutions in South Africa.

A CSIR-managed programme introduces students to machine-learning topics, tools and theories, and provides them with datasets on which to apply these techniques. From left are Gary Bezuidenhout of the University of the Witwatersrand, Pelonomi Moiloa of the University of the Witwatersrand, Anathi Mafuna of the University of KwaZulu-Natal, Dr Quentin Williams of the CSIR, Jonathan Gerrand of the University of the Witwatersrand, Ndamulelo Netshiavha of the University of Pretoria, Percy Mbebwe of the University of Johannesburg and Nkosinathi Ndlovu of the University of the Witwatersrand.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE

To achieve sustainable and inclusive growth by 2030, South Africa needs to maintain and upgrade existing infrastructure and develop technologies to support future infrastructure. This includes maintaining and building transport, water, energy, and information and communications technology infrastructure. The CSIR's interventions in support of economic and social infrastructure take two forms – the design of technological solutions and the development of policies.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: TRANSPORT

In brief

Most of South Africa's goods are transported via the country's roads and railways, making this infrastructure crucial for economic development. The CSIR and Transnet have joined forces to design a locomotive for African conditions and the CSIR is developing a device that warns of obstacles on tracks. CSIR experts also developed long-life road construction materials and tailored a smart truck standards framework that governs on-road vehicle performance.

The CSIR-developed Survey and Inspection Device on display at Africa Rail 2016.

Optimising rail and road infrastructure

The challenge: An efficient transport sector

An efficient transport system is vital for socio-economic development in South Africa. However, the country's transport infrastructure is ageing and it is further challenged by high transport logistics costs, skills shortages and a limited local manufacturing capability. These factors adversely affect other sectors and the country's economic development.

RESEARCH AND DEVELOPMENT FOR RAIL

A locomotive to support rail transport in Africa

Market analysis commissioned by Transnet Engineering identified significant opportunities in Africa for locomotives designed for African conditions. Transnet wants to establish itself as the preferred original equipment manufacturer for rolling stock in Africa, reducing the need to import skills and components from abroad.

The CSIR has partnered with Transnet to support an initiative that focuses on the development of the Trans Africa Locomotive.

A train control and monitoring subsystem provides for the control interface between the train driver and the traction, breaking and many other locomotive functions. Therefore, its efficiency is critical to safety. Transnet and the CSIR formed a joint team consisting of system engineers, electronic engineers and software developers for the development of this system. The first phase of this collaboration focused on establishing the system requirement and interface specifications. The team developed the electronic hardware, as well as the software for the first prototype unit as

part of an effort to establish this development capability. This unit will be integrated in the first prototype of the Trans Africa Locomotive.

The next phase will require a more rigorous system engineering process to ensure that the resulting system will be safety certifiable and will meet requirements for functionality, reliability and maintenance.

An advanced warning system for railways

The CSIR collaborated with Transnet to develop a survey inspection device to detect obstacles and defects on South Africa's railway tracks in real time. Defects and objects on train tracks lead to delays, accidents and derailments, with significant associated costs.

In obstacle detection mode, the device moves ahead of a train, surveying the track for obstacles and notifies the train driver of the obstacle or anomaly on the rail track using live video feedback.

The device is also able to monitor the condition of electrical overheads using a multispectral camera, as well as assess the condition of the track. When a defect is found, the GPS position and nature of the defect is stored and/or relayed to the command centre via GSM. The technology is currently in trial phase.

RESEARCH AND DEVELOPMENT FOR BETTER ROADS

Developing long-life, cost-effective road construction materials

The CSIR has developed long-life road construction materials to support heavily trafficked roads where trucks that are loaded with heavy goods often cause premature failure of traditional asphalt layers in terms of rutting. The high modulus asphalt is a mix of very hard paving grade bitumen and good quality fully crushed aggregates tailored for South Africa's road conditions. Since being tested in the eThekwini Municipality in KwaZulu-Natal (KZN), it has been implemented on other roads in KZN and Gauteng.

Smart Trucks show greater overall transportation efficiency

The South African transportation industry is embracing the new performance-based standards Smart Trucks, a research project led by the CSIR. The Smart Truck standards framework was specifically tailored for the South African context, comprising 12 safety and two infrastructure standards that govern actual on-road vehicle performance.

Initially, all performance-based assessments were outsourced to experts in Australia and New Zealand. In collaboration with other technical experts, two CSIR engineers have helped to build local capacity for conducting these vehicle safety assessments. Vehicle assessment under the performance-based assessment scheme includes vehicle performance standards to ensure they are stable on the road, can turn and stop safely and are road- and structure-friendly.

Smart Truck designs are assessed using simulation tools developed by the University of Michigan, as well as pavement analysis software developed by the CSIR.

The CSIR records operational data of each Smart Truck on a monthly basis, tracking key performance indicators. To date, the 165 Smart Trucks in use have shown a 70% reduction in crash rates, 14% reduction in fuel consumption, saving over 67 000 trips, 1.9 million litres of fuel and more than 5 000 tons of carbon dioxide.

The CSIR was contracted by the Southern African Bitumen Association to develop long-life and cost-effective road construction materials that would be able to withstand heavy traffic loading. The material was tested in the eThekwini municipality in KwaZulu-Natal.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ENERGY

In brief

The CSIR installed its first solar photovoltaic (PV) power plant on its Pretoria campus as part of investigations into technologies and policies to support the increased use of renewable energy in South Africa and to study aspects of distributed energy generation. The installation follows the earlier formation of the CSIR Energy Centre. It also marks the start of the journey to an energy-autonomous campus.

In one study conducted at the CSIR solar photovoltaic plant, researchers are assessing the impact of dust and dirt build-up on the ability of photovoltaic panels to yield power.

New solar photovoltaic plant contributes to research studies and energy autonomy

The challenge: Investigating aspects of renewable energy and distributed energy generation

The rising cost of electricity and environmental concerns related to the burning of fossil fuels have prompted many businesses and private households to look at alternative sources of energy, such as solar power. Many energy consumers are expected to become small-scale energy producers. This requires new business models for service providers and answers to technical questions related to solar farms and distributed energy generation.

In its effort to become energy-autonomous, the CSIR wants to generate significant amounts of renewable electricity, while consuming minimally from the national electricity grid and feeding its surplus energy into the grid.

Research and development: An on-site photovoltaic power plant

As part of these plans, the CSIR's first solar PV power plant was constructed between June and August 2015 in Pretoria. The solar array consists of a total of 1 800 PV modules with a total surface of 3 493 m^2. The power generated feeds directly into the CSIR's campus grid, therefore, no energy storage is needed.

The panels are controlled by a single-axis solar tracker that allows the modules to tilt and follow the movement of the sun from east to west. This tracking system is generally more expensive to install and maintain, but has a higher energy yield as opposed to a fixed-tilt system.

The CSIR's one-axis tracking PV facility is the first of its kind in the country with a 100% South African designed and made tracking system and substructure, including the control algorithms.

Outcome: Immediate cost savings and on-site study area

The PV plant produced 700 000 kWh between October 2015 and April 2016, which is the equivalent of the electricity needed to power approximately 200 middle-income households during the same period. The total savings on the CSIR's electricity bill for this period was R650 000.

The plant has achieved a lifetime energy cost of 83 cents per kWh, which compares favourably with existing utility-scale solar PV plants in the Northern Cape and is cost-competitive compared to other methods of electricity generation.

It is projected that the facility will have an annual electricity yield of close to 1 200 MWh, about 4% of the CSIR's electricity needs on its Pretoria campus.

Further research

Dust and dirt build-up can impair the PV panels' ability to yield power, but the cost of regular cleaning will ultimately increase the price of energy generated. In one of the first research projects using the plant, researchers are assessing the impact of the dust and dirt build-up on yield. The researchers have divided the arrays into different blocks with some of the modules being routinely cleaned, while others are left uncleaned. The purpose is to derive a cost-optimal operational plan for the cleaning of the modules.

The CSIR will also be analysing the operational performance of a solar PV system that tracks the sun on a single axis versus one that is installed at a fixed tilt. This information will be used to develop a tracking model with optimal energy yield. The researchers will study the average annual degradation of the PV modules and identify any hotspots.

Future benefits

The CSIR plans to balance supply and demand with other campuses that are connected to the South African grid in a 'virtual power plant' approach. This means that during times of oversupply at the CSIR campus, that excess will be supplied to another campus, anywhere in South Africa, that is experiencing undersupply at that time. The facility has an expected lifespan of at least 25 years. The solar power generated will equate to an annual carbon dioxide avoidance of approximately 1 200 tons, which will contribute to a substantial reduction of the CSIR's carbon footprint.

A construction worker installs a solar photovoltaic module at the CSIR.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ENERGY

Study shows abundance of wind and solar resources in South Africa

The potential to produce electricity from wind turbines in South Africa is significantly greater and more widely spread than initially thought. This was the finding from a study undertaken to quantify the combined effect of wind and solar energy resources in the country.

The study results show that across South Africa, solar photovoltaic (PV) and wind resources are good enough to be able to produce globally competitive solar and wind power and that over 80% of the land mass has enough wind potential to achieve a 30% average annual load factor. The load factor is a measure for the average utilisation of wind turbines. In countries like Spain and Germany, which are known for their good wind resources, actual average load factors of the entire wind fleets are 25 – 27% and 20 – 23%, respectively. The 'good wind' resource is not restricted to the Cape area, as was previously thought, and therefore, wind plants can be established almost everywhere in South Africa.

The results also indicate that wind and solar PV installations can provide a smooth power output when the power plants are dispersed over a large area. Consequently, short-term fluctuations in the combined aggregated power output can be avoided almost entirely by spreading solar PV and wind power plants across the country. This, in combination with the cost competitiveness of wind and solar PV, means that these two energy sources can economically and technically supply bulk power to meet large parts of the country's electricity requirements.

Furthermore, the results indicate that power output from wind and solar PV plants do not happen at the same time, they complement each other, which benefits the power system. Solar PV output is higher during the day and wind output is higher in the evening, which is ideal for meeting the evening peak load.

The results of this study will be used as input to South Africa's strategic grid plans and the Transmission Development Plan. The high-quality, high-resolution wind and solar PV resource data are already being used in the modelling of the revision to the Integrated Resource Plan. The datasets have been made available to the public.

The study was undertaken in collaboration with the South African National Energy Development Institute, Eskom and Germany's Fraunhofer Institute for Wind Energy and Energy System Technology.

South African-German collaboration on energy: Dr Stefan Bofinger, Fraunhofer IWES; Joanne Calitz, CSIR; Crescent Mushwana, CSIR; Sipho Mdhluli, Eskom; Terence van Zyl; Eugéne Mabille, CSIR; and Nicolene Botha, CSIR.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ENERGY

Promoting renewable energy across SADC

The CSIR is leading a project to support the development and integration of renewable energy resources in power systems in the Southern African Development Community region.

This project is part of a plan by the International Renewable Energy Agency based in Abu Dhabi, to support the development of enabling market environments for renewable energy. It is implemented in partnership with the Electricity Control Board of Namibia, the Zimbabwe Electricity Regulatory Authority and the Regional Electricity Regulators Association of Southern Africa.

The CSIR will, by improving coordination in regional planning, support the development and integration of renewable energy resources in regional power systems. The project also includes a review of international best practice and an assessment of current regional planning approaches in an effort to identify the benefits of renewable energy projects.

The objective of the project is to inform relevant stakeholders in southern Africa, including electricity regulators and policymakers, about the status quo of current planning processes and to highlight potential areas of improvement. The project will include the implementation of national pilot programmes in Namibia, Tanzania and Zimbabwe with the aim of developing recommendations to improve the design and implementation of national integrated resources plans.

The CSIR is working with the Regulatory Assistance Project, a US non-governmental organisation of electricity regulation experts. The National Renewable Energy Laboratory acts as advisor to the CSIR on the project.

The eThekwini Municipality in KwaZulu-Natal has fitted thousands of residential solar water heaters in low-income communities, such as these on the roofs of houses at Verulam in Durban.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ENERGY

Success in the synthesis of a metal-organic framework-carbon composite for hydrogen storage applications

As part of research into the use of different materials to store hydrogen, the CSIR successfully synthesised a composite material consisting of a chromium-based metal-organic framework and zeolite-templated carbon.

Hydrogen is considered an energy-carrier with potential for various forms of power applications, but its storage presents problems because as a gas at ambient temperature and pressure, it has a low energy density by volume and therefore, it has to be compacted. Materials-based storage involves storing hydrogen either through chemical bonding with specific materials or storing hydrogen inside certain porous materials such as metal-organic frameworks. For this research, South African minerals like chromium, zirconium and platinum group metals are used.

CSIR researchers discovered that there is a significant enhancement of the surface area and hydrogen storage capacity of the resulting composite material over the individual metal-organic framework and carbon materials. They succeeded in finding an easy way of generating hybrid materials with improved properties and attractive hydrogen storage capacities. The development will make the hydrogen storage system integration more promising for industrial and commercial applications.

Microscopy images of electrospun nanofibres for incorporation of porous hydrogen storage materials. On top of the images are electrospun nanofibre materials before and after heat treatment.

CSIR researcher Priya Annamalai fills up a dewar with liquid nitrogen for use during sample analysis on an accelerated surface area and porosimetry instrument.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ENERGY

Fully radiometric inspection camera systems for the export market developed at the CSIR

The CSIR is developing a next-generation camera inspection system for power lines. It will form part of the future product mix of Uvirco, a company formed in 2008 when the CSIR-developed inspection camera was first commercialised.

The new system aims to quantify radiation in the ultra-violet and infra-red wavelength bands as a means to significantly improve the diagnostic value of the instruments. The project is being co-funded by the Technology Innovation Agency.

In the early 1990s, Eskom faced a challenge with damaged overhead insulators which led to power supply failures. These insulators were not easy to manually inspect due to the high voltages and their distance from the ground.

In response to the Eskom problem, the first prototype camera was developed by the CSIR in 1993, the start of the CoroCAM range of corona detection cameras. These cameras detect and visualise ultraviolet discharges, an indication of electricity leaks.

Early clients included power utilities, insulator manufacturers and researchers as far afield as France, Thailand, Argentina and the USA.

The CoroCAM is assembled, tested and qualified in South Africa and is used in more than 50 countries (95% of cameras produced locally are exported).

The next-generation QUViR camera: A hand-held multi-spectral imager with fingertip control and viewfinder.

Mihlali Tapi of the CSIR with a tripod-mounted next-generation QUViR camera with built-in liquid crystal display.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ICT

In brief

South Africa's high-performance computing capability has been significantly enhanced by upgrades at the Centre for High Performance Computing.

CSIR climate modellers and oceanographers are developing the first African-based earth system model. For this they need computing power amounting to tens of millions of central processing unit hours, which is provided by the Centre for High Performance Computing. The earth system model will provide information at scales that will allow CSIR researchers Dr Stewart Bernard and Dr Sandy Thomalla to develop high-tech capabilities to support the Operation Phakisa Oceans Economy.

South Africa strengthens its high-performance computing capability

The challenge: Giving research an edge

High-performance computing, the use of parallel processing for running advanced application programmes quickly and efficiently, is a key enabling technology for a growing number of sectors. While supercomputing has become indispensable to, for example, model complex physical events in astronomy, climate change and genetics, the list of applications continues to grow as different fields are introduced to its possibilities.

The CSIR, by hosting the Centre for High Performance Computing on behalf of the Department of Science and Technology, plays a key role in developing South Africa's high-performance computing to ensure maximum impact for the academic and research sector, as well as for industry.

Research and development: A comprehensive national programme

The National Integrated Cyber Infrastructure System (NICIS) is a R300 million per annum national programme run by the Department of Science and Technology and hosted by the CSIR. The role of the NICIS is to build South Africa's capability to generate, manage and transfer 'big data'.

The CHPC is one of three pillars of the NICIS. It provides massive parallel processing capabilities and services to researchers in industry and academia. The other main pillars are the South African National Research Network, which provides high-speed connectivity, as well as the Data Intensive Research Initiative of South Africa that implements tools and facilities to enable efficient data-driven scientific and engineering discoveries.

In the past year, the CHPC has achieved significant milestones in servicing its user base and in advancing high-performance computing in South Africa.

Fifteen times faster than before: A new peta-scale machine unveiled

To further improve the centre's computational power, the CHPC introduced a new peta-scale machine, with over 40 000 cores. A peta-scale machine is a super computer with processing speeds capable of a thousand-trillion floating point operations (flops) per second. Flops are used in computing to compute extremely long numbers. The system, named Lengau (Setswana name for Cheetah), owing to its speed of 1 000 Teraflops, is 15 times faster than the previous system. Lengau was placed 121st on the computing Top 500 international list shortly after being taken into use and put South Africa in the company of leading supercomputing nations.

A trusted computing partner for the European Organization for Nuclear Research

The CHPC plays a critical role in enabling South Africa to participate in global science programmes. South Africa became one of the leading countries to support two particle detector experiments – Large Hadron Collider experiments – of the European Organization for Nuclear Research (CERN). In April 2015, South Africa signed a memorandum of understanding (MoU) with CERN, which gave South Africa admittance to the world computing grid. This marks a milestone in South Africa's partnership with CERN, which the country has been supporting since 2013. With the signing of the MoU, the CHPC is now recognised as a Tier-2 facility.

A new cloud computing service for users

The CHPC is part of the Square Kilometre Array (SKA) Science Data Processing consortium alongside Cambridge University, SKA-SA and Daresbury Laboratories. As part of its role in this consortium, the CHPC has developed a cloud service to provide flexibility to some of the research domains. This is a collaborative tool used for data distribution for the SKA. It was successfully deployed in 2015.

Using decommissioned computing systems for training

The CHPC piloted a project to ensure that decommissioned computing systems are used as small-scale processing environments and in training facilities in the country and around the continent. The CHPC acquired systems from the Texas Advanced Computing Center (TACC) and distributed them to the local universities of Fort Hare, Venda, KwaZulu-Natal, Witwatersrand and Stellenbosch.

The project enables institutions to include high-performance computing in their computer science curricula. It is anticipated that the operation of these small-scale systems will contribute to the training of more system administrators at universities, as well as provide a platform for next-generation scientists and engineers. In November 2015, 19 of these scientists and engineers from South Africa's institutions and SADC countries were supported by the National Science Foundation (USA), the Department of Science and Technology (South Africa) and Airlink to travel to Austin, Texas, to attend a week's training at TACC. The 19 scientists also participated in the 2015 Supercomputing Conference.

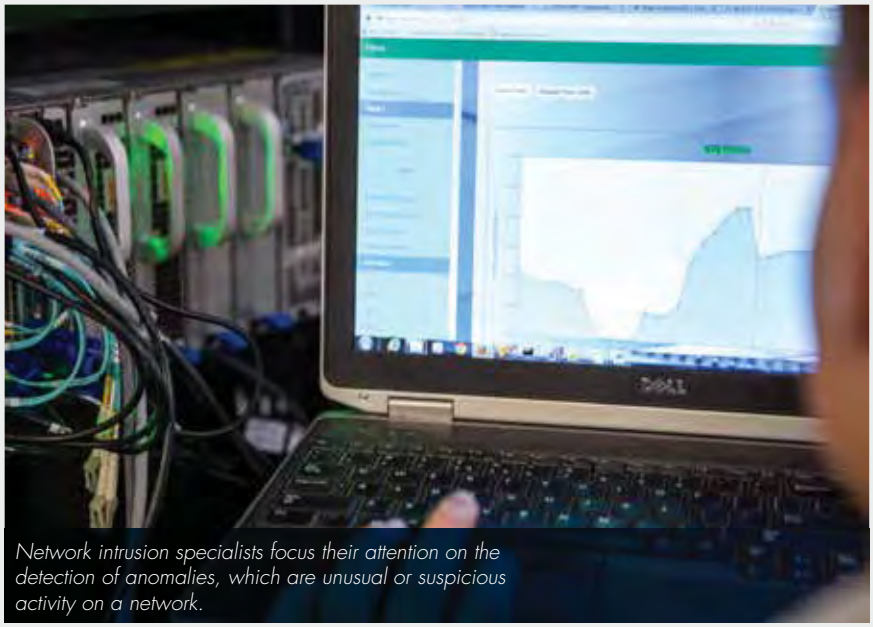
Dr Happy Sithole, head of the Centre for High Performance Computing, showcasing the components of Lengau, South Africa's first petaflop machine.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ICT

In brief

Cybercrime poses a significant threat to local business. The CSIR has developed prototype software to detect network port scanning, a type of reconnaissance activity used by cybercriminals to discover vulnerabilities in information and communications technology (ICT) systems that may be exploited.



Network intrusion specialists focus their attention on the detection of anomalies, which are unusual or suspicious activity on a network.

Network port scan detection system provides early warning against cybercrime

The challenge: The cost of cybercrime and early detection of threats

Cybercrime is reported to cost South African companies around R5.8 billion per year in lost revenue and damages. Small, medium and micro-sized enterprises are of particular concern due to their small ICT budgets and lack of dedicated ICT staff. The Internet of Things, which involves the collection and communication of data from many devices deployed in society – for example medical devices – is also vulnerable to security breaches when cyber criminals attempt to gain access to confidential personal information. Conventional signature-based intrusion detection technology is designed to detect known threats from a large database of threat signatures. New cyber threats and malware spread quickly and may cause significant damage before a signature is developed, and the threat database is updated. Sophisticated malware may also change its internal structure over time, thereby evading technology that is designed to detect the original signature. This is why network intrusion specialists focus their attention on anomalies – unusual or suspicious activity performed during the various phases of such attacks.

As a first step in compromising a network, cybercriminals often perform a type of reconnaissance activity to discover computers that are connected to the network, as well as services offered by these systems. The latter activity is referred to as network port scanning. The early detection of such activity can alert a host to an impending threat.

Research and development: An early warning system

Network intrusion detection experts at the CSIR have developed a prototype software package for personal computers that rapidly

and accurately detects port scan activity on hosts connected to a network. By automatically detecting network port scan activity, the technology creates an opportunity for that system to block all further network communication from the host, thereby containing the threat or keeping it from inflicting damage.

The researchers proposed a network port scan detection algorithm that uses a novel detection metric that involves the statistical modelling of connection attempts. It significantly improves the accuracy and the reliability of port scan detection as compared to a widely-used open-source intrusion detection system.

The technology's ability to accurately and rapidly detect network port scans was demonstrated on network traffic data recorded over three weeks on a segment of the CSIR's intranet.

The researchers used the technology to detect port scans that were injected into the recorded network traffic data. Port scans of different intensities were considered, including low-intensity port scans that are specifically designed to evade intrusion detection systems.

The technology was shown to outperform an existing system in terms of its accuracy in distinguishing port scans from ordinary network traffic. Future work will involve performance comparisons with other systems and improving overall accuracy.

The technology could facilitate rapid and improved containment of cyber threats in computer networks, thereby limiting the damage caused by these threats and ultimately saving the users time and money.

CSIR researchers developed technology to detect port scan activity, a type of reconnaissance activity that cybercriminals perform to discover computers that are connected to a network.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: ICT

In brief

As part of national initiatives to improve the country's cyberinfrastructure, specifically to provide high-speed connectivity to higher education and research institutions, the CSIR-hosted South African Research Network (SANReN) continued to improve the network through upgrades, backbone extensions, new metro networks and advanced services such as federated identity management.

Pervasive connectivity and bandwidth connectivity for South Africa's research community

The challenge: The limitations of commercial Internet connectivity for the education and research community

Affordable, quick and high-bandwidth Internet connectivity is critical for education and research institutions. However, such connectivity has not been available for the education and research community in South Africa due to the high costs associated with the speed and high bandwidth required.

CSIR research and development: Continually improving and expanding the country's research network

Government has over the past ten years invested in a dedicated national research and education network that is operated by the Tertiary Education and Research Network of South Africa (TENET) with the CSIR-hosted South African Research Network (SANReN) in charge of its rollout and the incubation of services that run on the network.

In the past year, SANReN and TENET continued to make progress in growing and upgrading the network and ensuring connectivity for the higher education research community. SANReN has connected a further 11 higher education and research sites, including the Walter Sisulu University campuses in Queenstown and Whittlesea, as well as the South African National Space Agency Space Science site in Hermanus. This brings the total number of sites connected to the network, to 210. The capacity of the links to various higher education and research sites were also upgraded, thereby growing the average bandwidth available per site from 2.8 Gbps to 3.5 Gbps.

SANReN has added the Mconf web conferencing tool that enables researchers to collaborate seamlessly. It uses web real-time communication, the latest technology in this area.

SANReN will extend the service to local researchers and innovators through its network.

The Mconf service has been particularly useful to the Human Heredity and Health in Africa (H3Africa) initiative. H3Africa scientists study genomic influences on disease across their continent, from differences in the progression of HIV in children, to developing new sequencing methods for the Ebola virus, to collecting more than 35 000 nasal swabs from children to show how concentrations of nose and throat micro-organisms may play a role in pneumonia.

H3Africa has a working group called H3ABioNet, which engages in education, training and in developing bioinformatics and genomics tools for research. Members of the network are spread all over Africa, from Tunisia in the north to South Africa, and from Morocco in the west to Sudan in the east. The network uses video conferencing extensively to bring members together on a regular basis. As an example, H3ABioNet recently held two video seminars focusing on big data. Two distinguished scientists presented talks focused on the current challenges, strategies and ongoing infrastructure and initiatives to deal with big data and genomics. The conference and the seminars were hosted on the Mconf service provided by SANReN.

CSIR spectrum management technology secures international recognition

A CSIR-developed dynamic spectrum management tool that makes it possible to efficiently allocate the amount of usable spectrum has received Ofcom certification. Ofcom is an independent regulator and competition authority for the UK communications industry.

Spectrum is the medium over which all wireless communications devices (televisions, mobile phones, tablets, radios, microphones and more) communicate. Television white spaces (TVWS) are the unused spectrum channels in the TV broadcasting frequencies. The CSIR has developed a tool that identifies and makes use of TVWS channels for broadband services without generating interference with adjacent primary licensed services. This harmonious co-existence between TVWS networks and TV broadcasting networks is made possible through a CSIR-developed technology, the white spaces spectrum database.

The certification of the CSIR-developed technology – after the extensive qualifications process by Ofcom – means that the CSIR's white space spectrum database can now be used to provide TVWS services in the UK. It also means that TVWS original equipment manufacturers can connect to the CSIR-developed white space spectrum database and get spectrum allocations through the Ofcom portal.

The CSIR-developed database was one of seven global spectrum databases that were certified as part of the same UK Ofcom process. This development makes it possible for the CSIR to assist the Independent Communication Authority of South Africa to efficiently manage and assign spectrum and to contribute to global standards in future wireless and dynamic spectrum access technologies.

The technology has also generated interest in Africa, and in 2015, the Botswana Institute for Technology Research and Innovation (BITRI) signed a research agreement to collaborate with the CSIR on dynamic spectrum access. BITRI is collaborating with the CSIR in building its own TVWS experimental network, as well as an instance of a geo-location database to harness its national spectrum resources. The CSIR is assisting in the design and deployment of the Botswana TVWS network test-bed and supporting information and communications industrialisation in Africa.

Agreeing to collaborate on dynamic spectrum access are, from left (back), Kagiso Keatimilwe, CSIR; Sikhonzile Sikhosana, DST; Nakale Kelapile, Botswana Institute for Technology Research and Innovation (BITRI); Moshe Masonta, CSIR; Dr Fisseha Mekuria, CSIR; Dr Ephraim Gower, BITRI; Moses Tsalaile, BITRI; and Dr Aubrey Mokotedi, BITRI. From left (middle) are Dr Ntsibane Ntlatlapa, CSIR; and Kagiso Chikane, CSIR. From left (front) are Dr Quentin Williams, CSIR; and Prof. Thato Tsalaile, BITRI.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: WATER

In brief

South Africa is a water-scarce country, which makes the management and conservation of our water infrastructure vital. In response, the CSIR has developed a five-year water science plan which determines research priorities that focus on the development of methods to determine water risks and tools to improve and protect the quality and quantity of our water resources.

A CSIR researcher collects a water sample at the Motetema wastewater treatment works in Sekhukhune District Municipality in Limpopo.

Building new and conserving natural infrastructure for a water-safe future

The challenge: Sustained water supply

According to the Department of Water and Sanitation's 2013 Strategic *Overview of the Water Sector in South Africa*, the current utilisation of water resources exceeds reliable yield. This means that during years with lower than average rainfall, it is likely that the country will experience water shortages, as were seen in many parts of the country in 2015. Poor governance, wastage, leakages, inefficient use, and distribution of water resources exacerbate the crisis.

Furthermore, South Africa's investments in the construction and maintenance of engineered water infrastructure will be undermined in the long run if we do not protect the limited ecological infrastructure that provides us water, according to an earlier report by WWF South Africa, titled *Defining South Africa's water source areas*, which maps South Africa's key water sources.

Research and development

In support of national efforts, the CSIR is directing its resources to several research and development projects that focus on water governance, wastewater treatment and understanding the role of ecological infrastructure.

Using algae to treat wastewater

The CSIR initiated an algae-based wastewater treatment project at the Motetema wastewater treatment works in the Sekhukhune District Municipality in Limpopo to facilitate the effective and efficient removal of nutrients and pathogens in wastewater treatment works.

Wastewater treatment works in South Africa are facing significant challenges, mainly due to ageing infrastructure, insufficient technical skills and limited financial resources. Inefficiently treated wastewater which is released into rivers poses a risk to the environment and human health in downstream communities.

The algae-based treatment, which was implemented in existing treatment ponds in Motetema, uses a specific community of algal species, which have been isolated and cultured in the laboratory. The algae remove nutrients which they need for their growth from the water. They also create unfavourable conditions for pathogens and *E. coli* bacteria by increasing the pH level of the water.

CSIR researchers are training the operators of the ponds and have developed a manual with operational and maintenance guidelines, which can be used by municipalities to manage algae-based wastewater treatment systems.

The final stage of the project will include the introduction of fish to consume algae and residual pathogens with the added benefit of creating an aquaculture (fish-farming) venture.

Restoring wetlands

In a study published in the journal *Ecological Indicators*, researchers from the CSIR and Stellenbosch University (SU) demonstrated, by successfully rehabilitating a wetland near Emalahleni in Mpumalanga, that certain types of freshwater algae are useful bioindicators for wetland rehabilitation. Algae are sensitive to changes in the environment, particularly to the pH level of water. Depending on the species, they thrive at different pH levels and their presence or absence therefore indicates water quality. The Grootvlei valley bottom wetland is heavily impacted by acid mine drainage from an abandoned coal mine upstream and effluent from an industrial steel plant.

The researchers rehabilitated the wetland by expanding the existing wetland area through the redirection of surface flow at the point of entry of the wetland using concrete structures. Concrete structures rather than the conventional rock-filled wire basket-like structures were necessary due to the acidic and corrosive nature of incoming water. These structures slowed down and redirected water flow.

Water and algae samples were taken over a period of two years.

Through the study it was evident that the increased size of the wetland, which slowed the flow and increased the contact time between water and sediment, improved the water quality downstream. This resulted in an increase in the species diversity and richness of algae after rehabilitation. The algae were sensitive to the change in the wetland and were found to be good indicators of the water quality. The wetland monitoring continues.

Protecting the Dwars River

The Dwars River is a tributary of the Berg River which is a major source of water to the Cape Town metropolitan area. Through their engagement with the agricultural community in the area, researchers from the CSIR and the SU identified two major water quality issues: nutrient enrichment that stimulates the growth of filamentous algae that clogs crop sprayers as well as *E. coli* pollution. *E. coli* contamination in the Berg and Dwars Rivers periodically exceeds the European Union's allowable standards for food production.

The researchers found that the river is highly phosphate sensitive and does not have an efficient ability to self-purify. They found that pollution control systems are urgently required and suggested the implementation of artificial floating wetlands – for example reeds that are planted in a floating mat – in the two saturated sewage waste water ponds in Pniel to assist with nutrient removal. The researchers also investigated the viability of tradable permits for green algae pollution, basically purchasing a 'right to pollute' a certain amount. The more a farm or plant pollutes, the more it needs to contribute toward the management of green algae blooms, a strategy never before implemented in South Africa. This work was recently published in the *Journal of Environmental Management*.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: OCEANS

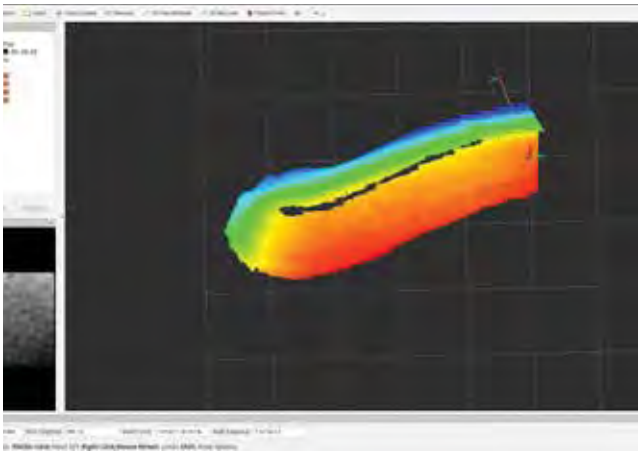
Automating breakwater inspections

The CSIR has developed a software package and a simulator as part of a proposed approach to breakwater inspections using aerial vehicles.

Breakwaters are rubble mounds with dolos-armouring that protect the entrances to ports. The CSIR currently monitors the breakwaters, and reports on their condition under contract to the Transnet National Ports Authority. However, these existing monitoring methods are both time-consuming and expensive. Engineers visit the ports, conduct physical inspections and photographically document the state of the port, but sometimes inspections are cancelled due to bad weather conditions. Once captured, the photographic data need a significant amount of manual processing as experts attempt to compare images over time to see if any dolos units have moved or broken.

The CSIR investigated options for autonomous breakwater inspection and recommended that 3D models of the breakwater be obtained by mounting a 3D camera on a drone. Researchers developed a software suite that allows for an aerial vehicle, such as a drone, to be controlled manually and autonomously, as well as to perform 3D mapping. Implementation of the proposed solution would allow for overlapping scans of breakwaters to be obtained reliably and repeatedly at lower operational cost. It would also make it possible to construct a complete three-dimensional model of the breakwater, which would also simplify the change monitoring process. They developed a simulator to test the software.

Trials conducted at the CSIR's coastal and hydraulics laboratory in Stellenbosch confirmed the feasibility of the approach and the next step will include the testing of the approach on suitable platforms in real-life conditions.



Breakwater spurs (below) are used to protect a harbour or shore from the force of the waves. A 3D reconstruction of a scale breakwater spur (above) is formed by incrementally registering overlapping 3D scans while estimating the motion of the camera at the same time, using a robotics technique called simultaneous localisation and mapping. Red areas of the spur represent breakwater armour regions closer to the viewer, while blue areas are further away.

Research, development and implementation for

ECONOMIC AND SOCIAL INFRASTRUCTURE: OCEANS

Assessing the ecological significance of contaminants in sediments

The CSIR, in partnership with the Engineer Research and Development Centre of the United States Army Corps of Engineers, is evaluating the use of various approaches to assess the ecological risk posed by the dredging and disposal of contaminated sediment, using the Victoria and Alfred Basins in the Port of Cape Town as a case study.

The research findings will be used to advise the Department of Environmental Affairs, which is responsible for regulating the disposal of dredged material in South African marine waters, as well as Transnet National Ports Authority, which manages South African ports, on tools that can be used in the short- and long-term to determine if sediment identified for dredging in South African ports is of a suitable quality for disposal offshore, and to identify ecological risks associated with various management options.

Dredging is an excavation activity that involves gathering underwater sediment to keep waterways navigable or to enlarge existing shipping channels or terminals where ships load and unload. Typically the sediment is disposed of at a different location.

Various forms of physical, chemical and biological evidence were used to assess the quality of sediment in the basins and the ecological risk posed by sediments and its simulated dredging and disposal.

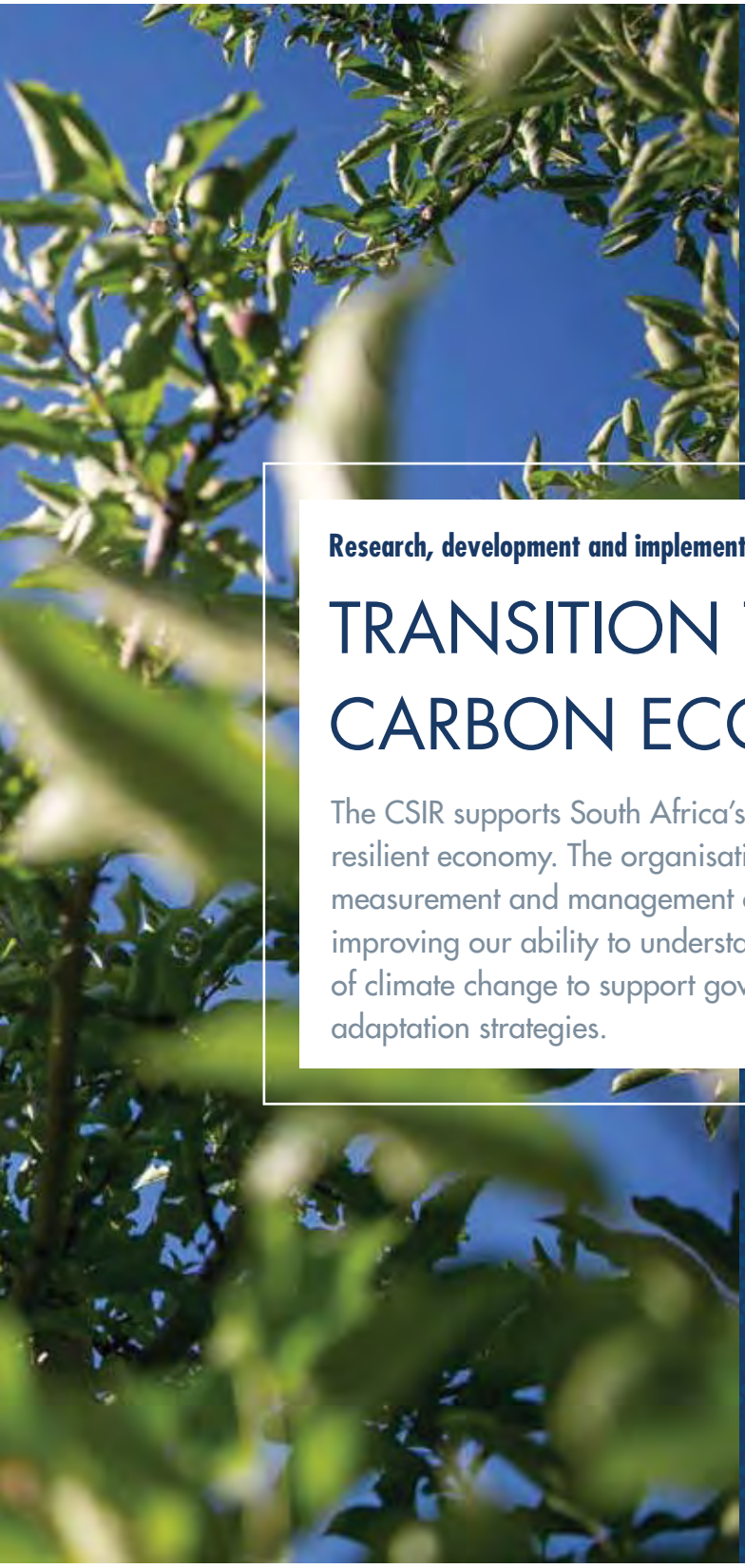
Bottom sediment collected at 12 locations across the Victoria and Alfred Basins was analysed for a wide range of potential chemical contaminants, including metals, oils, pesticides and polychlorinated biphenyls. The toxicity of the sediment and particles was tested under controlled conditions in the laboratory, using amphipods and mysids (two types of small shrimp-like crustaceans that are sensitive to water pollution).

The structure and composition of the organisms that live in or on the bottom of sediments were also evaluated.

The relationship between sediment contaminant concentrations, toxicity and the structure and composition of the organisms that live in or on the bottom of the sediment will be used to determine if the various tools provide complementary information.

CSIR researchers collected sediment at 12 locations in the Victoria and Alfred Basins in Cape Town for analyses to determine the ecological risk posed by the dredging and disposal of contaminated sediment.

The CSIR is collaborating with the Water Research Commission, the South African Apple and Pear Producers' Association, the Agricultural Research Council and the universities of Pretoria and Stellenbosch to refine estimates of the water requirements of high-yielding apple trees in the Western Cape. This collaboration enables all aspects of water management and fruit production practices to be comprehensively addressed in estimating the water use of these apple orchards. Previous studies on tree water use quantified the water requirements of apple orchards, but these were not exceptionally high-yielding orchards. In this study, researchers are looking at a broad range of methods to refine estimates of water use and to reduce uncertainties in the estimates of the water requirements of apple orchards.



Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

The CSIR supports South Africa's transition to a low-carbon, resilient economy. The organisation works on improving the measurement and management of our natural resources and improving our ability to understand the long-term effects of climate change to support government's mitigation and adaptation strategies.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

In brief

Climate change is the most serious collective environmental challenge ever faced by humankind. Failure to mitigate its impact and to adapt to it will reduce our ability to provide food and secure our livelihoods. The CSIR is developing the first African-based earth system model to provide reliable projections of the potential impact of climate change on the African continent. This will help answer questions such as what might happen to the local climate if greenhouse gas concentrations continue to increase, as well as whether or not climate change will result in the more frequent occurrence of strong El Niño events and drought in southern Africa.

The amount of computing power required to enable CSIR climate modellers to participate in the Coupled Model Intercomparison Project six-registered group of the World Climate Research Programme is considerable, amounting to tens of millions of central processing unit hours. This computing power is provided by the CSIR-hosted Centre for High Performance Computing.

Science contributes to climate change preparedness

Challenge: Inadequate models to shed light on climate variability in Africa

Only one out of the 30 earth system models in use was developed in the southern hemisphere and therefore very few models can provide an adequate understanding on climate variability in Africa and the Southern Ocean, which is extremely important for global climate regulation.

The current global models display southern hemisphere data at a resolution of 50-200 km, as opposed to northern hemisphere data at 1-10km. This resolution is inadequate for scientists in the southern hemisphere to understand the dynamics. The model being developed by CSIR climate modellers and oceanographers will include processes at a resolution of 1-10 km, which will enhance the sensitivity of the model regarding the ocean and land in the southern hemisphere. This will also make the decadal and centenary projections more accurate and allow CSIR climate modellers to model processes that respond quickly to change, similar to monitoring a patient's breathing and heartbeat.

The research and development: An African-based earth system model

The CSIR has begun the development of the first African-based earth system model. This will be a coupled model – it

incorporates the physics and chemistry of the atmosphere and the oceans to enable accurate and more realistic climate projections for Africa. The multidisciplinary effort is driven by CSIR experts in the fields of global change, high-performance computing, and modelling and digital science.

In 2015, the CSIR officially became a Coupled Model Intercomparison Project six-registered (CMIP6) group of the World Climate Research Programme. The CMIP6 is an experimental design for a framework for global climate change modelling until 2020. The CSIR is the first CMIP-registered group in Africa, meaning that the sixth assessment report of the Intergovernmental Panel on Climate Change will, for the first time, contain African-derived projections of future global climate change. The report assesses the evidence of climate change that has occurred to date, combines climate change projections obtained from all leading climate change institutions globally and converts the information collected into a set of plausible climate futures.

The CSIR's investment in the development of this model is aimed at informing the country's adaptation strategies for climate change. Projections generated by the CSIR have directly informed the Intended Nationally Determined Contributions that South Africa has submitted to the 21st Conference of the Parties of the United Nations Federation Convention on Climate Change. The models have also informed the national communication on climate change of South Africa.

Research and development: Incorporating climate change resilience into business plans

To help counter the threat of climate change, South African businesses need to potentially change the way they operate, and one of the ways they will start doing this is by changing their business plans and strategies. The CSIR has partnered with PricewaterhouseCoopers to define seven resilience principles that help embed a resilience approach in business strategy, management and reporting. The principles were developed in a series of workshops with a multidisciplinary team made up of specialists from various backgrounds, including auditing and reporting, ecology, social science, business management and resource economics. Interviews were also conducted with 10 companies from different industries that are considered leaders in integrated reporting.

The seven principles: Systems, risk and adaptation, decoupling, restoration, wellbeing, collaborative governance, and innovation and foresight, ensure that a business is better equipped to continue operating and creating value in the short- and long term, respond to opportunities arising from change and anticipate, identify and adapt to change.

The principles are underpinned by the goal of sustainable development and their application is enabled by a series of worksheets, which allows businesses to assess the extent to which they are currently addressing resilience.

Southern Ocean and global climate regulation

Considered the lungs of the planet, the Southern Ocean – a key area of focus in the model development process – is a fundamental part of regulating the global climate. Increasing concentrations of carbon dioxide accelerate climate change, but the current climate models are unable to provide an adequate understanding of how this will be affected by potential changes in the carbon flux over the Southern Ocean under climate change.

The Southern Ocean plays a big role in how the global climate works. The importance of the Southern Ocean in regulating global climate is underscored by three big numbers:

- 80% of the total heat uptake of the global ocean is through the Southern Ocean;
- 50% of carbon dioxide uptake of the global ocean is through the Southern Ocean; and
- 75% of ocean productivity outside of the Southern Ocean depends on nutrients delivered by the Southern Ocean.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

In brief

Implementation of the waste research, development and innovation (RDI) roadmap, which will guide South Africa's public and private sector investment in waste RDI over the next 10 years, has commenced. The focus is on supporting waste-related research, development and innovation, strengthening partnerships across government, business and academia, as well as unlocking local and international opportunities for co-investment in waste and secondary resources research.

Small-scale entrepreneurs sorting recyclables.

Diverting waste from landfill towards value-adding alternatives

The challenge: Reducing generation of waste at source

The final disposal of products after use by consumers is regarded as the weakest link in the product value chain. An estimated 90% of all waste produced in South Africa ends up at a landfill, despite a strong policy approach towards establishing a regional secondary resources economy based on recovery and reprocessing of recyclable waste. The ongoing disposal of waste to landfill is driven by the high cost of prevention, reuse, recycling and recovery of waste, relative to the low cost of disposal of waste to landfill.

Research and development: Supporting a 10-year Waste RDI roadmap for South Africa

In 2012, the Department of Science and Technology (DST) and the CSIR embarked on a process to develop a waste RDI roadmap to guide South Africa's public and private sector investment in waste RDI over the next 10 years. The roadmap was published in early 2015.

With an investment ask of approximately R3.9 billion over the next 10 years, the successful implementation of the roadmap is expected to assist government and industry in significantly increasing the diversion of waste away from landfill towards value-adding alternatives, through more effective decision-making, faster insertion of context-appropriate technology, strengthened RDI capability and capacity and the transfer of know-how and technology.

The CSIR has been contracted by the DST to implement the roadmap, and will drive a process to strengthen South Africa's human capital in this area, research and development, and innovation through grants and university scholarships.

Nine scholarships were awarded – eight for Master's and one for a doctoral degree following two-post graduate scholarship calls for the 2016 academic year. The scholarships focus on issues aligned with the six clusters and five priority waste streams of the Waste RDI Roadmap.

In addition, 10 waste-related research projects and one technology upscaling project, with a total investment ask of R14.8 million, were awarded to South African universities and science councils.

Incorporating waste pickers into the South African economy

CSIR waste experts are also investigating ways in which informal waste pickers can be integrated into the waste and recycling economy. Through regional workshops, the CSIR and its partners, the Department of Environmental Affairs, Amalgamated Beverages Industries, Green Cape and the Institute of Waste Management of Southern Africa have explored current views on the integration of the informal sector into the waste and recycling economy in South Africa.

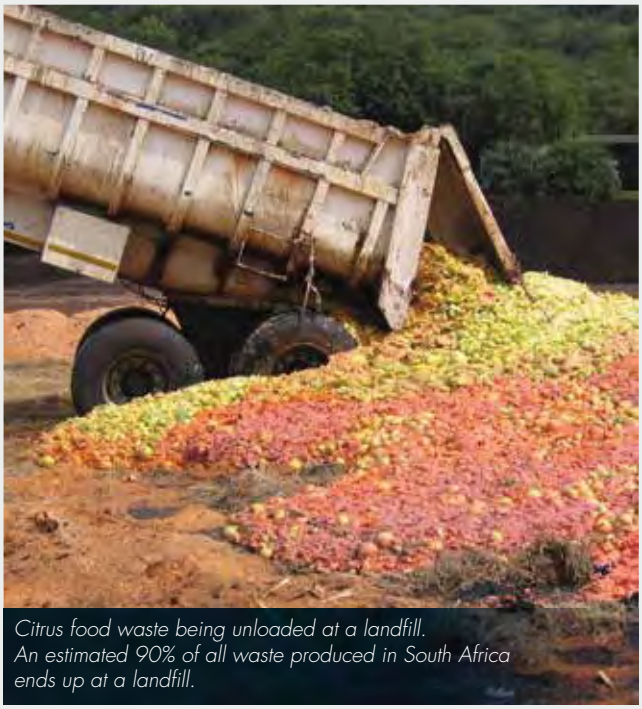
Representatives from business, government (local, provincial and national) and academia gave their views on the role of the informal sector in the recovery of recyclable waste from municipal solid waste. This issue is significant, especially with the proposed implementation of an Extended Producer Responsibility (EPR) policy in South Africa for certain waste streams. The EPR shifts the responsibility for the management of certain waste streams from government to waste producers. If not responsibly designed and implemented, these EPR schemes could compromise the livelihoods of 60 000 to 90 000 waste pickers.

Four scenarios regarding the integration of the informal sector emerged from these workshops: Using the informal sector in its current format, as a largely marginalised and unregulated community, recovering value at little to no cost to the value chain; integrating the informal sector into recycling programmes, with some level of regulation and monitoring, including increased support from business and industry; formalising the informal sector through the establishment of cooperatives and small-to-medium enterprises by government and business; or absorbing the informal sector through a labour-intensive process, based on an employment model led by the formal waste and recycling sector. This research has been provided to the paper and packaging sector to inform the development of an appropriate Industry Waste Management Plan for South Africa. Further research on this topic, to be conducted by the University of the Witwatersrand, is being supported through Waste RDI Roadmap grant funding, managed by the CSIR.

Quantifying the cost of food waste in South Africa

The CSIR estimated that in 2013, South Africa lost R71.4 billion through inedible food waste. Researchers had developed a model to derive the cost per ton of the inedible food waste. The model takes into account the costs of inedible food waste disposed of at landfills.

The model is based on an estimate of the opportunity costs of this waste – in particular the value that could have been acquired had the food been used for bio-energy generation, composting and the production of animal feed. The CSIR-developed model will help municipalities, government officials and private businesses assess and understand the total cost of food waste in South Africa. The costs should be compared to the rates for substitutes to landfilling to make informed decisions regarding waste management alternatives.



Citrus food waste being unloaded at a landfill. An estimated 90% of all waste produced in South Africa ends up at a landfill.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

Determining the water requirements of KZN farmers

CSIR researchers have worked with the Department of Water and Sanitation to determine how much water is being used by farmers in KwaZulu-Natal and how much is required for irrigation, commercial forestry and other activities. A series of maps detailing this water usage is being produced as part of this project.

The project specifically focuses on commercial farms in the province, given that agriculture uses more than 60% of the country's water resources. The information will be used by the department to update the Water Use Authorisation Registration Management System.

The validation component of the project involved the CSIR generating a database of crop types and their water requirements on each identified property before asking users to submit further information to validate the data. Information required included types of crops or forest land uses on each property, the extent of each land-use type, total irrigated area for each crop type, reservoirs presence and current water use.

Earth observation technologies were used to determine the extent and types of crops and plantations, as well as reservoir areas for current and historical periods. CSIR hydrologists were able to determine the water requirements and estimate the capacity of farm reservoirs using remote-sensing data.

In 2015, the project team commenced with the verification component of the project. This involved hosting stakeholder sessions in the province where farmers assisted in verifying the information collected through the validation component. The maps will contain detailed information on what crops are being planted where and how much water is needed for irrigation purposes. This will assist the province with long-term planning of water resources.

Agricultural activities in South Africa, such as those undertaken on this farm in Underberg, KwaZulu-Natal, consume more than 60% of the country's water.

Stakeholder engagement sessions were held to verify information collected on the water use of KwaZulu-Natal farmers.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

A green economy project design and implementation framework for agriculture

The CSIR has developed a green economy project design and implementation framework for the agricultural sector. The framework assists the South African agricultural sector to smoothly transition to implementing projects that adhere to the requirements of a green economy.

The green economy is a vision that aims to improve people's lives through sustainable development. Its purpose is to promote economic, environmental and social well-being.

The CSIR-developed framework consists of two components. The first component is a three-step process for identifying, distilling and integrating the issues that are at the core of an agricultural green economy. The second component is a six-step project design and implementation process.

The first three steps aim to develop an understanding of what a green economy entails, define the objectives of the project and identify the success factors and related actions for the project. The next three steps aim to develop a monitoring and evaluating plan, to define the project risks and challenges and identify ways to manage them. The framework provides a format for dealing with diverse factors while allowing flexibility for application in specific contexts.

The framework was developed using a case study of small-scale vegetable farming in the Tzaneen Local Municipality, in Limpopo. The aim was to assess opportunities available for rural communities to transition to a green economy founded on small-scale, crop-based agriculture in South Africa.

The study revealed that small-scale agriculture is an underutilised asset that could drive South Africa's green economy and provide the unemployed with an opportunity to participate in the country's economy.

The CSIR developed a green economy project design and implementation framework for the agricultural sector using a case study of smallscale vegetable farming in the Tzaneen Local Municipality in Limpopo.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

Pioneering geophysical monitoring of acid mine drainage

The CSIR is assessing the use of electrical resistance tomography (ERT) as an alternative to on-going borehole monitoring of acid mine drainage in the Cradle of Humankind, a World Heritage Site north-west of Johannesburg in Gauteng. The limited number of monitoring boreholes and the karst environment, characterised by caves and sinkholes, have contributed to the need to improve the lateral delineation of the contaminated groundwater.

By using ERT and borehole monitoring as part of a water resources monitoring programme, researchers hope to determine changes in the quality of groundwater in the area. High sulphate levels exceeding 1 000 mg per litre of water have a negative impact on the local ground water resources. The ERT method is similar to medical imaging methods such as electrical impedance tomography. In ERT, a line of approximately 50 electrodes or metal stakes, connected with multi-core cables to a control unit, are embedded in the ground. A survey involves injecting electrical currents into the earth using a pair of electrodes and measuring the resulting potential differences using several other electrode pairs. This process is repeated in a systematic way for a few hundred different electrode pairs.

ERT surveys produce two-dimensional images of the subsurface electrical resistivity structure. These images can then be used to make inferences about the subsurface geological or geohydrological structure. The plan is to annually conduct the ERT surveys in an attempt to detect transient changes in groundwater quality.

The implementation of ERT is expected to significantly contribute to the monitoring of the water quality and the impact of acid mine drainage on groundwater systems downstream of the Bloubank Spruit, an agricultural and heritage site close to the Cradle of Humankind. The future outcomes of the study will determine if ERT is a suitable technique for monitoring acid mine drainage.

CSIR researchers are monitoring water quality and the impacts of acid mine drainage on groundwater systems using electrical resistance tomography. The pilot study is in the Cradle of Humankind and will determine the success of this method.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

Annual standards for air pollutants in the Vaal Triangle exceeded

The CSIR, on behalf of the Department of Environmental Affairs, conducted a study in the Vaal Triangle Air-shed Priority Area to determine if air pollution levels exceed South African air pollution standards.

Areas within the Vaal Triangle Air-shed Priority Area include the local municipalities of Emfuleni and Midvaal in Gauteng, the administrative regions of Doornkop and Soweto, Diepkloof and Meadowlands, and Ennerdale and Orange Farm within the City of Johannesburg, and the Metsimaholo Municipality in the Free State. Four monitoring stations in the area collected data from 2013 to 2015. The outdoor concentrations of air pollutants, specifically nitrogen dioxide, sulphur dioxide and particulate matter were measured at the stations on a real-time basis.

The measured ambient pollutant concentrations showed that the concentrations of nitrogen dioxide and particulate matter exceeded the legal standards in some areas. The South African annual standard for nitrogen dioxide is 21 parts per billion and for particulate matter with a diameter of 10 micrometres or smaller, 40 micrograms per cubic metre. The outcomes revealed that, in 2013, the annual average nitrogen dioxide levels were exceeded in the Zamdela area (over 23 parts per billion), Diepkloof (over 37 parts per billion) and Kliprivier (over 21 parts per billion). Annual average particulate matter levels in Kliprivier, Sebokeng, Three Rivers, Sharpeville and Zamdela were all above 45 micrograms per cubic metre. Sulphur dioxide did not exceed the South African annual standards.

The sources of air pollution in the Vaal Triangle are coal mines, industries, power stations and vehicles. Exposure to nitrogen dioxide and particulate matter may lead to an increase in all-cause mortality, a decline in lung function, an increase in susceptibility to respiratory illnesses, stroke and heart conditions.

CSIR researchers used monitoring stations to measure the outdoor concentrations of air pollutants on a real-time basis.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

Developing an investment framework for environmental and natural resource management

The CSIR has developed a framework for investment in environmental and natural resource management (ENRM) for a green economy in South Africa. The aim of the framework is to inform the ENRM funding window of the Green Fund. However, its relevance extends to investment in environmental and natural resource management in the country more broadly.

The Green Fund was established by the South African government through the Department of Environmental Affairs and it is managed by the Development Bank of Southern Africa. It provides catalytic finance for initiatives that can assist in the country's transition to a green economy. The Fund's ENRM window specifically aims to support projects and programmes that protect and enhance biodiversity and the resilience of the country's ecosystems. Through this window, the Green Fund seeks to capitalise on the job creation potential of the natural resource management sector.

The development of the framework was guided by interviews conducted with representatives from 18 organisations, including government institutions and private companies. The proposed investment framework includes four themes with related short-, medium- and long-term recommendations. The purpose of the first two themes is to enhance governmental coordination of the country's transition to a green economy, as well as to enable greater private sector investment in ENRM. Theme 3 focuses on supporting a practical understanding of the opportunities and constraints to operationalising the principles of a green economy in the restoration of ecological infrastructure. The fourth theme focuses on increasing technical and financial support for small businesses in the biodiversity economy.

Investigating biofuel potential in sub-Saharan Africa

As part of an international team, led by the United Nations University World Institute for Development Economics Research, the CSIR has set out to provide clear empirical evidence about the conditions under which biofuel production and use can improve human well-being and become an agent of poverty alleviation in the region.

Although several southern African countries have made efforts to stimulate their biofuel markets through domestic policies, most produce and consume little or no biofuel.

The team is assessing whether or not expanding the biofuels market through regional market integration outperforms a scenario where each country sets up its own markets.

The research seeks to understand how growing biofuel markets can interact with the rest of the international economy and compete or complement alternative choices for energy sources and land use. The CSIR's work has a particular focus on the parameters for possible biofuel production in the region, including which technologies and crops can be mobilised for future biofuel industries.

The research continues and results of these biofuel studies will be disseminated to local and regional biofuel producers, policymakers, practitioners, academics and other interested stakeholders.

Research, development and implementation to

TRANSITION TO A LOW-CARBON ECONOMY

Industry saves energy, water and waste through the work of the NCPC-SA

The manufacturing sector continues to realise energy, water and waste savings through National Cleaner Production Centre of South Africa (NCPC-SA) programmes. During 2015/16, the NCPC-SA assisted companies to achieve R75 million in resource savings and identified R232 million in potential savings through resource efficiency and cleaner production assessments. In the first seven months of implementation of the Industrial Symbiosis Programme, 244 tons of waste were diverted from landfill by six companies.

Industrial symbiosis is a resource efficiency approach where unused resources of one company are used by another. The NCPC-SA runs an industrial symbiosis programme in Gauteng and KwaZulu-Natal. After a twelve-month process of matching companies and their wanted and unwanted resources, the programme began facilitating waste exchanges in Gauteng in September 2015.

The exchange of 244 tons of primarily polyethylene, polystyrene and construction rubble resulted in financial savings of R406 000 and reduced virgin resource use by 220 tons. These are the first savings through a programme that promises significant environmental, social and economic benefits in both provinces.

Energy savings continue to mount through the NCPC-SA's Industrial Energy Efficiency (IEE) Project. Between 2010 and 2015, the IEE Project delivered savings of 1 800 GWh of energy in participating companies – enough energy to power 280 000 homes for one year. Financial savings resulting from these interventions now stand at R1.54 billion, with greenhouse gas emissions mitigation of 1.2 million tons of carbon dioxide equivalent.

New initiatives by the NCPC-SA include a focus on industrial water use and the Switch Africa Green project, aimed at supporting small and medium enterprises in the transition to a green economy.

The NCPC-SA is a programme of the Department of Trade and Industry, hosted and implemented by the CSIR.

The Consol Glass plant in Nigel saved R6.32 million in energy costs from July 2014 to July 2015.

The CSIR is contributing to the development of strategies, doctrine and technologies to counter environmental crimes, such as wildlife trafficking, poaching and illegal trade in animal products.

Research, development and implementation to

BUILD SAFER COMMUNITIES

CSIR interventions in support of national security include supporting technology integration by the security forces, as well as developing systems for information sharing, national surveillance and protection against cyber-security threats.

Research, development and implementation to

BUILD SAFER COMMUNITIES

In brief

The CSIR and its collaborators continue to develop and help implement technology interventions to stem the tide in wildlife crime, specifically rhino poaching.

Increased incidents of environmental crime called for the CSIR to intensify its involvement in environmental asset management – a multidisciplinary domain focusing on safeguarding all natural riches.

A multidisciplinary response to wildlife crime

The challenge: Rhino poaching

South Africa's rhino population continues to be under threat from poachers and the flourishing illegal trade in rhino horn. The CSIR is committed to collaborate, advise and develop technologies to support counter-poaching groups.

Research and development: A multidisciplinary intervention to reduce rhino poaching

Predictive modelling to help focus counter-poaching efforts

Poachers continuously change their tactics. Organisations involved in counter-poaching efforts have to anticipate these changes to be effective. CSIR researchers developed a predictive modelling tool to assist rangers in the Kruger National Park to focus their resources on the areas where incursions were most likely to take place.

The Kruger National Park is one of the hardest hit areas in South Africa, losing elephant and rhino at an alarming rate. The Park is known for being difficult to patrol due to the vast land area to be covered with limited ranger capabilities, varying landscapes and extreme weather conditions.

The predictive modelling tool utilises a statistical model based on expert knowledge and a data driven model, which is used for making predictions. By using data mining, algorithms are deployed to find patterns within poaching data. By recognising patterns in poachers' behaviour, counter-poaching efforts can be directed to specific areas of interest. This moves forces from being reactive, to being more focused and proactive in their counter-poaching tactics.

Investigation of electro-optic systems for wide area surveillance in the Kruger National Park

In 2014, SANParks asked the CSIR to provide programme and project management, systems engineering and design support for a security system to be implemented in the Kruger National Park. In response, the CSIR has evaluated various perimeter intrusion-detection systems and ranger-mobility systems. Field trials were conducted to establish the feasibility of radar systems in conjunction with electro-optic systems that can be used for wide area surveillance to detect and classify possible threats.

Assisting the frontline

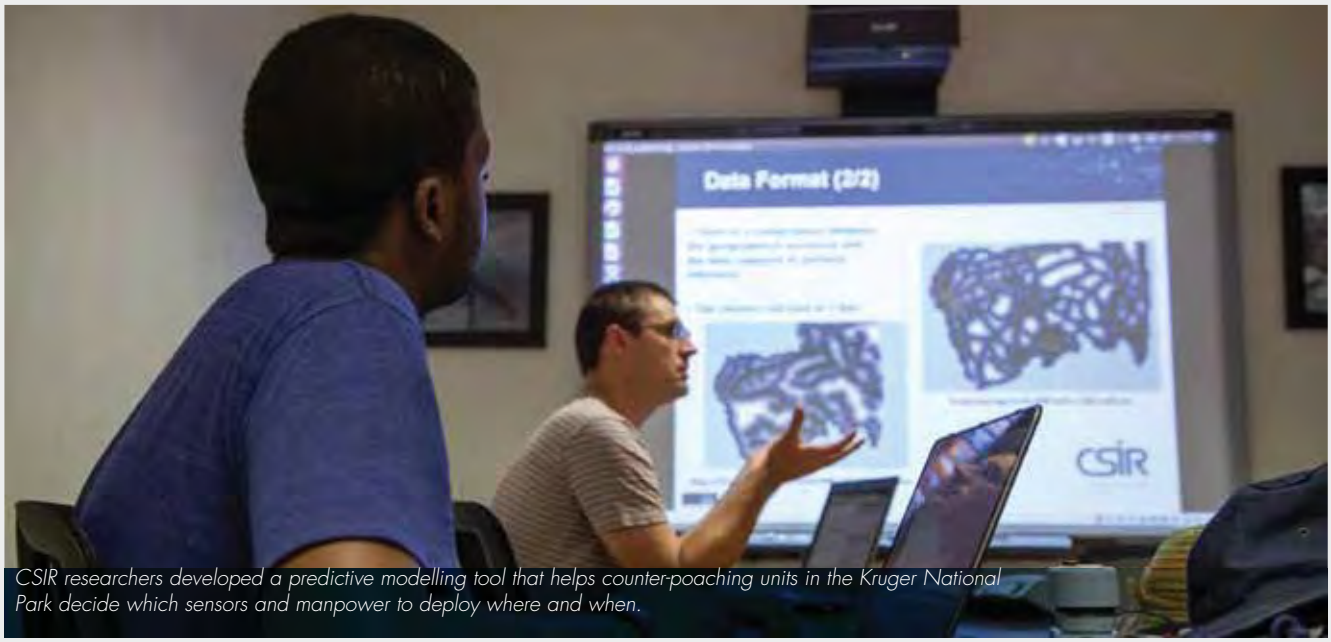
In an effort to improve the effectiveness of rangers, the CSIR evaluated their tactical field equipment such as weapon systems and night vision devices.

CSIR researchers with experience in working with special operations groups also assisted conservation groups with doctrine development and risk analysis in environmental crime. With longstanding partner StopRhinoPoaching.com, the CSIR hosted workshops aimed at informing rangers on readily available technologies that can assist in their missions. The CSIR also helped SANParks optimise the use of dogs in detecting fire-arms, ammunition and endangered animal material such as rhino horn or ivory.

Secure communications between groups is also a matter of concern and the CSIR partnered with StopRhinoPoaching.com and Seecrypt to provide security groups with a communication platform that is protected against hacking and interception. The platform provides for secure voice communication and messaging. There are currently more than a hundred Seecrypt users who are involved in counter-poaching efforts.

Whole-of-government approach

System engineers at the CSIR designed a whole-of-government approach to help address the onslaught on the country's natural assets, which include abalone, rhino horn and ivory. This entailed that they assess the problem from all levels in society – national, community and individual. In a multidisciplinary approach, they bring together the skill sets of environmental asset management specialists, engineers as well as natural and social scientists to look at the problem from their own perspectives and contribute to a more comprehensive view of the challenges. Through various workshops held over the year, diverse stakeholders involved in counter-poaching started to align their efforts for effective solutions.



CSIR researchers developed a predictive modelling tool that helps counter-poaching units in the Kruger National Park decide which sensors and manpower to deploy where and when.

Research, development and implementation to

BUILD SAFER COMMUNITIES

In brief

The CSIR has developed a multi-purpose electronics pod that evaluates and tests radar and electronic warfare systems in flight. The modular payload can be reconfigured for various research, test, evaluation and training scenarios.

The CSIR-developed radar and electronic warfare test and evaluation pod takes to the skies on a Hunter Hawker jet aircraft.

New electronics testing platform proves its mettle in flight

The challenge: Testing airborne electronics

Radar and electronic warfare are critical elements of a defence capability, and require specialist infrastructure to accurately measure and analyse targets and to test the effectiveness of countermeasures. While laboratory tests are useful indicators of a system's performance, the ultimate test of systems for aircraft is in-flight performance validation.

Research and development: Experimental platform for airborne electronics takes to the sky

In September 2015, the CSIR took a first-of-its-kind radar and electronic warfare test and evaluation pod, called Inundu pod, from a research laboratory environment to the sky. The pod was installed on a Hunter Hawker jet aircraft and successfully flight-tested against CSIR radar and electronic warfare systems.

Inundu pod is designed to cater for electronic warfare test and evaluation, and electronic support applications. It serves as an experimental platform for airborne electronics, the benefit being that these electronics can be rapidly implemented and flight-tested without requiring hardening or extensive flight clearance processes.

The pod can be utilised to evaluate the performances of electronic warfare and radar systems by, for instance, simulating anti-ship missiles. By interfacing with ground control stations via a telemetry link, the same scenario can also be used to train electronic warfare and radar operators against airborne threats. Exercises such as these assist with operational support for doctrine development and optimisation, as well as acceptance testing of new systems.

Inundu pod interfaces with a base station via a telemetry link for in-flight control. The pod's on-board equipment includes an inertial measurement unit used for determining position and velocity in space and time, as well as a global positioning

system, which enables scripted, waypoint programming of modes and techniques. This means that the pod can perform according to pre-established behaviour based on defined conditions. For example, the pod will automatically switch on at a certain distance from the target base stations and switch off at another predefined distance.

For the instrumented test flight, the pod was powered by batteries housed in a second pod that was symmetrically mounted on the aircraft, but a platform-independent power supply is being developed. The simulator hardware in the pod is based on technology developed by the CSIR.

A platform to train radar and electronic warfare engineers

As part of an industry development project that aims to allow engineers who own or are employed by small, medium or micro enterprises (SMMEs) to work alongside seasoned CSIR engineers to further develop their skills, two engineers from Sovereignty Systems joined the CSIR team during the development of the pod.

Special focus is placed on developing the radar and electronic warfare sector in South Africa as it has been identified as a sovereign capability in the 2014 Defence Review. The CSIR aims to contribute to this capability by developing the country's intellectual and skills capital in the radar and electronic warfare domain.

Upping SA's readiness levels

The South African National Defence Force has an extensive and diverse border to protect from land, air and maritime threats. Radar and electronic warfare measures and counter-measures can provide forces with much-needed information during safety and security operations. Technology such as the Inundu pod significantly contributes to the training of operators and the development of technologies used in border safeguarding.

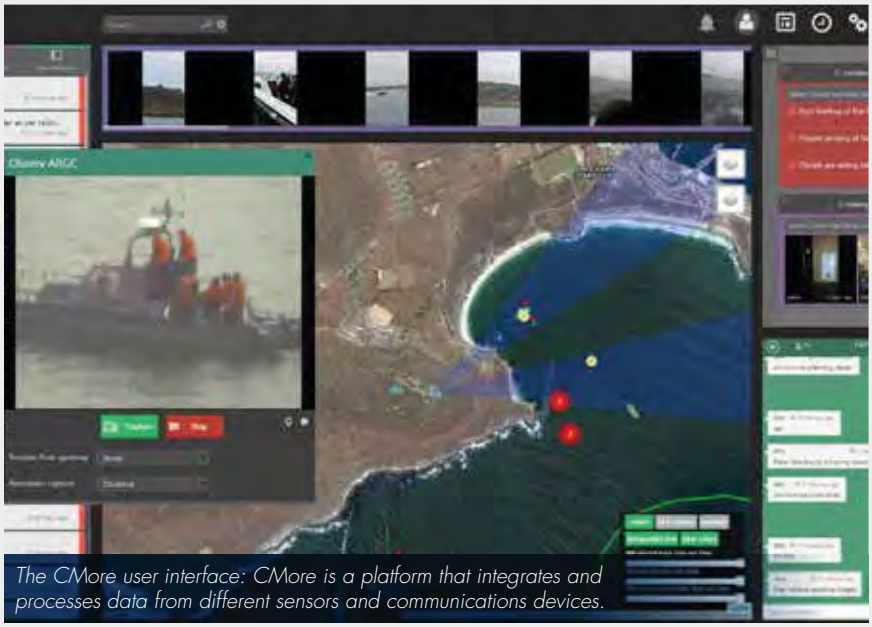
The CSIR has developed an airborne laboratory environment to test electronics in flight. The pod allows for rapid implementation and flight testing of experimental electronic hardware and new technologies in a fast jet environment.

Research, development and implementation to

BUILD SAFER COMMUNITIES

In brief

The CSIR has developed an innovative situation awareness and decision-support platform, Cmore, using modern web and mobile technology. It addresses the need for shared awareness among users through the consolidation of information from various sensors and external systems as well as real-time analytics.



The CMore user interface: CMore is a platform that integrates and processes data from different sensors and communications devices.

A platform for shared awareness

The challenge: Decision-making rooted in full situation awareness

Situation awareness is the ability to perceive and comprehend a situation and then being able to make predictions on how a situation may unfold. Information is key in gaining insight and understanding of a situation, to make informed decisions and to position oneself to be proactive within the context of the current situation.

Research and development: A platform for real-time situation awareness

The CSIR has developed a platform that incorporates information from various elements and sensors into a consolidated view that provides commanders of armed forces units with real-time situation awareness.

Consolidating information from different sources

Cmore is a secure cloud-based platform with both mobile and web-based desktop applications which are used to view and contribute information to the system.

The platform is able to exchange information with a diverse set of services and sensors, such as detection systems and various other entity tracking systems. In addition to consolidating information from various sources, Cmore also allows for the secure distribution of information with the ability to share and collaborate with users from anywhere in the world.

During complex deployments and operations, many different sensors are deployed, for example radar, optronic, electronic warfare, tracking or detection systems. Cmore allows for the filtering of information to mitigate information overload. It allows users to only see the information that is relevant to them at a specific point in time. This assists in decision-making and provides shared situation awareness to all members involved.

Cmore's flexible information model and ease of use make it suited for domains such as conservation, disaster response and management, as well as safety and security. The system

fully exploits the geographic nature of events and real-world entities.

Border safeguarding

Cmore was first developed in response to the need for border safeguarding, where interdepartmental and multinational agencies are required to collaborate.

The team considered social networking technologies, as well as mobile communications combined with traditional command and control functions, such as tracking, threat detection and situation awareness to create the initial technology demonstrator. The work was funded by Armscor.

Cmore was used in various border safeguarding experiments after which the platform was redesigned and refined. It is now used in land, air and maritime border safeguarding experiments, with an increasing focus on collaboration between different governmental departments and organisations. The system was subsequently tested during a South African Police Service night operation.

Environmental asset management

Cmore allows different users to communicate and share information. In the environmental asset management environment this capability has helped counter-poaching groups to collaborate and consolidate their efforts. Notifications of events, tracks discovered, comments, images and other types of information are received in real time, eliminating delays, misunderstandings or missed opportunities, typically caused by outdated information. Real-time voice, video, text and geographical information shared between, for example, counter-poaching teams, assist groups to direct scarce resources to where they are most effective.

The Cmore system was taken into use in the Kruger National Park to support counter-poaching efforts in 2015 and is now also used in other public as well as private parks. These efforts will be replicated in the Southern African Development Community region through conservation partners to serve as collaboration platform for groups within southern Africa.

The CSIR continues to refine and expand Cmore capabilities by collaborating with stakeholders, including the South African Police Service, Eskom, the Gauteng Disaster Management and Emergency Services and the Department of Environmental Affairs. More than 45 organisations are registered users of the Cmore system.

The Cmore team is represented by, from left (seated) Pieter Botha, Herman le Roux, Estelle Lubbe, and back (standing) Priaash Ramadeen, Kgothatso Ngako, Shazia Vawda, Maanda Raudzingana and Alex Terlunen.

Research, development and implementation to

BUILD SAFER COMMUNITIES

Hub to coordinate cybersecurity activities nationally goes live

A virtual cybersecurity hub that contributes to South Africans' safe use of the Internet has been established at the CSIR. The hub serves as a central point for collaboration between industry, government and civil society on matters relating to cybersecurity.

The hub was created to coordinate cybersecurity activities at a national level. Its mandate includes developing public-private relationships and establishing sector computer security incident response teams. The hub offers services that promote user-safety in a range of areas. It acts as an information centre that offers solutions on how to deal with security incidents and to update pre-emptive measures that will strengthen a user's system against cyber-attacks.

Experts assist users in responding to incidents and then involve the relevant authorities for further investigation.

In order to establish an incident management process, the hub receives incident reports from users and stakeholders. This archive of lessons learnt is used to further research and develop measures that counter cyber-attacks. Knowledge gained is reported during regular meetings where trending attacks and incidents during specific periods are discussed.

The hub has become a point of reference for many Internet users when dealing with cybersecurity issues. It continues to provide information, best-practice guidelines and teaching tools that help South Africans protect themselves against identity theft, online fraud and financial risks, as well as manage their children's online presence.

The facility has its roots in the 2012 National Cybersecurity Policy Framework and is operated by the Department of Telecommunications and Postal Services, and hosted by the CSIR.

A growth in connectivity and progress towards bridging the digital divide are adding significant value to society but at the price of greater exposure to cybercrime. A virtual cybersecurity hub has been established at the CSIR and is operated by the Department of Telecommunications and Postal Services.

Research, development and implementation to

BUILD SAFER COMMUNITIES

Novel satellite imagery solutions help keep South Africa safe

The CSIR has developed numerous systems that help draw insights and make forecasts from datasets obtained from multiple satellite sensors. The CSIR's multidisciplinary skills enable the organisation to process, analyse and use the data to help keep South Africa's infrastructure and citizens safe.

Using satellite aperture radars (SAR) as part of a system called Azimuth, the CSIR detected signs of a sinkhole in Centurion in Gauteng. South Africa has extensive areas underlain by dolomitic rock, which is associated with sinkholes. Over 3 000 sinkhole and subsidence events have been recorded in South Africa between the early 1960s and the end of 2012. Azimuth is designed to detect centimetre- to millimetre-scale surface deformation and early detection can prevent loss of life and reduce damage to infrastructure.

The CSIR also used SAR to aid the Department of Agriculture, Forestry and Fisheries to monitor the country's exclusive economic zone for illegal fishing and illegal dumping of bilge (waste sludge oil). A system based on these satellite aperture radars, called SeaFAR, is able to detect and identify vessels exhibiting suspicious behaviour and predict their movements. The system is then able to alert authorities. Successes include the detection and identification of a ship that dumped illegal bilge for 160 km between Madagascar and Mozambique and the detection of a fishing vessel that exhibited suspicious behaviour. Suspicious behaviour typically includes ships that loiter, ships that intermittently switch off their transponders or have no vessel transponders on-board, and foreign-flagged vessels displaying activities that indicate fishing inside the country's exclusive economic zone.

The CSIR's Advanced Fire Information System is operational in Argentina, Portugal and across southern Africa. It uses satellite data to detect fires in real-time and issue automatic warnings to the cell phones or tablets of users such as farmers, conservationists and managers of electricity transmission infrastructure.

SeaFAR is used to monitor and track unidentified vessels in South Africa's exclusive economic zone.

Research, development and implementation to

BUILD SAFER COMMUNITIES

A tool to protect communities from veldfires

The CSIR has developed a tool to reduce veldfire risks along the wildland-urban interface. The tool is now helping Western Cape fire authorities protect people and property from fire.

It will allow Fire Protection Associations (FPAs) around the country to map the fire risk to their communities by estimating the potential fire hazard and the vulnerability of the adjacent urban environment. This allows the FPAs to identify areas with high fire risks (hazard and vulnerability) for mitigation actions.

The CSIR developed the 10-step tool to better understand how vulnerable different communities were to veldfire damage. This is a particular issue in the fynbos biome of the Western Cape which, ecologically speaking, needs regular fires to remain healthy.

Fynbos has many species which are quite slow maturing and require fire to regenerate from seed. Fire management in the Western Cape has to both meet ecological requirements and minimise fire hazard.

Working in the area between Helderberg and Gordons Bay, the researchers used aerial photographs to define the urban edge and marked out a belt or buffer zone on either side of it. Then, by analysing the buildings and infrastructure inside the urban edge and the fuel types outside the urban edge, they created a map of potential fire risk for the area.

They have shown FPAs around the Western Cape how to use the tool to map their own areas. This will provide the FPAs with useful risk information and help them limit loss of life and property in the future. The work was funded by the GEF Fynbos project.

A firebreak separating buildings and flammable vegetation along the wildland-urban interface at Gordons Bay in the Western Cape.

Research, development and implementation to

IMPROVE HEALTH

The CSIR uses its vast expertise to help improve the health of all South Africans. Scientific and technological interventions include the development of interconnected and inter-operable point-of-care devices, technology for diagnostics, vaccine development and new methods to understand disease mechanisms at cellular and molecular level. The CSIR also provides technical support to the National Health Insurance initiative.

CSIR researchers are working on a disposable test device that will help communities to identify contaminated water. *More on page 88.*

Research, development and implementation to

IMPROVE HEALTH

In brief

One of the challenges with reducing South Africa's infant mortality rate, is improving access to specialist obstetric care for those who need it while reducing unnecessary referrals. In trials undertaken in the Tshwane district, a CSIR-developed Doppler ultrasound device detected abnormalities in 10% of screened cases. Initial results show that this technology has the potential to significantly reduce the perinatal mortality rate.

The Umbiflow device can be used by trained nurses at primary care clinics and has the potential to reduce unnecessary referrals to specialists.

Promising preliminary results for point-of-care fetal ultrasound device

Challenge: Improving perinatal care with scarce resources

Perinatal deaths include stillbirths and babies that die in the first week after birth. The number of deaths and the causes of deaths recorded are an indicator of the quality of prenatal, obstetric and neonatal care provided and help health authorities to improve the care provided.

According to Statistics South Africa, in 2013, there were 22 116 perinatal deaths. Two-thirds of these were still births. The South African Medical Research Council's ninth *Saving Babies Report (2012 - 2013)* found that the top causes of perinatal deaths in the state health sector included unexplained stillbirth and spontaneous preterm birth. The report stated that some of the top avoidable causes of baby deaths are delays in referring patients for specialist care and fetal distress not being detected by fetal monitoring.

The specialist obstetric care required for fetal monitoring of high-risk pregnancies is a scarce resource in the public health care sector. The challenge is to improve access to this level of care for those women who really need it, while reducing unnecessary patient referrals.

Research and development: Developing a device for clinics that indicates whether a fetus is healthy or potentially sick

Fetal size is used as a simple metric to assess the health of a fetus during pregnancy and concerns are raised whenever a fetus is smaller than expected.

Fetal growth restriction is normally detected by using a tape measure to measure the distance across the mother's abdomen, called the symphysis-fundal height. When growth restriction is suspected, a clinic-based nurse must refer the pregnant woman

to a higher level of care, where a conventional Doppler ultrasound test can be done using an expensive imaging device to establish if the smaller-than-expected fetus is healthy or sick. The use of the tape measure provides a mere estimate, which may lead to many unnecessary referrals in cases where small fetuses are healthy.

CSIR researchers have developed and tested an ultrasound device, called Umbiflow, which can be used in clinics before deciding about such a referral. A trained nurse can use the device to measure the blood flow in the umbilical cord, detecting if the placenta is no longer providing sufficient nutrients and oxygen for a fetus to reach its growth potential.

Outcome: An effective technological bridging device to help prevent perinatal mortality

An earlier field trial conducted in Kraaifontein, in the Western Cape, showed that referrals of patients with suspected fetal growth restriction can be reduced by 55% if the Umbiflow technology is made available at the primary care level. Conducting Umbiflow measurement at a clinic was shown to be more cost-effective than referral to a secondary hospital for a Doppler test.

In the latest clinical study in Tshwane district, 1 017 women have been screened so far and the abnormal test rate was around 10%. Umbiflow detected absent end-diastolic blood flow in the umbilical cords of these fetuses, an indicator that they were at very high risk for stillbirth. Umbiflow is proving to be an effective technological bridging device capable of detecting fetuses at risk of death. The perinatal mortality rate for women who had access to Umbiflow testing was 11.3 per 1 000 deliveries, and among those who did not use Umbiflow, the mortality rate was 20 per 1 000 deliveries for the first six months of the study.

A trained nurse uses the Umbiflow device at a Tshwane clinic to measure the blood flow in the umbilical cord. The blood flow indicates the ability of the pregnant woman's placenta to provide sufficient nutrients and oxygen for her fetus to reach its growth potential.

Research, development and implementation to

IMPROVE HEALTH

The CSIR and UCT partner to battle cancer with precision medicine

In an effort to improve the survival rate of cancer patients, the CSIR has teamed up with the University of Cape Town (UCT) to understand the genetic mutations that characterise some cancers, and use this to identify chemotherapeutic agents that will provide the best clinical outcomes.

Chemotherapeutic drugs are the heavy artillery in the fight against cancer, but they are still highly toxic to all rapidly-dividing cells in the body, leading to immune suppression, hair loss, and inflammation. Chemotherapy drugs vary in their ability to target specific cancer cells.

Genomic advances are making it possible to improve the survival rate of cancer patients by selecting the most efficacious drug. Traditionally, doctors have used cellular anatomy and molecular markers to choose between the hundreds of first-line chemotherapeutic drugs available to treat tumours.

To make the most of advances in the tools of cell biology, such as imaging and stem cell biology, researchers from the two institutes have joined forces to form the Biomedical Translational Research Initiative (BTRI). With a dual footprint at both the CSIR and UCT, the team works with clinicians to understand genetic variations that characterise a particular cancer and tie these to effective chemotherapeutic agents in order to recommend better treatment approaches to doctors.

The team uses molecular tools such as synthetic biology, imaging and microscopy to provide molecular diagnostics and targeting of tumours in clinical contexts where they can be highly effective. This research informs what mutations or variants are driving a tumour, which allows the researchers to identify specific drugs that are best tailored to work against those mutations.

Dr Musa Mhlanga and Dr Peter Pitrone of the BTRI working on an advanced microscope that they built.

The BTRI will initially focus on breast and colorectal cancer. The people of Africa, and especially southern Africa, have the greatest degree of genetic diversity in the world. Yet nearly all cancer research occurs outside Africa on non-African patients. As a result, the genetic variants that have been discovered and linked to successful therapeutic regimens and positive clinical outcomes, all originate from Europe and North America. These same genetic variants are far less common in Africa, where, instead, never-before-seen genetic variants occur. This means that genetic variants that result in good or poor prognosis remain largely unidentified in African populations and thus are unable to inform therapy, hence the elevated mortality and morbidity rates of cancer in Africa.

The BTRI is funded by the Department of Science and Technology and implemented by the CSIR.

Research, development and implementation to

IMPROVE HEALTH

Investigating the activity of natural compounds faster than previously possible

The CSIR is successfully using an earlier breakthrough in high-content high-throughput microarray screening technology to identify active compounds and groups of atoms in molecules that are responsible for the drug's actions, for specific biological targets.

The CSIR's high-throughput microarray printing technology first found application in the miniaturisation of genomics experiments. It can compress several individual RNA-interference (RNAi) experiments onto a single glass slide. The technology, which has been licensed and is being used in a range of patented products, is characterised by its simplicity, low cost, speed and efficiency. The state-of-the-art printing platform provided a miniaturised high-density RNAi microarray product that enabled researchers to screen a large number of genes with relative ease and in a short time. Genome-wide screening can therefore be achieved for a fraction of the investment required for conventional technologies.

Adopting this array technology in natural compounds printing will provide researchers with a tool to rapidly profile the activity of hundreds of compounds in parallel.

With the fast-growing pool of chemical-compound libraries, there is an urgent need to find new, quick, cost-effective and easy ways to profile the activity of these compounds against hundreds of biological targets.

As part of an ongoing optimisation project, the CSIR has shown that encapsulated compounds could be immobilised onto a solid substrate allowing for the activity of these compounds to be investigated against different biological targets.

The CSIR has a long history of investigating South Africa's rich biodiversity with a view of developing botanical preparation to treat allergies, colds, influenzas and other illnesses.

A CSIR researcher using high-throughput microarray printing technology to compress an RNAi experiment onto a glass slide.

Research, development and implementation to

IMPROVE HEALTH

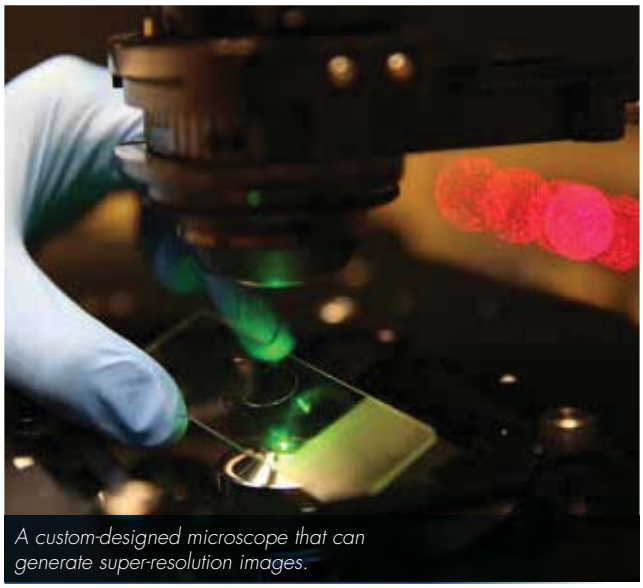
Using super-resolution microscopy to diagnose disease in a dish

Scientists at the CSIR, in collaboration with colleagues at Institut Pasteur, University College London, Necker Hospital and the Université Paris-Descartes, have identified the first visual proof of complex intra-cellular structures acting as pre-formed regulators of the immune response. The work demonstrates how super-resolution microscopy can provide novel insights into the single-molecule mechanism of genetic disorders, as well as crucial cellular mechanisms.

Until recently, there were no simple approaches to prove the existence of complex intra-cellular structures and therefore, little means of understanding the basic molecular pathways as a stepping stone to unravelling mechanisms of disease. This is largely due to the very basic physical properties of light itself, which cannot be resolved below 200 nm. Since many structures in the cell may be smaller than this, they cannot be visualised with conventional microscopy.

Through extensive research over the past decade, scientists have been able to overcome this problem. The CSIR custom-designed the first – and to date only – super-resolved fluorescence microscope in the country. Using this technology, the researchers have been able to provide the first visual proof of these higher-order structures.

One of the critical pathways in human cells is called the nuclear factor kappa-light-chain-enhancer of activated B cells (NFkB) signalling cascade. Every cell in the body must have an innate ability to respond to an outside stimulus or attack. Whatever form that signal may take, essentially healthy cells will respond by moving the protein NFkB from the cell body (cytoplasm) to the DNA storage area (the nucleus). There it will activate genes that lead to the cell's protection. Although extremely simplified, in this way, mankind stays healthy.



A custom-designed microscope that can generate super-resolution images.

A recently proposed theory suggests that the intermediate protein, which links the signal from the outside of the cell to the successful movement of NFkB to the nucleus, might be able to do this by forming complex structures that would be able to act as a finely tuned regulator – waiting for a minimum signal threshold to arise before switching on a green light of activation. The research team used super-resolution microscopy to reveal the complex structure of this intermediate protein in non-stimulated cells and have identified how this structure is held together in cellulo.

Research, development and implementation to

IMPROVE HEALTH

An affordable and durable prosthetic paediatric knee

The CSIR is developing a low-cost prosthetic device to improve the lives of paediatric amputees.

Current paediatric prosthetic solutions are mainly aimed at children living in first-world environments. Lower-cost options imported from other low-resource countries are still unaffordable to many amputees in South Africa, and are of inadequate design and made of non-durable materials.

The CSIR prototype uses durable materials that offer a long-lasting, safe and low-cost solution to young amputees. In addition, a motion-detection device is attached to the paediatric knee to monitor the leg movement of amputees over time. This allows healthcare practitioners to monitor the general health of amputees.

In addition, the device is able to measure the pressure inside an amputee's prosthetic socket to detect areas of high pressure. Early detection is vital for the prevention of pressure sores, preventing further possible amputation. Work is currently being done to qualify the device as an ISO 13485-certified product through international auditors.

A motion-detection device attached to the prosthetics for activity monitoring.

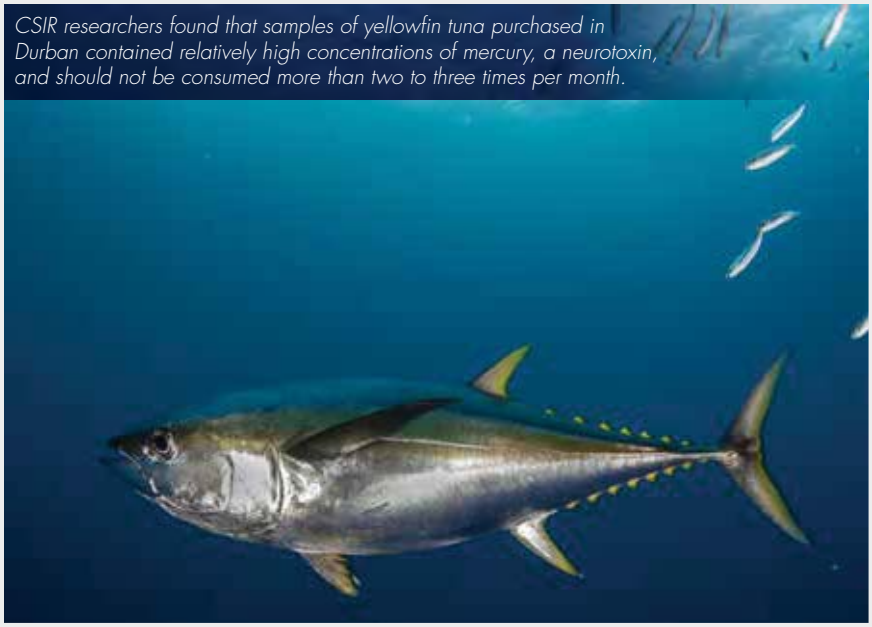
A paediatric knee developed for young amputees.

Research, development and implementation to

IMPROVE HEALTH

In brief

A CSIR study has found that several fish sold in South Africa's retail stores contain mercury levels well above World Health Organization guidelines. The CSIR has produced an advisory to guide consumers on the number of meals they can safely eat for different types of fish species, based on a meal size of 227 g.



CSIR researchers found that samples of yellowfin tuna purchased in Durban contained relatively high concentrations of mercury, a neurotoxin, and should not be consumed more than two to three times per month.

CSIR research on mercury in fish informs consumer choices

The challenge: Fish are rich in nutrients, but may accumulate mercury, a neurotoxin

Nutrients found in fish are essential for the development of the central nervous system, the heart, brain and eyes. Therefore, consumers are constantly encouraged to eat fish. But fish may accumulate mercury in their tissue if exposed to it in contaminated water.

While health authorities in some parts of the world offer advice to the public on which fish they can safely consume without the risk of excessive exposure to mercury, very little information has been available about mercury concentrations in fish locally and South Africans have therefore not been privy to such advice.

Research and development: CSIR formulates recommendations based on sampling of retail fish

The CSIR has initiated research on the concentrations of mercury in fish sold in South African retail stores. The research will provide the public with advice on how many servings of fish commonly available in retail stores they can safely consume. This will allow people to make informed decisions on the type of fish they eat.

CSIR researchers purchased fish from retail stores in Durban over a period of approximately 11 months. They mostly purchased whole fish to identify the species correctly, but in cases where only fish steaks were available, they took DNA samples to verify the species. The fish were measured, weighed, dissected and subsamples were analysed for the presence of mercury.

The researchers used the test results to produce a table, which advises consumers on the number of meals they can safely eat for different types of fish species.

The results showed that swordfish had the highest mercury concentrations in their tissue. This is primarily because they are

CAUTION: <1 meal per month

SWORDFISH

Mercury concentration (mg/kg wet weight)	Recommended numbers of meals
>0.94 - <1.9	<1
>0.47 - 0.94	1
>0.31 - 0.47	2
>0.23 - 0.31	3
>0.12 - 0.23	4
>0.08 - 0.12	8
>0.06 - 0.08	12
>0.03 - 0.06	>16

2 - 3 meals per month

KINGKLIP
YELLOWFIN TUNA
CAPE SALMON

MERCURY IN FISH - HELPNG YOU MAKE AN INFORMED CHOICE

All fish illustrations (other than West Coast Sole, Tomato Rockcod and tinned tuna) are by Elaine Heemstra and copyright owned by the South African institute for Aquatic Biodiversity, from *A Guide to the Coastal Fishes of Southern Africa* (2004) by Phil and Elaine Heemstra.

4 - 8 meals per month

KOB SPECIES
MUSSELCRACKER
STEENBRAS
CATFACE ROCKCOD
RED ROMAN
TOMATO ROCKCOD
CARPENTER
DORADO
HAKE

12 - ≥ 16 meals per month

YELLOWTAIL
CANNED TUNA
WEST COAST SOLE

For more information contact:
bnewman@csir.co.za

CSIR researchers used the mercury test results to produce a table that advises consumers of the number of 227 g portions they can safely eat for different types of fish species.

apex predators and accumulate all the mercury in the fish that they eat. CSIR researchers recommend that people eat no more than one meal of swordfish every second month and that children should avoid eating swordfish altogether.

The lowest mercury concentrations were found in yellow tail, west coast sole and canned tuna and those can be eaten 12-16 times per month without any risk. Other low-risk species that people can eat four to eight times per month include red roman, steenbras and hake. Kingklip, yellowfin tuna and Cape salmon had relatively high concentrations of mercury and can be consumed two to three times per month.

Outcome: This research is ongoing and the CSIR will be analysing more fish species and other seafood products while also looking at their omega 3 fatty-acid content.

Research, development and implementation to

IMPROVE HEALTH

Successful trials of device to rapidly detect *E. coli* in water

A CSIR-developed disposable device that can rapidly detect the microbial organism *Escherichia coli* (*E. coli*), without the need to send samples to laboratories, has been successfully field-trialled at the Tshwane (Daspoort) Waste Water Treatment Works. The presence of *E. coli* in water sources typically indicates sewage contamination, and if consumed, can result in severe illnesses and even death.

The field trials were used to validate the performance of the device, called ColiSpot, against gold standard methods and assess its early warning capability. The device is being developed to provide wastewater treatment facilities with a test capable of preventing the discharge of contaminated water into the environment. The aim is to eventually provide communities at risk of water-borne diseases with a test that will prevent the consumption of contaminated water.

Bacterial and viral pathogens have been classified as one of the key water-quality risks in South Africa. The World Health Organization reported that annually, two million deaths worldwide are attributed to unsafe water, sanitation and hygiene, and now considers microbial hazards as the main challenge in the delivery of safe drinking water.

Current methods of assessing microbial water quality, which is an indication of sewage contamination, involve the detection of *E. coli* and faecal coliform bacteria. While effective, traditional methods for the detection of these bacteria require 18-24 hours, a fully equipped laboratory and trained personnel.

ColiSpot addresses the shortcomings of traditional techniques by reducing the total detection time for *E. coli*, and negating the need for a full laboratory. ColiSpot aims to provide a complete solution – from sample pre-treatment and detection – to determining the amount of analyte in a sample and ultimately will include transmission of the results to a centralised database to allow for remote monitoring.

Loading of an enriched sample onto the ColiSpot sensor.

Research, development and implementation to

IMPROVE HEALTH

CSIR study identifies the use of agricultural pesticides and their potential risks to human health

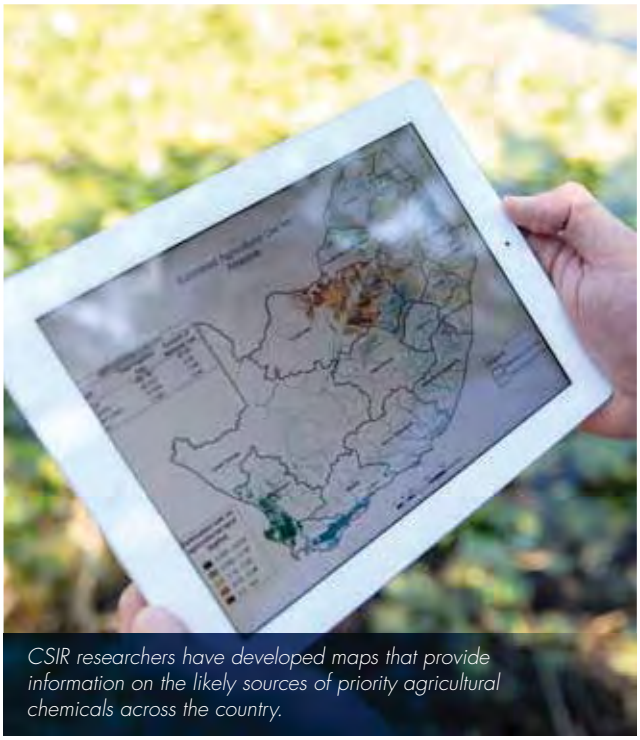
The CSIR has made significant advances in addressing knowledge gaps in managing the risks associated with agricultural pesticides in South Africa. Researchers developed a method to prioritise pesticides according to their potential risk to human health and have also mapped the use of these chemicals across the country.

South Africa is an agriculturally intensive country with over 3 000 different herbicide, insecticide and fungicide products registered for use in this sector. A number of studies conducted in the country have shown that pesticides frequently enter water resources and affect aquatic ecosystems and human health, and can then cause cancerous tumours, birth defects and other developmental disorders.

CSIR researchers developed an Excel-based risk indicator that allows for pesticides to be prioritised according to indices of quantity of use, toxicity potential and hazard potential, which combines toxicity with an indicator of environmental mobility. It enables users such as water resource managers and farmers to prioritise pesticides at a national or crop-specific scale according to any one of the aforementioned indices or a combination of all three.

By using geographic information system tools and mapping the spatial distribution of different crop types across the country, it was possible to map the distribution of the use of high-priority chemicals – posing a significant health risk – applied to those crops.

The maps are the first of their kind in South Africa and can be used to make national, provincial and catchment-based assessments of pesticide use, which are essential for performing spatial assessments of human and environmental risk. Furthermore, they can provide information on the likely sources of priority chemicals across the country, therefore providing valuable input into the development of water quality monitoring programmes.



CSIR researchers have developed maps that provide information on the likely sources of priority agricultural chemicals across the country.

Research, development and implementation to

IMPROVE HEALTH

Deployment of the Health Patient Registration System underway

The CSIR has partnered with the National Department of Health to develop a Health Patient Registration System, which has been deployed to 650 government primary healthcare facilities across the country.

The system, which is funded by the department, enables the electronic registration of patients onto a national database. It therefore provides the ability to track patient visits across health facilities. It also generates and manages the patient file number, which allows for efficient retrieval of patient files at clinics. The waiting time for retrieval of patient files has been drastically reduced in facilities where the system has been deployed.

The system addresses the need for a patient registration system that enables planning and provision of health services, and that supports the tracking of usage of health services, as outlined in the National Health Insurance Green and White papers. Implementation of the system is expected to provide key information on demographic and epidemiological data, which is important for determining service needs and for refining reimbursement mechanisms.

New manual to help mines implement new code of practice on airborne pollutants

The CSIR has developed an operations manual that will assist mines with a code of practice to assess the personal exposure of mine employees to airborne pollutants in the workplace. Airborne pollutants are responsible for a range of occupational diseases in mineworkers.

The manual aims to help standardise the implementation of the revised "Guideline for the Compilation of a Mandatory Code of Practice for Airborne Pollutants" within the South African mining industry.

Developed at the request of the Mine Health and Safety Council (MHSC), the need for the manual emanated from the different interpretations by end-users of the current guideline. As a result, the codes of practices that are developed from the current guideline are not standardised across the South African mining industry.

In drafting the manual, CSIR researchers obtained feedback from stakeholders about problem areas in the current guideline. This information was used to develop the operations manual with practical examples and to provide guidance on how to address certain aspects of the guideline. The operational manual contains practical examples and video tutorials to help explain complex situations to make it easier for end-users to implement the revised guideline.

The roll-out of the revised guideline with the operations manual is being planned and coordinated by the MHSC.

Research, development and implementation to

IMPROVE HEALTH

CSIR and partners turn the tide against the spread of tuberculosis

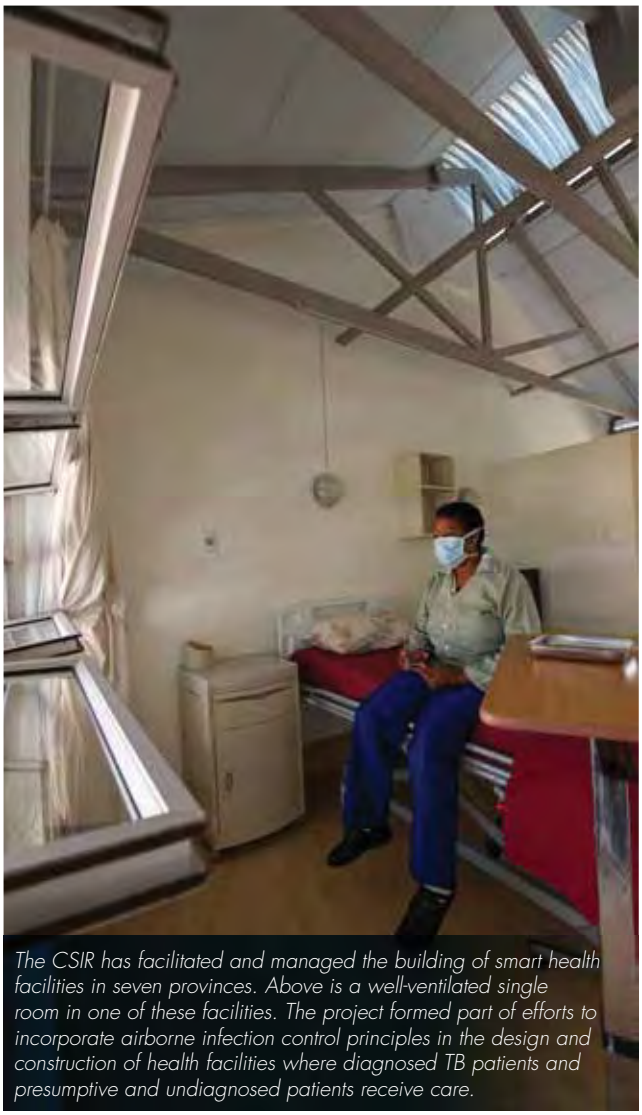
A five-year collaborative project with partners from the South African Department of Health, US Centres for Disease Control and Prevention (CDC), non-governmental organisations and academia has contributed to a better understanding of the transmission dynamics of tuberculosis (TB).

The collaborators trained 3 500 individuals, including health professionals, on the establishment and implementation of infection control programmes and building designers and engineers on the risks associated with airborne infections at health facilities. In addition, the CSIR has developed an infection control risk assessment tool which underwent internal reviews and was field tested at 400 health facilities around the country.

The CSIR had also developed norms and standards for hospital design, construction and maintenance. Contractors and designers now have to take these norms and standards into consideration when designing and building new health facilities.

In addition, the collaboration had resulted in the design, upgrade and construction of nine specialised drug-resistant tuberculosis health centres across the country, which had been co-funded by the Global Fund and the provincial health departments.

Other partners include the Development Bank of Southern Africa, the University of Pretoria, Harvard University and Fogarty International.



The CSIR has facilitated and managed the building of smart health facilities in seven provinces. Above is a well-ventilated single room in one of these facilities. The project formed part of efforts to incorporate airborne infection control principles in the design and construction of health facilities where diagnosed TB patients and presumptive and undiagnosed patients receive care.

Sustainable design in the context of the built environment requires an understanding of the role of the built environment in climate change adaptation and mitigation strategies. The CSIR's multidisciplinary skills base makes the organisation a valuable partner in conveying different aspects of sustainable design including energy, water, emissions, waste and ecology. CSIR experts participate in an annual Earth Sciences: Sustainable Design Workshop, which forms part of a module for third-year students in architecture, landscape architecture and interior architecture at the University of Pretoria (UP). Architecture student Silindzile Shongwe puts his work on display for the scrutiny of Llewellyn van Wyk of the CSIR and Graham Young of UP.

Research, development and implementation to

TRANSFORM HUMAN SETTLEMENTS

Fast-growing cities are not performing optimally, mostly due to ineffective spatial layout and management. A lack of decision-making capabilities and tools result in poor planning, management and prioritisation of interventions. The CSIR is supporting metropolitan areas and municipalities with spatial planning, the management of infrastructure and the long-term transition to greener and smarter economies.

Research, development and implementation to

TRANSFORM HUMAN SETTLEMENTS

In brief

The CSIR is assisting national and local government, cities and other stakeholders with urban planning strategies by making use of spatial and urban growth modelling and simulation software. A new CSIR-developed model has been used to simulate spatial growth patterns to better understand the future demand for infrastructure and services.

A CSIR-developed system for urban and regional planning, specifically land-use transportation interaction, can simulate spatial growth patterns in South Africa to better understand the future demand for infrastructure and services.

Land-use transportation interaction model helps plan for urban growth

The challenge: Urban spatial inefficiencies

In the developing world, mobility challenges and the role of government in providing public infrastructure are significantly different from those in the developed world. Factors such as extreme poverty and income disparities as well as mounting demands for basic services such as clean water, sanitation, and healthcare, pose daunting challenges to urban planners.

In South Africa, roughly 10% of the gross domestic product is invested annually into building and operating infrastructure and facilities in metropolitan municipalities alone. Many of these investments are aimed at overcoming the spatial inefficiencies inherited from the past and transforming human settlements by providing public transportation to improve mobility and access to job opportunities.

The long-term sustainability of these investments are intricately linked to future population and employment projections, specifically in the areas served by public transportation, which in turn is the cumulative result of the decisions made by households, businesses and property developers within the policy environment set by government.

Research and development: Developing a model to support the complex urban planning processes that shape South African cities

To facilitate decision-making within such a complex and sometimes adversarial planning process, CSIR experts in spatial urban and regional planning have developed a land-use transportation interaction model that can be used to simulate the expected outcome of various planning scenarios.

The model is based on adapted versions of two open source software packages: OpenTripPlanner, a platform to plan multi-modal transport itineraries; and UrbanSim, a state-of-the-art platform to simulate the urban growth patterns resulting from the decisions made by the main actors in an urban system. The model can be used to evaluate the likely consequences of policy scenarios aimed, for example, at limiting urban sprawl or increasing residential and employment densities in designated areas, or to promote walking or cycling to work. The CSIR adapted OpenTripPlanner to calculate the cost of commuting by different modes of transport, including by private car, bus, train and mini-bus taxi. UrbanSim subsequently uses these costs to assess accessibility to employment, which may in turn influence where the model predicts people may choose to live and work.

The model has recently been used by the Tshwane and Nelson Mandela Bay metropolitan municipalities to simulate population growth and spatial population distributions over the next 30 years, for various scenarios. The projections are being used to make better decisions on spatial planning, public transport corridors and infrastructure investment.

Outcome: A tool to evaluate the effect of different policy scenarios

The model has proven to be useful in evaluating the effect of policy scenarios on, for instance, urban densification. It can predict the consequences of investments in housing and transportation, and present that information to decision-makers in an accessible format. As one of the benefits of investment in public transportation, researchers have shown that the percentage of job opportunities that can be reached for R40 per day from the best located zones (100 of 2 690 in City of Tshwane) increases from less than 10% of the total number of non-home-based jobs in a city without public transportation, to more than 70% with public transportation.

The CSIR is assisting the Gauteng Department of Roads and Transport through the Gauteng Integrated Transport Modelling Centre to establish an in-house capability to do integrated land-use and transport modelling. A case study is also underway in the Ekurhuleni Metropolitan Municipality as the first step towards building a model for the whole of Gauteng.

The CSIR's Amy Pieterse with a map depicting the number of jobs that low-income households could reach by using public transport, while limiting travel expenditure to 30% of household income (+R40 per day). The number of jobs reached using public transport is much higher than that of private vehicles (for the same amount).

Research, development and implementation to

TRANSFORM HUMAN SETTLEMENTS

In brief

Spatial planning experts at the CSIR developed a housing demand model to help the Gauteng Department of Human Settlements plan for its future housing supply obligations. CSIR researchers are also working with the department on how to improve the upgrading of informal settlements in Gauteng.

With a predicted population of 19.4 million people living in Gauteng by 2030, informal housing is expected to grow rapidly.

Housing model helps forecast housing demand in Gauteng

Challenge: Migration to Gauteng pushes up housing demand

Gauteng is the fastest growing province in the country, with a predominantly young population with high mobility. People are attracted to the province because of the high levels of economic activity. Forecasts suggest that Gauteng's population will increase from 12.3 million in 2011 to 19.4 million people by 2030.

To enable the delivery of adequate housing to the fast-growing population, government decided that it needed to improve its understanding of household incomes, housing aspirations and levels of affordability of all people living in the province, and especially households living in informal settlements and backyard shacks.

Research and development: Housing demand model provides a housing outlook

The CSIR has developed a housing demand model in partnership with the Palmer Development Group. The model predicts that people living in informal types of housing are likely to increase from 20% in 2011 to 25% of households (1.78 million households) by 2030. This is an increase of just over a million households living in informal housing in 19 years.

The housing demand model combines a range of data and assumptions to make predictions about how the housing situation will change in the province under different economic and demographic conditions. It predicts changing patterns of where people are likely to be living in the future, covering all housing types, formal and informal, occupied by households

of all incomes, to improve understanding of the demand-supply dynamics in the whole housing sector.

Provincial housing outlook

A number of parameters can be altered in the model to generate different scenarios to help the provincial government with policy decisions. Two major factors that can be altered are economic growth forecasts for the province and population growth forecasts.

Other parameters that can be manipulated in the model are the budgets that government devotes to human settlement programmes, the mix of housing types that the state supports (from informal settlement upgrades, to RDP houses, and rental units in the inner city), and the level of involvement of the private sector. The Gauteng housing demand model is a powerful tool for officials to test the likely outcomes of different policy decisions over the next 15 years.

Apart from showing the implications of budget changes, the demand model also shows how the budget can be allocated in smarter ways to achieve more with what is available. For example, by shifting more responsibility for building low-cost housing to the private sector, more government funds are freed up to address programmes like the upgrading of informal settlements for households who cannot afford basic housing. The ideal situation is one in which the growing demand for housing in the province is met by the effective supply of adequate housing in the foreseeable future. Exploring the conditions that would create this balance between supply and demand is what the model is designed to support.

The CSIR is training officials from the Gauteng Provincial Government in the use of the housing demand model as a decision-making tool.

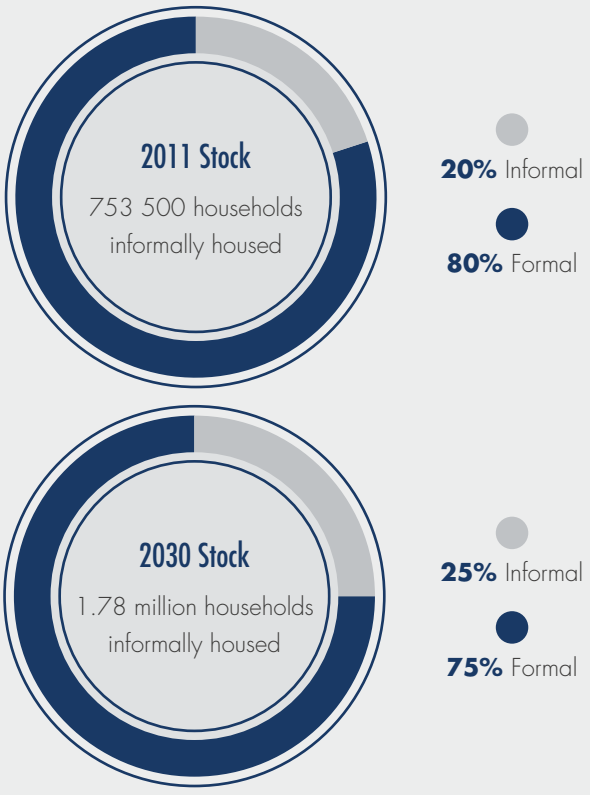
Upgrading informal settlements in Gauteng

In the second major project, the Gauteng Human Settlements Department wanted to understand the nature, scale and growth patterns of informal settlements in the face of the challenging task of upgrading housing and services in informal settlements. A total of 1 132 868 people lived in Gauteng's informal settlements in 2011, made up of 434 188 households (figures based on census information). To get a more current and accurate picture of the scale and growth, the CSIR sourced and analysed a dataset of built structures within informal settlements in the province.

The data used in the study provided a useful picture of the nature and dynamics of informal settlements in the province. The CSIR team recommended that, as part of a broader provincial strategy for informal settlement upgrading, the department uses the dataset more regularly to monitor the growth and/or decline in informal structures. This will ultimately improve and inform how it implements the Upgrading of Informal Settlements Programme in the province by revealing where the greatest needs for housing and services are emerging.

Gauteng Housing Stock: Formal to informal

Medium economic & population growth



Research, development and implementation to

TRANSFORM HUMAN SETTLEMENTS

Revising and updating guidelines for human settlement planning and design

The Department of Human Settlements has contracted the CSIR to revise and update the *Guidelines for Human Settlement Planning and Design*, known by its users as the Red Book.

The guidelines, first published in 2000, outline desirable qualities in South African settlements and provide practical guidance on how these qualities can be achieved. They provide built environment professionals, such as public and private sector engineers, town planners, urban designers and architects, with a set of performance-based guidelines to assist them with decision-making regarding urban planning and design, appropriate technologies and levels of service. Aspects addressed include water supply, sanitation, stormwater management, energy, roads, transport, public open spaces, public facilities, and safety and security.

A revision and update of the guidelines was necessary to ensure alignment with changes to policies and strategies governing the planning and design of sustainable human settlements. The revised guidelines will take into account recent developments in climate change, resource scarcity and globalisation as well as local realities such as poverty, inequality, rapid urbanisation and migration. They address issues such as pedestrian-friendly neighbourhoods, water-sensitive design, appropriate informal settlement upgrading and crime prevention through planning and design. Work on the revision continues and is expected to be completed by the end of 2017.

The CSIR has been contracted by the Department of Human Settlements to revise and update the Guidelines for Human Settlement Planning and Design.

Partnering for

AFRICAN RESEARCH, DEVELOPMENT AND IMPLEMENTATION

The CSIR subscribes to the African Union vision of an integrated and prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena. The organisation believes that it can contribute to innovation in Africa, tackling continental societal challenges through continental and global cooperation in science, engineering and technology.

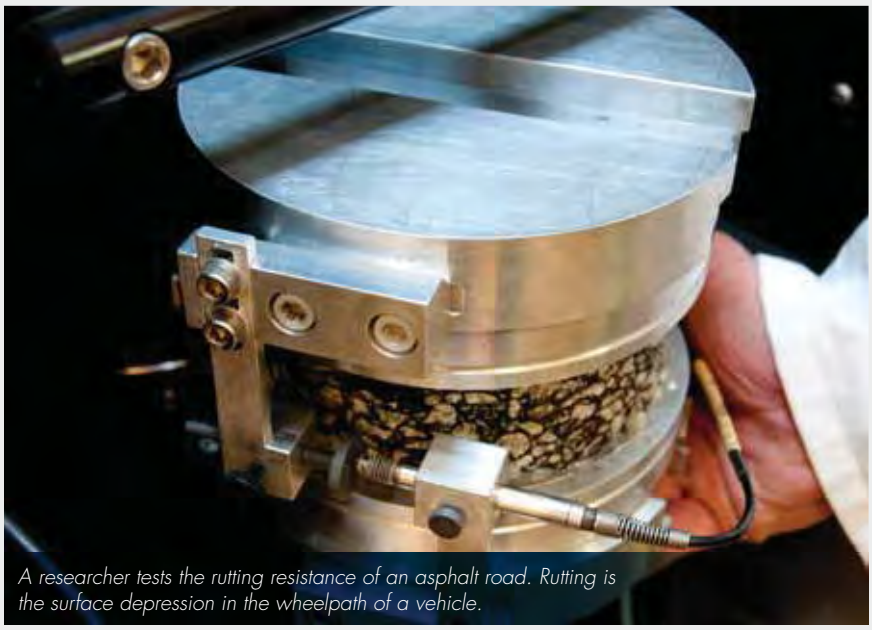
The SADC region needs to invest in water and energy infrastructure at the appropriate scale to develop economically and provide better livelihoods to enhance the quality of life of its citizens. The CSIR has partnered with the Stockholm Environment Institute, the South African Institute of International Affairs, the Global Water Partnership Southern Africa and the Stockholm International Water Institute to provide scientific evidence to enhance regional cooperation and integration in water and energy planning and development in the Southern African Development Community region.

Partnering for

AFRICAN RESEARCH, DEVELOPMENT AND IMPLEMENTATION

In brief

Like many countries in Africa, the Democratic Republic of Congo (DRC), Tanzania and Ghana are facing road infrastructure challenges, ranging from premature road failures to roads being washed away during rainy seasons. The CSIR is putting its multidisciplinary skills to use to develop guidelines and formulate recommendations that, when implemented, will contribute to longer-lasting roads.



A researcher tests the rutting resistance of an asphalt road. Rutting is the surface depression in the wheelpath of a vehicle.

Working towards improved road infrastructure in Africa

The challenge: Premature failing of road infrastructure in many African countries

Deteriorating roads in many African countries have resulted in the CSIR being invited to work with roads and transport authorities from these countries to assist them in addressing these challenges. The aim of this science, engineering and technology intervention is to find technological solutions that will contribute to longer road lifespans, safer travelling and reduced vehicle maintenance costs on the continent.

Research and development for alternative road surfacing in Ghana

The Africa Community Access Partnership (AfCAP), a UK Department for International Development programme, has focused its efforts on improving rural access roads in Africa through research and uptake. AfCAP contracted the CSIR to conduct research on steep hilly sections – with a gradient of more than 12% – of low-volume (feeder) roads in Ghana. CSIR engineers investigated different pavement options to address the challenges on these steep slope sections. The challenges mostly relate to erosion and drainage. In Ghana, the standard road surfacing for feeder roads is gravel. Unfortunately, these roads are susceptible to being washed away by torrential rains typical of tropical countries.

Prolonged rainy seasons in Ghana, coupled with weak natural gravels on the gravel roads, exacerbate the problems on the hilly sections of feeder roads.

The researchers developed a matrix of three alternative surfacing options, namely concrete, bitumen and stone setts or cobbles, for comparison with the gravel-wearing courses currently used by

the road authorities in Ghana. These surfacings will be placed over road-base materials, which comprise either mechanically stabilised lateritic gravel or a mixture of laterite gravels with different additives such as lime, pozzolana and quarry dust.

Road forensics in Tanzania

Tanzania is facing high incidences of premature failures on their asphalt roads, which consist of crushed or uncrushed stones bound with bitumen. Some pavements experienced failures within two years of construction or rehabilitation. CSIR engineers conducted a forensic investigation into the causes of premature failures of bituminous layers in high-volume urban roads and highways carrying heavy goods vehicles. The goals were to identify the factors that contributed to the premature asphalt failures, to identify an asphalt mix design methodology that would be suitable for Tanzania and to develop viable solutions that would mitigate the occurrence of premature failure in the future. Detailed findings and practical recommendations have been offered to assist the Tanzania National Roads Agency in making future decisions regarding asphalt road construction.

Following the acceptance of the recommendations, the CSIR has been contracted to develop a new asphalt design guideline to counter high incidents of premature asphalt road failures in that country. The solutions recommended in the asphalt guideline will help ensure that asphalt paving in Tanzania will last the expected 12 to 20 years.

Technical audit of a road upgrade project in Tanzania

CSIR engineers were contracted by the Tanzania National Roads Agency to carry out a technical audit for a project funded by the government of Tanzania and the African Development Bank. This involved an assessment of the procedures and mechanisms used by the contractor and construction supervisor consultant in their respective duties of project implementation, approval of laid pavement layers and supervision of the overall quality of the work. Premature pavement distress was observed in the form of longitudinal cracking. To establish whether the most likely cause of the cracks was due to the quality of material used for construction, the test results that were provided as part of the as-built information for the project were reviewed, complemented by additional in-situ testing. Implications and recommendations for corrective measures were provided.

New bituminous binder specifications for Africa

The state of Africa's deteriorating roads, even when newly constructed, has prompted a rethink on bitumen specifications. The CSIR is developing new performance-based specifications to be adopted in various parts of the continent. Changes that contributed to the reconsideration of bitumen specifications include a significant increase in traffic levels and loads, as well as a changing climate, which is leading, for example, to higher temperatures. CSIR researchers evaluated new bitumen test properties that measure the performance of the bitumen, taking climate and traffic loading into account.

Natural bitumen in the DRC

Natural bitumen typically occurs in small quantities as deposits on the earth's surface and its properties are usually significantly different from refined bitumen. The CSIR investigated surface deposits of natural bitumen at several locations in the DRC. The surface deposits were shown to be bituminous in nature, but also contained volatile compounds, fine aggregate, filler, vegetable matter and waste materials. The CSIR refined the bituminous products and successfully manufactured, characterised and incorporated them into a hot mix asphalt design. The resulting asphalt mixes were compared to standard bitumen in an identical asphalt mix design containing the same aggregate, grading and binder content. The asphalt mixes compared favourably against the reference mix in terms of performance-related laboratory tests. This investigation has attracted a similar investigative study into bitumen deposits in the South Buton island in Indonesia.

A typical hilly road in Ghana. These roads are susceptible to being washed away by torrential rains.

Partnering for

AFRICAN RESEARCH, DEVELOPMENT AND IMPLEMENTATION

In brief

The CSIR has developed diagnostic instruments that test for infectious diseases, such as foot-and-mouth disease, avian influenza and brucellosis, and that supply real-time results in the field to enable immediate decision-making around containment strategies. The field 'laboratory' will significantly reduce the time between detection and containment, resulting in healthier animals, as well as contributing to export opportunities and the financial sustainability of rural areas.

A team of rangers taking foot-and-mouth disease samples from a buffalo in Rwanda. The CSIR leads a SADC foot-and-mouth disease programme in collaboration with the University of Pretoria and the Agricultural Research Council. Outside South Africa, collaborators include Zambia, Namibia, Botswana, Mozambique and Rwanda.

Point-of-care diagnostics to speed up control of infectious diseases in livestock

The challenge: Controlling infectious diseases in southern Africa

Livestock farming is a way of living for many people in the SADC region. Outbreaks of a viral disease not only affect the health of the animals, but also result in stringent food safety regulations, preventing the export of animals and animal products to lucrative foreign markets.

Diseases such as foot-and-mouth disease, avian influenza and brucellosis can debilitate the economic viability of rural areas – typically areas where it is already difficult to achieve economic sustainability.

In this programme, researchers set out to meet the challenge of containing an outbreak, minimising the spread of the disease and animal losses. Time is a critical factor. After detecting a possible disease, technicians need to diagnose the disease and find out if, and how far, it has spread before they can consider containment. This becomes time-consuming in rural areas where, by the time the samples reach the laboratory, tests are done and the technician returns to the field, the infected animal might already be dead or sold.

This scenario would change if technicians had a 'preliminary laboratory' in the field, adapted to African conditions, where subsequent to sampling and testing, a conclusive answer as to the presence of an infectious disease, was available on the spot. Tests in the same area or further afield will then determine the area of spread, enabling rapid confinement and treatment.

Research and development: Developing point-of-care molecular diagnostic instruments

In response, the CSIR has developed point-of-care molecular diagnostic instruments, with a communications capability, which can be used in the field. Adapted to the African climate and conditions where electricity and connectivity are often a problem, the instruments are powered independently from the grid and report results in real time to a laboratory for further analysis by specialists who provide live feedback.

The technology takes care of the crucial gap between the livestock owner and relevant authorities that know there is a problem and making a decision for treatment and containment.

Connected to this research, but still in the early research phase, is a project to design Differentiating Infected from Vaccinated Animals (DIVA) vaccines. These vaccines use 'designer' bugs that are not infectious, but can protect against strains of infectious diseases, especially where animals are immune, either because of surviving a disease or because of a previous vaccination.

Outputs and outcomes: Building technological and human capacity

Researchers have developed tests for different diseases and the instruments to conduct the tests. Further developments include communications tools and work processes on how to use the instruments. Encouraging preliminary results are being reported from validation field trials.

For this research, the CSIR has partnered with commodity groups that have vested interests in the health of their animals, for example Milk SA. Other collaborators include the University of Pretoria and the Agricultural Research Council, as well as countries where foot-and-mouth disease is endemic, such as Zambia, Namibia, Botswana, Mozambique and Rwanda.

Regarding human capital development, four South African students are enrolled for PhDs. A further 30 personnel are trained within the programme through annual training interventions. Six PhD candidates from the African collaborating countries will enrol in 2017.

Impact: Improving rural economy and impact on livestock economy in the SADC region

In 2015, a competition sponsored by The World Academy of Science and the International Science, Technology and Innovation Centre selected this programme as one of the top 10 programmes from developing countries with ideas that could produce significant health and environmental benefits.

With the new infrastructure and know-how of detecting infectious diseases in the field, the impact of the point-of-care molecular diagnostic instruments will also extend to regulatory authorities and laboratories that will draw from the skills and increased capacity.

The early containment of diseases will benefit the health and numbers of livestock, offering quality animals and animal products for export. In the long term, this innovation will contribute to the preservation and securing of economic sustainability of villages by using science proactively.

Angelique Ingabire from the Rwanda Agricultural Board and the CSIR's Simone Hammersley preparing samples for real-time polymerase chain reaction during a training course at the CSIR for laboratory staff from African countries participating in the programme. The course was funded by South Africa's Department of Science and Technology, the National Research Foundation and SANBio.

KNOWLEDGE DISSEMINATION

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New international patents granted

Patent title	Patent number	Country
A method of memoization	9,037,798	United States of America
A process for the production of Ambrafuran	700 599	Switzerland
Array printing	2736631	EPO-European Patent Office
Array printing	9,012,375	United States of America
Array printing	10-1545826	Republic of Korea
Diagnosis of tuberculosis	9,176,134	United States of America
Emulsion-derived particles	267234	India
FliD - Production of heterologous proteins or peptides	ZL200880124570.4	China
Gaussian/FTB resonator	9,031,113	United States of America
Hoodia - Extraction of appetite suppressant compounds from plants	2026666	EPO-European Patent Office
In-shell pasteurization of eggs	0510091-7	Brazil
Management and treatment of benign prostatic hyperplasia	9,061,023	United States of America
Method for converting aloeresin to aloesin	265799	India
Method for converting aloeresin to aloesin	5763691	Japan
Method for converting aloeresin to aloesin	10-1555639	Republic of Korea
Process for obtaining optically active vicinal diols from meso-epoxides	271718	India
Switching between video streams	3358	ARIPO
Titanium powder production process	ZL201180020692	China
Upgrading of titaniferous material	9,017,625	United States of America
Upgrading of titanium nitride	ZL201180059585.9	China

CORPORATE GOVERNANCE

Corporate governance

Framework

Corporate governance is formally concerned with the organisational arrangements that have been put in place to provide an appropriate set of checks and balances within which the stewards of the organisation operate. The objective is to ensure that those to whom the stakeholders entrust the direction and success of the organisation act in the best interest of these stakeholders. It is about leading with integrity, responsibility, accountability and transparency.

The CSIR is committed to principles and practices that provide its stakeholders with the assurance that the organisation is soundly and ethically managed. A management model that governs and provides guidance for the way that all employees interact with various stakeholder groups has been established to provide this assurance.

The underpinning principles of the Group's corporate governance rest on the three cornerstones of an effective and efficient organisation, namely: a long-term strategic planning process; day-to-day management processes and effective change management processes. These processes are supported by people and systems that plan, execute, monitor and control the strategic and operational domains of the organisation. The supporting infrastructure and its evolution are documented in the management model, which is reviewed and updated to align with organisational changes.

In accordance with the Scientific Research Council Act, 1988 (Act 46 of 1988, as amended by Act 71 of 1990), the appointment of the CSIR Board is by the Executive Authority (the Minister of Science and Technology). The Board provides oversight strategic direction and leadership, determines goals and objectives of the CSIR and approves key policies. The Board has adopted formal Terms of Reference that are in line with the Scientific Research Council Act, the Public Finance Management Act (PFMA), 1999 (Act 1 of 1999), as amended by Act 29 of 1999 and best practice.

The CSIR Board and its Executive Management Committee believe that the organisation has complied with the relevant principles incorporated in the Code of Corporate Practices and Conduct, as set out in the King Report.

Shareholder's Compact

In terms of Treasury Regulations issued in accordance with the PFMA, the CSIR must, in consultation with the Executive Authority, annually agree on its key performance objectives, measures and indicators. These are included in the shareholder's performance agreement (Shareholder's Compact) concluded between the CSIR Board and the Executive Authority.

The Shareholder's Compact promotes good governance practices in the CSIR by clarifying the roles and responsibilities of the Board and the Executive Authority, as well as ensuring agreement on the CSIR's mandate and key objectives. The chairperson of the Board and the Executive Management Committee hold bilateral meetings with the Executive Authority to ensure performance in line with the Shareholder's Compact.

Financial statements

The Board and the CSIR Executive Management Committee confirm that they are responsible for preparing financial statements that fairly present the state of affairs of the Group as at the end of the financial year and the results and cash flows for that period. The financial statements are prepared in accordance with International Financial Reporting Standards (IFRS). In addition, the Board is satisfied that adequate accounting records have been maintained.

The Auditor-General independently audits and reports on whether or not the financial statements are fairly presented in conformity with IFRS. The Auditor-General's Terms of Reference do not allow for any non-audit work to be performed.

Corporate governance

Enterprise risk management

The Board is responsible for ensuring that a comprehensive and effective risk management process is in place.

Enterprise risk management in the CSIR is an ongoing process, focused on identifying, assessing, managing and monitoring all known forms of significant risks across all operations and Group companies. This has been in place for the year under review and up to the date of approval of the annual financial statements.

A structured process of enterprise risk management ensures that the goals and objectives of the CSIR are attained. This takes cognisance of the fact that the risks identified are often inter-linked and cannot be managed in isolation. CSIR systems review aspects of economy, efficiency and effectiveness. The management of risk is assigned at appropriate levels to ensure adequate responses.

Documented and tested processes allow the CSIR to continue its critical business operations, in the event of interruptions that could possibly impact on its activities. Based on the internal audit, the organisational results achieved, the audit report on the annual financial statements and the management report of the Auditor-General, the Board is satisfied that the system of risk management has been effective during the year under review.

The CSIR has defined three broad risk categories, namely: systemic risks, strategic risks and operational risks.

Systemic risks

Systemic risks originate from macro-economic and national challenges affecting the National System of Innovation and National Government Business Enterprise space in which the CSIR operates.

Continued evaluation of macro-economic influences, ongoing assessment and engagement with stakeholders remain key in directing research activities towards achieving the CSIR's mandate.

Strategic risks

The organisation has effective mechanisms in place for identifying and monitoring strategic risks that impact the CSIR Group's ability to deliver on its mandate. The procedures for implementing a risk management process include a focus on areas such as: human capital assessment and development, research impact areas, technological development and business continuity.

Operational risks

The CSIR endeavours to minimise operating risk by ensuring that the appropriate infrastructure, controls, systems and people are in place throughout the Group. Key processes employed in managing operating risk include research ethics and good research practices, segregation of duties, transaction approval frameworks, financial and management reporting and the monitoring of metrics that are designed to highlight positive and/or negative performance across a broad range of key results areas (KRAs). The Operations Committee, which comprises members of the Executive Management Committee, Operating Unit Executive Directors, Centre Managers and Group Managers, oversee operational matters.

Sustainability

The Board has reviewed the Group's financial budgets for the period 1 April 2016 to 31 March 2017 and is satisfied that adequate resources exist to continue as a going concern for the foreseeable future. The Board confirms that it has assessed key sustainability risks and there is no reason to believe the business will not be a going concern in the year ahead.

Corporate governance

The income streams of the CSIR are detailed in the notes to the annual financial statements.

Internal audit

The Group has an internal audit function that reviews its operations. The Audit and Risk Committee approves the internal audit charter, the annual audit plan and budget of the CSIR internal audit to maintain its independence.

The annual audit plan is based on the key risks to the organisation and outcome of enterprise risk assessment conducted by management, as well as specific areas highlighted by internal audit and the Audit and Risk Committee. In addition, areas highlighted by internal control reviews by the external auditors are incorporated into the internal audit plan.

The annual audit plan is flexible in ensuring it is responsive to changes in the business and emerging risks. A comprehensive report on internal audit findings is regularly presented to management and quarterly presented to the Audit and Risk Committee.

The internal audit function operates in conformance with International Standards of the Professional Practice of Internal Auditing (The Standards) of the Institute of Internal Auditors (IIA). The previous external quality assurance review of Internal Audit yielded satisfactory results. The next review is due in the 2016/17 financial year.

Internal control and combined assurance

The Board has ultimate responsibility for the system of internal control designed to mitigate risks, identify, evaluate, manage and provide reasonable assurance against misstatements and losses.

The system comprises self-monitoring mechanisms to allow for actions to be taken to correct deficiencies as they are identified.

A combined assurance approach is in place to assist in addressing key enterprise risks.

Management and the Risk Office identify controls that are necessary to mitigate risks. Internal Audit is the third line of defence and provides assurance on the effectiveness of risk management and the system of internal control.

For the year under review, the internal financial controls have been assessed as effective.

Audit

External auditors are responsible for the independent audit and to report on the annual financial statements. The statements comply with International Financial Reporting Standards.

In line with the requirements of the PFMA and good governance, the internal audit function provides assurance to the Audit and Risk Committee and management on the adequacy and effectiveness of internal controls. Information is derived from an independent evaluation of risk management, governance processes and internal controls. Corrective action is identified and improved controls are recommended.

Approval framework and policies

The approval framework governs the authorisation processes in the CSIR. It deals with, among others, the construction of strategic plans, development of operational plans and budgets, appointment of staff, approval of salaries, intellectual property management and investment in and disposal of property, plant and equipment. It also defines authority levels in relation to organisational positions.

Corporate governance

Appropriate controls are in place to ensure the compliance with the above framework. A comprehensive set of procedures exists to provide the necessary checks and balances for the economical, efficient and effective use of resources. The essence of this framework is that it is comprehensive, clear and unambiguous, as well as easy to assimilate and internalise.

Other policies that are in support of the CSIR mandate and strategic priorities cover the following key areas: building and transforming human capital, governance and financial sustainability, transferring technology and human capital, strengthening the science and technology base, and performing relevant research and development (R&D).

All subsidiary companies are under the control of a duly appointed Board of Directors.

The Board reserves all matters with the potential to have material impact on the operations and reputation of the CSIR to itself.

Code of business ethics and organisational values

The Board and CSIR Executive Management Committee have approved and adopted a code of ethics that reflects their commitment to a policy of fair dealing and integrity in conducting their operations. The code aligns closely to the CSIR set of values, compliance to laws and regulations and requires all employees to maintain the highest ethical standards, ensuring that business practices are conducted in a manner that is beyond reproach. Monitoring ethical behaviour is devolved to operating unit level and transgressions are addressed by means of procedures detailed in the CSIR Conditions of Service and the PFMA.

Employee participation

The CSIR strongly encourages effective and modern workplace practices and relationships to foster employee participation and work process involvement as a key practice at all levels in the organisation. Employee participation happens, for example, through the Transformation and Employment Equity Committee, formal induction programmes, technical and strategic focus groups and task teams.

Governance structure

The CSIR Board

The responsibilities of the Board are governed by the Scientific Research Council Act and the PFMA. The Board approves the strategy, goals, operating policies and priorities for the organisation and monitors compliance with policies and achievement against objectives.

With the exception of the CEO of the CSIR, all members of the Board are non-executive. Board members are actively involved in and bring independent judgement to bear on the Board's deliberations and decisions.

The Board, of which the current number of members adheres to the statutory minimum requirements, meets quarterly. For the year under review, the Board met on 25 June 2015, 10 September 2015, 28 and 29 October 2015 for a strategy session, 12 November 2015, 10 December 2015 and 18 February 2016. The annual financial statements for the 2015/16 financial year were approved on 30 June 2016.

The Board has the following sub-committees: the Audit and Risk Committee, the Human Resources and Remuneration Committee, and the Research, Development and Innovation Committee (formerly Strategic Review Committee) (see page 138). The members of these committees are selected according to the skill sets required for the committees to fulfil their functions. For the 2015/16 year the committees complied with their respective Terms of Reference.

The Board has adopted formal Terms of Reference reflected in the Board Charter, which are annexed in the Shareholder's Compact.

Governance structure

CSIR Board members (1 April 2015 to 31 March 2016)

Prof. Thokozani Majozi
Chairperson of the CSIR Board
NRF/DST Chair: Sustainable Process Engineering, University of the Witwatersrand

Dr Sibusiso Sibisi
Chief Executive Officer, CSIR

Adv. Ghandi Badela
Advocate, Duma Nokwe Group

Ms Phindile Baleni
Director General, Gauteng Premier's Office

Dr Philip Goyns
Senior Climate Change Advisor, Promethium Carbon

Dr Antonio Llobell
Chief Executive Officer, BioGold International

Dr Ramatsemela Masango
Executive Director, Mzansi Energy Solutions and Innovations (Pty) Ltd

Ms Mokgadi Maseko
Director, Leruo Corporate Consulting

Mr Joel Netshitenzhe
Executive Director and Board Vice-Chairperson, Mapungubwe Institute for Strategic Reflection

Ms Ayanda Noah
Group Executive: Distribution, Eskom

Prof. Mamokgethi Phakeng
Vice Principal of Research and Innovation, Unisa

Governance structure

Schedule of attendance of the CSIR Board and CSIR committee meetings (1 April 2015 to 31 March 2016)

Board member	Board meetings	Audit and Risk Committee	Human Resources and Remuneration Committee	Research, Development and Innovation Committee
Majozi	5			
Sibisi	5[a]	4[a]	3[a]	4[a]
Badela	4	4	4	
Baleni	3	0	1	
Goyns	5		4	4
Llobell	2			2
Masango	5			4
Maseko	4	3		
Netshitenzhe	5			2
Noah	1	3		
Phakeng	5		4	4

[a] Attends in capacity as CEO.

Governance structure

Executive Management Committee

The Executive Management Committee has executive responsibility for the CSIR and consists of the following Executive members:

1. CEO: Dr Sibusiso Sibisi
2. Group Executive, Human Capital: Ms Goitsemang Huma (from May 2015)
3. Group Executive, Research and Development: Dr Molefi Motuku
4. Chief Financial Officer: Mr Chris Sturdy
5. Group Executive, Strategic Alliances and Communication: Dr Rachel Chikwamba
6. Group Executive, Operations: Mr Laurens Cloete
7. Group Executive, Shared Services: Mr Raynold Zondo

All Executives are employed on a five-year contract.

Governance structure

CSIR leadership team

The CSIR management is responsible for strategy implementation and managing the day-to-day affairs of the CSIR and its operating units in accordance with the policies and objectives approved by the CSIR Board.

This leadership team comprises the members of the CSIR Executive Management Committee and Operating Unit Executive Directors and Centre Managers.

Other internal structures that contribute to governance at the CSIR include the Executive, Operations and Strategic Committees, the Strategic Research and the Research Advisory Panels.

Board of Directors and Group companies

The CSIR Executive appoints the boards of the various subsidiary companies.

Board and Executive Management remuneration

Details of the Board are set out on pages 133 to 134 of the Corporate Governance Report. The membership and Terms of Reference of each Board committee are further described on page 138.

Remuneration of Board members and the Executive Management is set out in Note 18 of the annual financial statements.

Remuneration of Executive Management is in accordance with the remuneration policy that has been approved by the Board.

General

The CSIR acknowledges that systems of corporate governance should be reviewed continuously to ensure that these are sound and consistent with world-class standards relevant to the operations of the Group.

The CSIR will continue to comply with all major recommendations of the Code of Corporate Practices and Conduct as set out in the King Report on Corporate Governance.

Public Finance Management Act (PFMA)

The PFMA came into effect on 1 April 2000 and has had an impact on governance matters regarding the regulation of financial management in the public sector. For the financial period reported, the CSIR has complied with the PFMA requirements.

Materiality framework

The materiality framework for reporting losses through criminal conduct and irregular, fruitless and wasteful expenditure, as well as for significant transactions envisaged per section 52 of the PFMA, has been finalised and incorporated into the Shareholder's Compact. No material losses through criminal conduct and irregular, fruitless and wasteful expenditure were incurred during the year.

CSIR Board committees

Audit and Risk Committee

1 April 2015 to 31 March 2016

Chairperson: Ms A Noah

Members: Adv. G Badela
Ms P Baleni
Ms M Maseko

Meetings: 16 April 2015
24 June 2015
9 September 2015
12 February 2016

Purpose:

- To deal with all matters prescribed by the regulations issued regarding the PFMA and the Scientific Research Council Act;
- To perform the final review of the key risk matters affecting the organisation;
- To agree on the scope and review the annual external audit plan and the work of the CSIR internal auditors (including the internal audit charter); and
- To act in an unfettered way to understand the dynamics and performance of the organisation without restrictions.

The Audit and Risk Committee has adopted formal Terms of Reference and is satisfied that it has complied with its responsibilities as set out in the Terms of Reference.

Human Resources and Remuneration Committee

1 April 2015 to 31 March 2016

Chairperson: Adv. G Badela

Members: Ms P Baleni
Dr P Goyns
Prof. M Phakeng

Meetings: 14 April 2015
24 June 2015
9 September 2015
9 February 2016

Purpose:

- To influence and advise on human resources and remuneration matters in the organisation; and
- To approve remuneration changes and bonus payments and review the remuneration of the Executive Management.

The Human Resources and Remuneration Committee has adopted formal Terms of Reference and is satisfied that it has complied with its responsibilities as set out in the Terms of Reference.

Research, Development and Innovation Committee (formerly Strategic Review Committee)

1 April 2015 to 31 March 2016

Chairperson: Prof. P Phakeng

Members: Dr P Goyns
Dr A Llobell
Dr R Masango
Mr J Netshitenzhe

Meetings: 11 May 2015
8 September 2015
9 November 2015
16 February 2016

Purpose:

- To provide guidance and advice on the long-term trajectory and composition of the CSIR's science and technology portfolio in the context of the needs of the country; and
- To ensure that key innovation and research processes are conducted effectively and benchmarked against international best practice, and that research outputs, organisational climate and credibility remain congruent with the role and objectives of the institution.

The Research, Development and Innovation Committee has adopted formal Terms of Reference and is satisfied that it has complied with its responsibilities as set out in the Terms of Reference.

Board and committee meeting attendance

(1 April 2015 to 31 March 2016)

Board meetings

Board members	25/06/15	10/09/15	12/11/15	10/12/15**	18/02/16
T Majozi (Chair)	Present	Present	Present	Present	Present
S Sibisi	Present*	Present*	Present*	Present*	Present*
G Badela	Present	Present	Apology	Present	Present
P Baleni	Apology	Present	Apology	Present	Present
P Goyns	Present	Present	Present	Present	Present
A Llobell	Apology	Apology	Present	Present	Apology
R Masango	Present	Present	Present	Present	Present
M Maseko	Present	Apology	Present	Present	Present
J Netshitenzhe	Present	Present	Present	Present	Present
A Noah	Apology	Apology	Apology	Apology	Present
M Phakeng	Present	Present	Present	Present	Present

* Attends in capacity as CEO
** Special Board meeting held

Audit and Risk Committee meetings

Committee members	16/04/15	24/06/15	09/09/15	12/02/16
A Noah (Chair)	Present	Apology	Present	Present
G Badela	Present	Present	Present	Present
P Baleni	Apology	Apology	Apology	Apology
M Maseko	Apology	Present	Present	Present

Human Resources and Remuneration Committee meetings

Committee members	14/04/15	24/06/15	09/09/15	09/02/16
G Badela (Chair)	Present	Present	Present	Present
P Baleni	Present	Apology	Apology	Apology
P Goyns	Present	Present	Present	Present
M Phakeng	Present	Present	Present	Present

Board and committee meeting attendance

(1 April 2015 to 31 March 2016)

Research, Development and Innovation Committee meetings (formerly Strategic Review Committee)

Committee members	11/05/15	08/09/15	09/11/15	16/02/16
M Phakeng (Chair)	Present	Present	Present	Present
P Goyns	Present	Present	Present	Present
A Llobell	Present	Apology	Present	Apology
R Masango	Present	Present	Present	Present
J Netshitenzhe	Apology	Present	Apology	Present

Meetings are open to all Board members.

Report of the Audit and Risk Committee

for the year ended 31 March 2016

The committee is pleased to present its report for the financial year ended on 31 March 2016.

The committee's responsibility

The committee has adopted formal Terms of Reference approved by the Board. Accordingly, the committee has conducted its affairs in compliance with its Terms of Reference and has discharged its responsibilities contained therein.

Committee members and attendance

The committee consists of the members as stated on page 138 of this report. In accordance with its approved Terms of Reference, the committee met quarterly during the year under review. The committee met on 16 April 2015, 24 June 2015, 9 September 2015 and 12 February 2016. The schedule of attendance is shown on page 139 of this report.

The effectiveness of internal control

The system of internal control applied by the CSIR over financial risk management is effective, efficient and transparent. In line with the PFMA and King III, the internal audit provides the committee and management with assurance that the internal controls are appropriate and effective. This is achieved by means of the risk management process, as well as the identification of mitigating measures and on-going assessment thereof.

From the quarterly reports of the internal audit, the audit report on the annual financial statements and the management report of the Auditor-General of South Africa, it was noted that no matters were reported that include any material deficiencies in the system of internal control or any deviations therefrom. Accordingly, the committee can report that the system of risk management and internal control over financial reporting for the period under review was efficient and effective.

Internal audit

The Group has an internal audit function that has a direct line of reporting to the committee. Its charter and audit plans are approved by the committee to ensure it operates independently. The committee is satisfied that the internal audit function is operating effectively and has addressed the risks pertinent to the CSIR through its audits.

Risk management

The committee is satisfied that the CSIR has a risk management process focused on identifying, assessing, managing and monitoring significant risks across all operations and Group companies. This has been in place for the year under review and up to the date of approval of the annual financial statements.

Evaluation of financial statements

The committee has evaluated the annual financial statements of the CSIR Group for the year ended on 31 March 2016, and based on the information provided, the committee considers that it complies, in all material respects, with the requirements of the various acts governing disclosure and reporting on the annual financial statements. The committee concurs with the Executive Management that the adoption of the going concern premise in the preparation of the annual financial statements is appropriate. Therefore, the committee has, at its meeting on 27 June 2016, recommended the adoption of the annual financial statements by the CSIR Board.

Ayanda Noah
Chairperson of the Audit and Risk Committee
27 June 2016

Report of the Auditor-General

for the year ended 31 March 2016

Report of the Auditor-General to Parliament on the Council for Scientific and Industrial Research

Report on the consolidated and separate financial statements

Introduction

I have audited the consolidated and separate financial statements of the Council for Scientific and Industrial Research and its subsidiaries set out on pages 156 to 203, which comprise the consolidated and separate statement of financial position as at 31 March 2016, the consolidated and separate statement of profit or loss and other comprehensive income, statement of changes in equity, and statement of cash flows for the year then ended, as well as the notes, comprising a summary of significant accounting policies and other explanatory information.

The accounting authority's responsibility for the consolidated and separate financial statements

The accounting authority is responsible for the preparation and fair presentation of these consolidated and separate financial statements in accordance with the International Financial Reporting Standards (IFRS) and the requirements of the Public Finance Management Act of South Africa, 1999 (Act No. 1 of 1999) (PFMA), and for such internal control as the accounting authority determines necessary to enable the preparation of consolidated and separate financial statements that are free from material misstatement, whether due to fraud or error.

Auditor-General's responsibility

My responsibility is to express an opinion on these consolidated and separate financial statements based on my audit. I conducted my audit in accordance with International Standards on Auditing. Those standards require that I comply with ethical requirements, and plan and perform the audit to obtain reasonable assurance about whether the consolidated and separate financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the consolidated and separate financial statements. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the consolidated and separate financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the entity's preparation and fair presentation of the consolidated and separate financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made by management, as well as evaluating the overall presentation of the consolidated and separate financial statements.

I believe that the audit evidence I have obtained is sufficient and appropriate to provide a basis for my audit opinion.

Opinion

In my opinion, the consolidated and separate financial statements present fairly, in all material respects, the financial position of the Council for Scientific and Industrial Research and its subsidiaries as at 31 March 2016 and their financial performance and cash flows for the year then ended, in accordance with the IFRS and the requirements of the PFMA.

Report on other legal and regulatory requirements

In accordance with the Public Audit Act of South Africa, 2004 (Act No. 25 of 2004) and the general notice issued in terms thereof, I have a responsibility to report findings on the reported performance information against predetermined objectives of selected objectives presented in the annual performance report, compliance with legislation and internal control. The objective of my tests was to identify reportable findings as described under each subheading but not to gather evidence to express assurance on these matters. Accordingly, I do not express an opinion or conclusion on these matters.

Report of the Auditor-General

for the year ended 31 March 2016

Predetermined objectives

I performed procedures to obtain evidence about the usefulness and reliability of the reported performance information of the following selected objectives presented in the annual performance report of the entity for the year ended 31 March 2016:

Objective 1: Scientific and technical on page 149
Objective 2: Learning and growth on pages 149 to 150

I evaluated the usefulness of the reported performance information to determine whether it was presented in accordance with the National Treasury's annual reporting principles and whether the reported performance was consistent with the planned objectives. I further performed tests to determine whether indicators and targets were well defined, verifiable, specific, measurable, time bound and relevant, as required by the National Treasury's Framework for managing programme performance information (FMPPI).

I assessed the reliability of the reported performance information to determine whether it was valid, accurate and complete.

I did not identify any material findings on the usefulness and reliability of the reported performance information for the following objectives:

Objective 1: Scientific and technical on page 149
Objective 2: Learning and growth on pages 149 to 150

Additional matter

Although I identified no material findings on the usefulness and reliability of the reported performance information for the selected objectives, I draw attention to the following matter:

- *Achievement of planned targets*

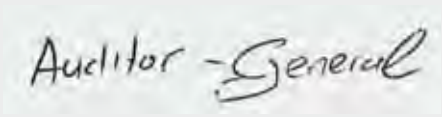
Refer to the annual performance report on pages 148 to 150 for information on the achievement of the planned targets for the year.

Compliance with legislation

I performed procedures to obtain evidence that the entity had complied with applicable legislation regarding financial matters, financial management and other related matters. I did not identify any instances of material non-compliance with specific matters in key legislation, as set out in the general notice issued in terms of the PAA.

Internal control

I considered internal control relevant to my audit of the financial statements, key performance indicators and performance reporting included in the executive report and compliance with legislation. I did not identify any significant deficiencies in internal control.



Pretoria
28 July 2016

AUDITOR-GENERAL
SOUTH AFRICA

Auditing to build public confidence

EXECUTIVE REPORT

Executive report

INTRODUCTION

On behalf of the CSIR Board, we take pleasure in submitting to Parliament, through the Minister of Science and Technology, our Annual Report and the audited annual financial statements of the CSIR Group for the financial year ended 31 March 2016.

In the opinion of the CSIR Board, the financial statements fairly present the financial position of the CSIR Group as at 31 March 2016 and the results of its operations for that year.

Statutory basis

As a statutory research council established by government, the CSIR is governed by the Scientific Research Council Act, 1988 (Act 46 of 1988). The organisation is listed as a Public Business Enterprise in terms of the Public Finance Management Act (PFMA), 1999 (Act 1 of 1999).

The CSIR mandate

The CSIR's mandate is as stipulated in the Scientific Research Council Act, 1988 (Act 46 of 1988):

The objects of the CSIR are, through directed and particularly multidisciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act.
– Extract from Scientific Research Council Act 46 of 1988

The existence of a vibrant economy and a capable state is a pre-requisite for any sustainable solution to South Africa's developmental priorities. Therefore, the work of the CSIR is aimed at supporting industrial development, as well as enhancing the capabilities of government in the areas of service delivery, policy development and information management.

Scientific Research and Development (R&D) will play a critical role in supporting the short-, medium- and long-term growth of the economy. In the short term, we need to develop and deploy technologies that improve the efficiency and competitiveness of our existing enterprises; while in the medium to long term, we need to develop the industries and sectors (based, for example, on the use of new technologies or the beneficiation of local resources) that will grow the economy, as well as understanding and mitigating the risks to long-term growth due to climate change and the mismanagement of our natural resources.

While sustained economic growth will almost certainly address the issues of unemployment and poverty, dealing with the threat of inequality will require a strong and capable state. The CSIR sees its role as providing the scientific and technological innovations that will improve the ability of the state to efficiently deliver basic services (such as health, education, social security, access to energy and shelter) to all South Africans, hence combating material inequality, as well as the inequality of access to basic services remains crucial.

Income sources

The CSIR is funded through a combination of baseline and ring-fenced grants from the Department of Science and Technology (DST) (our Parliamentary Grant) and earns contract research and development income from the public and private sectors; locally and internationally.

Grant funding is invested in research programmes, research infrastructure, as well as in R&D skills development. There are a number of policies and guidelines that underpin the effective utilisation of grant funding.

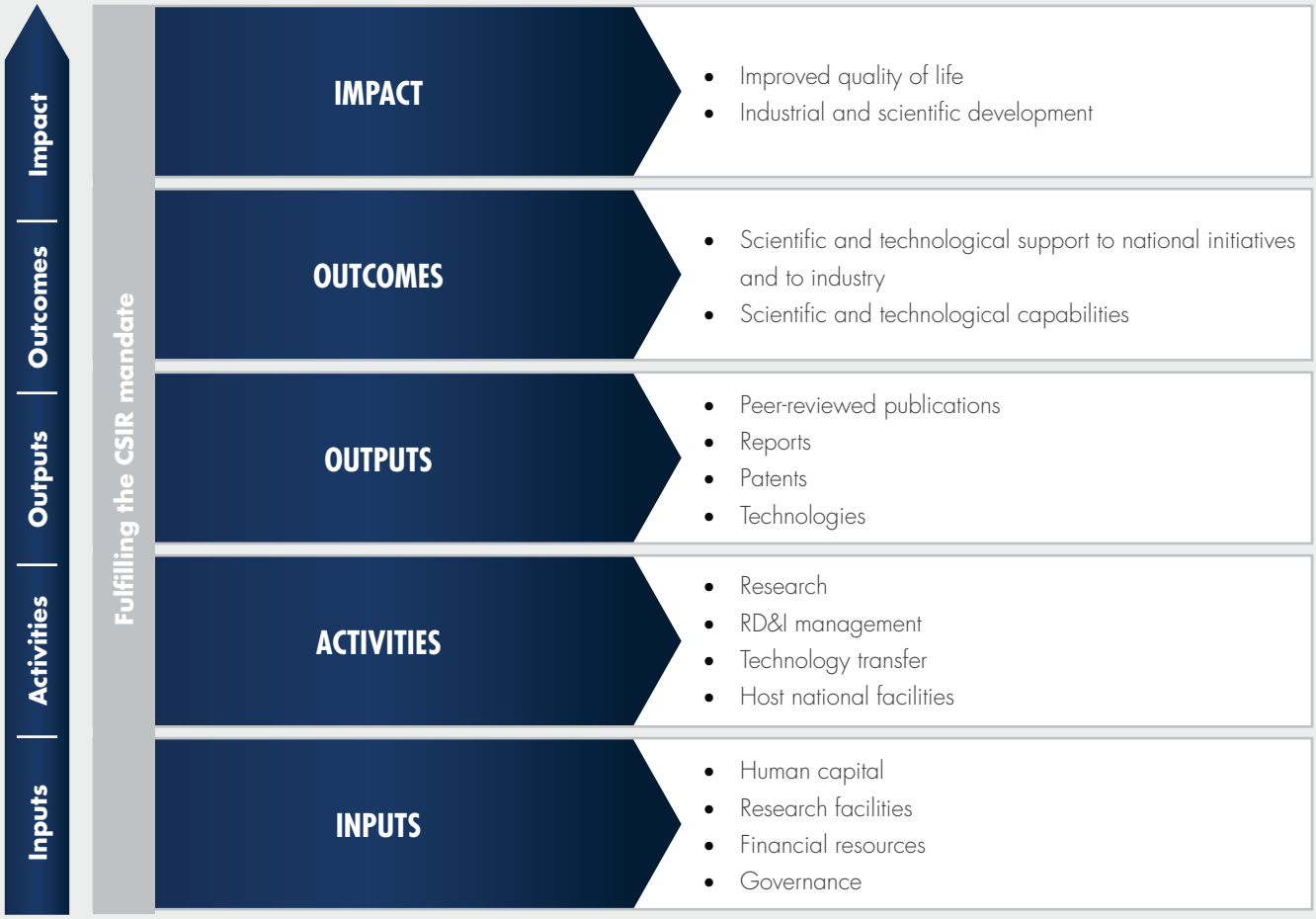
Executive report

Strategic overview

The CSIR is mandated to contribute to the improved quality of life of all South Africans. Meeting this mandate requires that the CSIR responds to the triple challenge of unemployment, inequality and poverty that faces South Africa. The national government intends to address these challenges through a broad range of programmes, guided by the National Development Plan (NDP) and further articulated through government's Programme of Action and sector-specific initiatives. The CSIR's research agenda is also influenced by the DST's national R&D strategy and its Ten-Year Innovation Plan.

The CSIR's strategy is structured around a framework aligning organisational inputs, activities and outputs with this role and the mandate (Figure 1). The CSIR's role is further defined by organisational competences and capabilities, reinforced through an effective network of local and international research partnerships.

Figure 1: The CSIR framework for fulfilling its mandate



Executive report

To contribute to the programme of national development, the CSIR has organised its R&D activities around the concept of a **Research Impact Area (RIA).**

There are six RIAs: Health, Defence and Security, Built Environment, Natural Environment, Industry and Energy, and these are supported by a set of **core technologies** (materials, sensors, photonics, robotics, information and communications technology (ICT) and modelling). The immediate impact of this R&D work is further sharpened by three cross-cutting **Flagship Programmes** (Health, Safety and Security and Transnet Capability Development) and are derived from the R&D outputs generated over time from the RIAs and that focus on short-term interventions that transfer technological solutions to external stakeholders.

The RIAs and flagship programmes have been chosen to provide a coherent and organised response to key national development questions.

The **Natural Environment RIA** will support long-term economic growth and the transition to a low-carbon economy by:

1. Developing models to improve our understanding of the scale and impact of climate change;
2. Developing and implementing interventions to facilitate the growth of the green economy; and
3. Developing and implementing the tools and methods that improve our ability to understand, measure and sustainably manage our natural resources.

The **Defence and Security RIA** contributes to a safe future for South Africa by supporting the building of a capable state and developing technology solutions to ensure safer communities.

The main focus areas of the RIA are:

1. Information security: Promote the adoption and use of trusted technologies, as well as the development of secure systems;
2. Tactical and strategic situation awareness: Enhance South Africa's ability to meet its safety and security needs and obligations;
3. Command control and coordinations: Develop all-inclusive command, coordination and control solutions for multi-agency operations; and
4. Developing solutions for inter-operability and the standardisation of systems across organs of state tasked with defence and security.

The **Industry RIA** supports long-term economic growth (and thereby helps to grow the economy, create jobs and improve quality of life) by developing and transferring manufacturing technologies that improve the competitiveness of existing South African industry and by creating new manufacturing opportunities. The main focus areas are:

1. Beneficiation of South African minerals across the value-chain, focusing on titanium, aluminium and South African clays;
2. Biomanufacturing: Supporting bio- and agro-manufacturing product and process development to generate commercialisable products;
3. The development of new manufacturing processes for the aerospace and automotive industries;
4. Developing advanced materials and composites for industrial-scale manufacture;
5. Enhancing industrial competitiveness through the management of industry support programmes for the aerospace, biomanufacturing and foundry sectors, as well as technology localisation;
6. Improving industrial efficiency through fostering the optimal utilisation of resources; and
7. Utilising our Information Technology (IT) capabilities and infrastructure to create economic opportunities in wireless applications and the commercialisation of software technologies.

Executive report

The **Energy RIA** promotes achievement of the national vision of an energy-secure and low-carbon national economy through the development and implementation of renewable and alternative energy technologies, focusing in particular on:

1. Energy storage;
2. The development and demonstration of renewable energy technologies;
3. Building an enabling energy environment;
4. Energy system integration; and
5. Market design and policy-making.

The **Health RIA** contributes to improving the health of all South Africans. The main focus areas of the RIA are:

1. Combating the high burden of disease through the development of cost-effective bio-therapeutic technologies;
2. A seamless, secure and trustworthy health information system;
3. The development of medical devices, sensors and information systems to provide point-of-care assistance; and
4. Contribute towards greater food security and combat malnutrition by exploiting indigenous and naturalised plants.

The **Built Environment RIA** will contribute to the development and maintenance of our economic infrastructure and the transformation of human settlements. The main focus areas of the RIA are:

1. The collection, analysis and integration of data in decision-support systems for the planning, monitoring and maintenance of settlements;
2. Improving the design, maintenance and efficiency of buildings;
3. The development of appropriate design methods and maintenance procedures for road, port and railway infrastructure; and
4. Models and methods to support the development of a more efficient public and freight transport system.

OVERVIEW OF 2015/16 PERFORMANCE

Key performance indicators and performance reporting

The CSIR enters into a Shareholder's Compact agreement with the DST on an annual basis. The Compact contains a long-term strategic plan and a detailed operational plan with specific Key Performance Indicators (KPIs). The setting of KPI targets is supported by ongoing benchmarking against similar research organisations and trend analysis. Quarterly reports to the DST are the main forms by which the performance against these indicators is monitored.

The CSIR's KPIs provide a high-level basket of measures that reflects the strategic objectives of the organisation. These strategic objectives can be summarised as follows:

1. **Scientific and technical:** These KPIs are a measure of the extent to which we conduct research and technological innovation to foster industrial and scientific development. The KPIs that are linked to this strategic objective measure the annual aggregated outputs that are produced by these research programmes. These are academic publications, patents, technology demonstrators, the income earned from R&D performed on behalf of other parties and the income earned from royalties or the licensing of CSIR technologies.
2. **Learning and growth:** These KPIs measure the extent to which we are able to build and transform human capital. The CSIR's scientific and technical contributions are only possible through the skills and capabilities of our scientific staff (our science, engineering and technology (SET) base). Therefore, the ongoing development, renewal and transformation of the SET base is of critical importance for the organisation. The KPIs that are linked to this strategic objective include the overall size of the SET base, the number and percentage of that base with doctoral level qualifications and the number and percentage of the SET base that are black and female South Africans respectively.

Executive report

3. **Finance and governance:** Without a well-run and financially sustainable organisation, our ability to contribute to national development through our scientific and technological work would be severely compromised. The KPIs linked to this strategic objective include the level of investment we make to maintain our infrastructure, our Broad-Based Black Economic Empowerment (B-BBEE) status and our safety record.

The CSIR has met or exceeded all but one of the objectives set in the 2015/16 Shareholder's Compact. Once again, the organisation has delivered high-quality scientific outputs while growing and transforming our scientific base, as well as maintaining our already high standards regarding financial and corporate governance.

Scientific and technical

The CSIR has met or exceeded the annual targets for five of the six indicators in this category.

Table 1: CSIR performance: scientific and technical

Indicator	2015/16 Target	2015/16 Actual
Publication equivalents	≥490	516
Journal articles	≥300	340
New technology demonstrators	≥30	50
New patents granted	≥15	20
Contract R&D income	≥R1 786m	R1 967m
Royalty and licence income	≥R7.4m	R5.2m

The CSIR continues to place emphasis on the quality and quantity of our research outputs in the form of peer-reviewed publications (journal articles and conference papers), technology demonstrators and patents. The CSIR produced 516 publication equivalents, consisting of 340 journal articles, 309 peer-reviewed conference papers and 43 book chapters. This exceeds our target of 490 publication equivalents and 300 journal articles.

Technology demonstrators are a lead indicator of technology transfer and the excellent performance in exceeding this target further illustrates the greater efforts the CSIR is making in this area.

R&D contract income amounting to R1 967 million exceeded the budget by R181 million. Income from royalties and licensing amounted to R5.2 million, R2.2 million less than our target of R7.4 million. The lower than expected income from royalties and licensing is largely due to external conditions, including the slow growth rate of the economy and the drought over southern Africa.

Learning and growth

The CSIR has met or exceeded the annual targets for all seven indicators in this category.

Table 2: CSIR performance: learning and growth

Indicator	2015/16 Target	2015/16 Actual
Total size of SET base	1 850	1 969
Number of black South Africans in SET base	1 050	1 164
% of SET base who are black South Africans	≥57	59
Number of female South Africans in SET base	630	692
% of SET base who are female South Africans	≥34	35
Number of SET base with Doctorates	330	345
% of SET base with Doctorates	≥18	18

The better than expected growth in SET staff is a very positive indication of growth and was enabled by the sound financial performance of the organisation. The transformation of SET staff also continues to improve.

Executive report

The SET base consists of staff who primarily work on or manage research and development projects. At the end of the financial year, the SET base consisted of 1 969 employees, 119 more than the target of 1 850. The CSIR also comfortably exceeded the targets for the number and percentage of SET staff who are black South Africans and female South Africans respectively.

At the end of the financial year, 345 members of the SET base had a doctoral qualification, 15 more than the target of 330. This equates to 18% of the SET base.

Financial and governance

The CSIR has met or exceeded its target for all five indicators in this category.

Table 3: CSIR performance: financial and governance

Indicator	2015/16 Target	2015/16 Actual
Investment in property, plant and equipment	≥R113m	R308m
Total income	≥R2 450m	R2 697m
Net profit	≥ R54m	R59.2m
B-BBEE rating	Level 2 contributor	Level 2 contributor
Disabling injury frequency rate	<0.3	0.11

The CSIR continued to demonstrate its financial sustainability despite the current difficult economic climate. The solid performance in achieving corporate governance and citizenship targets was maintained. The value of investment in property, plant and equipment exceeded the target and included a significant investment in upgrading the Centre for High Performance Computing.

HUMAN RESOURCES OVERVIEW

At the end of the 2015/16 financial year, the CSIR had a staff complement of 2 685 employees. Table 4 gives the distribution of employees across the different occupational levels.

Table 4: CSIR employees by occupational level: 2016

Occupational level	Total
A. Top	13
B. Senior	99
C. Professional	1 227
D. Skilled	952
E. Semi-skilled	371
F. Unskilled	23
Total	2 685

The majority (81%) of CSIR employees are employed in the Professional and Skilled categories.

The CSIR is committed to the demographic transformation of its workforce. The composition of our workforce by gender, population group and nationality is given in Table 5.

Approximately 6% (147 employees) of our workforce are non-South Africans, with the majority being employed as technical professionals. Black South Africans account for 65% (1 725 employees) of all employees, with black male South Africans accounting for 33% and black female South Africans accounting for 32% of all employees.

Executive report

Table 5: CSIR employee demographics: by gender, population group and nationality

Occupational level	Male					Female				
	A	C	I	W	N-SA	A	C	I	W	N-SA
A. Top	3	1	0	4	0	2	1	0	0	2
B. Senior	20	4	11	38	9	4	0	1	11	1
C. Professional	213	32	70	389	92	146	21	45	190	29
D. Skilled	294	17	35	61	5	345	33	45	108	9
E. Semi-skilled	153	16	2	1	0	161	23	4	11	0
F. Unskilled	15	3	0	0	0	5	0	0	0	0
Total	**698**	**73**	**118**	**493**	**106**	**663**	**78**	**95**	**320**	**41**

A=African, C=Coloured, I=Indian, W=White, N-SA=Non-South African

Staff qualification profile

Three hundred and fifty-five (355) CSIR employees have doctoral qualifications[1] and 594 employees have masters-level qualifications. Table 6 shows the distribution of these qualifications by some key demographic groups. The proportion of doctorates that are black or female South Africans is relatively low (34% and 23% respectively) and the CSIR is committed to the long-term efforts needed to improve these numbers. The corresponding figures for masters-level qualifications are more positive – 37% of employees at this level are female South Africans and 52% are black South Africans.

Table 6: CSIR staff qualification: 2016

Qualification	Doctorate	Masters	Masters/ Doctorate
Total	**355**	**594**	**949**
SA female	81	220	301
% of all	23%	37%	32%
SA male	194	331	525
% of all	55%	56%	55%
SA black	119	307	426
% of all	34%	52%	45%

Ongoing qualifications

The CSIR is committed to supporting the academic development and transformation of its staff. Table 7 shows the number and distribution of staff studying to obtain higher (doctoral or masters) degrees. At the end of the 2015/16 financial year, 416 employees were enrolled for higher degrees (179 for doctorates and 237 for masters); 46% of these were female South Africans and 65% were black South Africans.

Table 7: CSIR staff studying for higher degrees: 2016

Staff enrolled for	Doctorate	Masters	Masters/ Doctorate
Total	**179**	**237**	**416**
SA female	80	111	191
% of all enrolled	45%	47%	46%
SA male	93	119	212
% of all enrolled	52%	50%	51%
SA black	106	164	270
% of all enrolled	59%	69%	65%

1 This is higher than the 345 reported in Table 2 since that statistic refers only to SET staff.

Executive report

FINANCIAL PERFORMANCE OVERVIEW

The CSIR remains financially sustainable and has exceeded its financial targets. The total operating income of the CSIR increased by 13% to R2.70 billion (2014/15: R2.38 billion). The Parliamentary Grant recognised as income in 2015/16 amounted to R680.5 million, an increase of 0.8% from the prior year amount of R675.3 million.

The CSIR's total contract R&D income increased by 17% to R1.97 billion (2014/15: R1.68 billion). This includes a R68.1 million (2014/15: R93.9 million) ring-fenced allocation from the DST.

The CSIR's continued alignment with national strategic priorities ensured that a significant part of the contract income was received from the South African public sector. Public sector income amounted to R1.65 billion (2014/15: R1.33 billion).

The continued investment in scientific infrastructure and equipment remains a priority to ensure that world-class facilities and equipment are acquired and maintained. Over the past five financial years, R967 million has been invested in property, plant and equipment with R308 million invested in the 2015/16 financial year.

Five-year review of income and expense indicators

	2016 R'000	2015 R'000	2014 R'000	2013 R'000	2012 R'000
Total income	**2 736 550**	**2 442 590**	**2 202 595**	**2 069 221**	**1 919 381**
Parliamentary Grant recognised as income	680 485	675 340	618 849	594 478	556 837
Contract income, royalty income, other income and net finance income	**2 056 065**	**1 767 250**	**1 583 746**	**1 474 743**	**1 362 544**
Local private and international sectors	320 950	348 388	361 353	361 018	320 491
Local public sector	1 645 798	1 331 042	1 134 470	1 027 998	952 909
Royalties and other income	49 347	30 202	38 766	39 351	50 771
Net finance income	39 970	57 618	49 157	46 376	38 373
Total expenditure	**2 677 568**	**2 390 203**	**2 151 664**	**2 020 769**	**1 850 383**
Employees' remuneration	1 468 155	1 339 345	1 229 566	1 108 202	1 014 879
Operating expenses	1 154 910	1 002 234	874 885	867 680	793 680
Depreciation	54 503	48 624	47 213	44 887	41 824

Executive report

Net profit and cash flow

The net profit of the CSIR amounts to R59.2 million (2014/15: R52.4 million). The cash and cash equivalent holdings of the CSIR stood at R1 005.2 million (2014/15: R975.9 million). The current ratio is comparable to the previous financial year at 1.1.

Five-year ratio analysis

	2016	2015	2014	2013	2012
Operating expenses					
Remuneration as a percentage of total income (excluding finance income)	54.4%	56.2%	57.1%	54.8%	54.0%
Remuneration as a percentage of total operating expenditure	54.8%	56.0%	57.1%	54.8%	54.8%
Asset management					
Investment in property, plant and equipment (Rm)	308.0	209.7	134.7	130.1	184.2
Investment in property, plant and equipment as a percentage of revenue	11.6%	8.9%	6.3%	6.5%	10.0%
Net asset turn	2.9	2.8	2.7	3.2	3.3
Current ratio	1.1	1.1	1.1	1.1	1.1
Cash flow					
Net cash from operating activities (R'000)	138 869	41 407	137 626	130 385	78 562
Cash and cash equivalents at end of year (including long-term fixed deposits) (R'000)	1 005 241	975 952	1 043 427	983 511	949 360

Definitions

Net asset turn: Total revenue (including finance income) divided by net assets.
Current ratio: Current assets divided by current liabilities.

The post-retirement medical benefit expense and liability and the effects of the adoption of IFRS, IAS39: Financial instruments – recognition and measurement, have been excluded for the comparison of financial indicators.

ANNUAL FINANCIAL STATEMENTS

STATEMENTS OF

Profit or loss and other comprehensive income

FOR THE YEAR ENDED 31 MARCH 2016

	Notes	GROUP 2016 R'000	GROUP 2015 R'000	CSIR 2016 R'000	CSIR 2015 R'000
Revenue	2	2 650 741	2 362 176	2 652 482	2 363 444
Other income		45 961	21 605	44 098	21 528
Total operating income		2 696 702	2 383 781	2 696 580	2 384 972
Expenditure					
Employees' remuneration		1 468 201	1 341 617	1 468 155	1 339 345
Depreciation and amortisation	6 & 7	54 514	48 652	54 503	48 624
Operating expenses		1 163 854	1 001 862	1 154 910	1 002 234
Total operating expenditure		2 686 569	2 392 131	2 677 568	2 390 203
Finance income	4	48 781	65 688	48 341	64 570
Finance expense	4	(8 371)	(6 952)	(8 371)	(6 952)
Share of profit of joint ventures and associates	8	2 193	2 426	-	-
Profit before income tax	3	52 736	52 812	58 982	52 387
Income tax expense	5	(1 554)	-	-	-
Profit for the year		51 182	52 812	58 982	52 387
Other comprehensive income					
Not subsequently reclassified to profit or loss:					
Remeasurement of post-retirement medical benefit obligation	17.3	704	8	704	8
May be subsequently reclassified to profit or loss:					
Change in value of available-for-sale financial asset	10	(526)	-	(526)	-
Other comprehensive income for the year		178	8	178	8
Total comprehensive income for the year		51 360	52 820	59 160	52 395
Profit attributable to:					
Stakeholders of the parent		51 182	52 812	58 982	52 387
Total comprehensive income attributable to:					
Stakeholders of the parent		51 360	52 820	59 160	52 395

STATEMENTS OF

Financial position

AS AT 31 MARCH 2016

	Notes	GROUP 2016 R'000	GROUP 2015 R'000	CSIR 2016 R'000	CSIR 2015 R'000
ASSETS					
Non-current assets		763 102	751 915	777 379	750 431
Property, plant and equipment	6	753 737	736 032	753 725	736 009
Intangible assets	7	-	-	-	-
Interest in joint ventures and associates	8	1 438	10 474	1 424	1 364
Interest in subsidiaries	9	-	-	16 053	7 649
Available-for-sale financial asset	10	6 177	5 409	6 177	5 409
Trade and other receivables	11	1 750	-	-	-
Current assets		1 397 100	1 351 141	1 381 123	1 343 040
Trade and other receivables	11	250 705	264 325	242 366	264 187
Inventory and contracts in progress	12	105 966	102 901	105 966	102 901
Cash and cash equivalents	23	1 012 879	983 915	1 005 241	975 952
Non-current assets held for sale	6.1	27 550	-	27 550	-
TOTAL ASSETS		2 160 202	2 103 056	2 158 502	2 093 471
EQUITY AND LIABILITIES					
Reserves		930 507	879 147	928 632	869 472
Retained earnings		930 507	879 147	928 632	869 472
Non-current liabilities		10 695	10 614	10 695	10 614
Post-retirement medical benefits	17.3	10 695	10 614	10 695	10 614
Current liabilities		1 219 000	1 213 295	1 219 175	1 213 385
Advances received	14	800 202	767 209	800 202	767 209
Trade and other payables	15	418 798	446 086	418 973	446 176
TOTAL EQUITY AND LIABILITIES		2 160 202	2 103 056	2 158 502	2 093 471

STATEMENTS OF

Changes in equity

FOR THE YEAR ENDED 31 MARCH 2016

	Retained earnings	Total
	R'000	R'000
GROUP		
Balance at 31 March 2014	826 327	826 327
Total comprehensive income	52 820	52 820
Profit for the year	52 812	52 812
Other comprehensive income for the year:		
Remeasurement of post-retirement medical benefit obligation	8	8
Balance at 31 March 2015	879 147	879 147
Total comprehensive income	51 360	51 360
Profit for the year	51 182	51 182
Other comprehensive income for the year:		
Remeasurement of post-retirement medical benefit obligation	704	704
Change in value of available-for-sale financial asset	(526)	(526)
Balance at 31 March 2016	930 507	930 507
CSIR		
Balance at 31 March 2014	817 077	817 077
Total comprehensive income	52 395	52 395
Profit for the year	52 387	52 387
Other comprehensive income for the year:		
Remeasurement of post-retirement medical benefit obligation	8	8
Balance at 31 March 2015	869 472	869 472
Total comprehensive income	59 160	59 160
Profit for the year	58 982	58 982
Other comprehensive income for the year:		
Remeasurement of post-retirement medical benefit obligation	704	704
Change in value of available-for-sale financial asset	(526)	(526)
Balance at 31 March 2016	928 632	928 632

STATEMENTS OF

Cash flows

FOR THE YEAR ENDED 31 MARCH 2016

	Notes	GROUP 2016 R'000	GROUP 2015 R'000	CSIR 2016 R'000	CSIR 2015 R'000
Cash flows from operating activities					
Cash receipts from external customers		2 035 880	1 765 929	2 034 269	1 767 088
Parliamentary Grant received		649 704	657 819	649 704	657 819
Cash paid to suppliers and employees		(2 586 888)	(2 443 881)	(2 584 844)	(2 441 383)
Cash generated/(utilised) from operating activities	22	98 696	(20 133)	99 129	(16 476)
Finance income received	4	48 551	65 953	48 111	64 835
Finance expense paid	4	(8 371)	(6 952)	(8 371)	(6 952)
Income taxes paid	5	(1 582)	-	-	-
Net cash from operating activities		137 294	38 868	138 869	41 407
Cash flows from investing activities					
Acquisition of property, plant and equipment	6	(100 543)	(130 512)	(100 543)	(130 482)
Proceeds on disposal of property, plant and equipment		2 233	825	2 233	825
Decrease in subsidiary loans		-	-	-	13 000
Decrease in interest in joint ventures and associates		1 250	7 000	-	6 000
Increase in available-for-sale financial asset		(1 294)	(1 705)	(1 294)	(1 705)
Acquisition of intangible assets	7	-	(123)	-	-
Net cash utilised in investing activities		(98 354)	(124 515)	(99 604)	(112 362)
Cash flows from financing activities					
Net cash utilised in financing activities		-	-	-	-
Unrealised exchange (losses)/gains on foreign cash balances		(9 976)	3 480	(9 976)	3 480
Net increase/(decrease) in cash and cash equivalents		28 964	(82 167)	29 289	(67 475)
Cash and cash equivalents at beginning of the year		983 915	1 066 082	975 952	1 043 427
Cash and cash equivalents at end of the year	23	1 012 879	983 915	1 005 241	975 952

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

1. PRINCIPAL ACCOUNTING POLICIES

The CSIR is a national government business enterprise (enacted by The Scientific Research Council Act, Act 46 of 1988) domiciled in the Republic of South Africa. The address of the CSIR's principal place of business is Meiring Naudé Road, Brummeria, Pretoria. The CSIR undertakes directed and particularly multi-disciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic.

The consolidated annual financial statements of the Group as at and for the year ended 31 March 2016 comprise the company and its subsidiaries (together referred to as the Group) and the Group's interest in associates and jointly controlled entities.

1.1 Basis of presentation

The consolidated annual financial statements have been prepared in accordance with International Financial Reporting Standards (IFRS) as issued by the International Accounting Standards Board (IASB) and the Public Finance Management Act, Act 1 of 1999 as amended by Act 29 of 1999.

The policies set out as follows have been consistently applied to all the years presented.

The preparation of financial statements requires management to make judgements, estimates and assumptions that affect the application of policies and reported amounts of assets and liabilities, income and expenses. The estimates and associated assumptions are based on historical experience and various other factors that are believed to be reasonable under the circumstances, the result of which forms the basis of making judgements about carrying values of assets and liabilities that are not readily apparent from other sources. Actual results may differ from these estimates. Estimates and underlying assumptions are reviewed on an ongoing basis. Revisions to accounting estimates are recognised in the period in which the estimate is revised and in any future periods affected.

The consolidated annual financial statements are presented in South African rand (R), which is the CSIR's functional currency, and are rounded off to the nearest thousand.

1.2 Basis of consolidation

Subsidiaries

Subsidiaries are all entities (including structured entities) over which the Group has control. The Group controls an entity when the Group is exposed to, or has rights to, variable returns from its involvement with the entity and has the ability to affect those returns through its power over the entity. Subsidiaries are fully consolidated from the date on which control is transferred to the Group. They are deconsolidated from the date that control ceases.

The Group applies the acquisition method to account for business combinations. The consideration transferred for the acquisition of a subsidiary is the fair values of the assets transferred, the liabilities incurred to the former owners of the acquiree and the equity interests issued by the Group. The consideration transferred includes the fair value of any asset or liability resulting from a contingent consideration arrangement. Identifiable assets acquired and liabilities and contingent liabilities assumed in a business combination are measured initially at their fair values at the acquisition date. The Group recognises any non-controlling interest in the acquiree on an acquisition-by-acquisition basis, either at fair value or at the non-controlling interest's proportionate share of the recognised amounts of the acquiree's identifiable net assets. Acquisition-related costs are expensed as incurred.

If the business combination is achieved in stages, the acquisition date carrying value of the acquirer's previously held equity interest in the acquiree is re-measured to fair value at the acquisition date; any gains or losses arising from such re-measurement are recognised in profit or loss.

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

Any contingent consideration to be transferred by the Group is recognised at fair value at the acquisition date. Subsequent changes to the fair value of the contingent consideration that is deemed to be an asset or liability is recognised in accordance with IAS 39 either in profit or loss or as a change to other comprehensive income. Contingent consideration that is classified as equity is not re-measured, and its subsequent settlement is accounted for within equity.

The excess of the consideration transferred, the amount of any non-controlling interest in the acquiree and the acquisition-date fair value of any previous equity interest in the acquiree over the fair value of the identifiable net assets acquired is recorded as goodwill. If the total of consideration transferred, non-controlling interest recognised and previously held interest measured is less than the fair value of the net assets of the subsidiary acquired in the case of a bargain purchase, the difference is recognised directly in profit or loss.

Inter-company transactions, balances and unrealised gains on transactions between group companies are eliminated. Unrealised losses are also eliminated. When necessary, amounts reported by subsidiaries have been adjusted to conform with the Group's accounting policies.

Investments in subsidiaries are measured at cost less accumulated impairment losses in the CSIR's annual financial statements.

Changes in ownership interests in subsidiaries without change of control

Transactions with non-controlling interests that do not result in loss of control are accounted for as equity transactions – that is, as transactions with the owners in their capacity as owners. The difference between fair value of any consideration paid and the relevant share acquired of the carrying value of net assets of the subsidiary is recorded in equity. Gains or losses on disposals to non-controlling interests are also recorded in equity.

Disposal of subsidiaries

When the Group ceases to have control, any retained interest in the entity is remeasured to its fair value at the date when control is lost, with the change in carrying amount recognised in profit or loss. The fair value is the initial carrying amount for the purposes of subsequently accounting for the retained interest as an associate, joint venture or financial asset. In addition, any amounts previously recognised in other comprehensive income in respect of that entity are accounted for as if the Group had directly disposed of the related assets or liabilities. This may mean that amounts previously recognised in other comprehensive income are reclassified to profit or loss.

Associates

Associates are all entities over which the Group has significant influence but not control, generally accompanying a shareholding of between 20% and 50% of the voting rights. Investments in associates are accounted for using the equity method of accounting. Under the equity method, the investment is initially recognised at cost, and the carrying amount is increased or decreased to recognise the investor's share of the profit or loss of the investee after the date of acquisition. The Group's investment in associates includes goodwill identified on acquisition.

If the ownership interest in an associate is reduced but significant influence is retained, only a proportionate share of the amounts previously recognised in other comprehensive income is reclassified to profit or loss where appropriate.

The Group's share of post-acquisition profit or loss is recognised in profit or loss, and its share of post-acquisition movements in other comprehensive income is recognised in other comprehensive income with a corresponding adjustment to the carrying amount of the investment. When the Group's share of losses in an associate equals or exceeds its interest in the associate, including any other unsecured receivables, the Group does not recognise further losses, unless it has incurred legal or constructive obligations or made payments on behalf of the associate.

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

The Group determines at each reporting date whether there is any objective evidence that the investment in the associate is impaired. If this is the case, the Group calculates the amount of impairment as the difference between the recoverable amount of the associate and its carrying value and recognises the amount adjacent to share of profit/loss of associates in profit or loss.

Profits and losses resulting from upstream and downstream transactions between the Group and its associate are recognised in the Group's financial statements only to the extent of unrelated investor's interests in the associates. Unrealised losses are eliminated unless the transaction provides evidence of an impairment of the asset transferred. Accounting policies of associates have been changed where necessary to ensure consistency with the policies adopted by the Group.

Dilution gains and losses arising in investments in associates are recognised in profit or loss.

Investments in associates are measured at cost less accumulated impairment losses in the CSIR's annual financial statements.

Joint arrangements

Under IFRS 11 investments in joint arrangements are classified as either joint operations or joint ventures depending on the contractual rights and obligations of each investor. The CSIR Group has assessed the nature of its joint arrangements and determined them to be joint ventures. Joint ventures are accounted for using the equity method.

Under the equity method of accounting, interests in joint ventures are initially recognised at cost and adjusted thereafter to recognise the Group's share of the post-acquisition profits or losses and movements in other comprehensive income. When the Group's share of losses in a joint venture equals or exceeds its interests in the joint ventures (which includes any long-term interests that, in substance, form part of the Group's net investment in the joint ventures), the Group does not recognise further losses, unless it has incurred obligations or made payments on behalf of the joint ventures.

Unrealised gains on transactions between the Group and its joint ventures are eliminated to the extent of the Group's interest in the joint ventures. Unrealised losses are also eliminated unless the transaction provides evidence of an impairment of the asset transferred. Accounting policies of the joint ventures have been changed where necessary to ensure consistency with the policies adopted by the Group.

Investments in joint ventures are measured at cost less accumulated impairment losses in the CSIR's annual financial statements.

1.3 Foreign currencies

Foreign operations

All foreign subsidiaries of the CSIR are foreign operations. There are no foreign subsidiaries in the period covered by this set of annual financial statements.

The financial statements of foreign subsidiaries are translated into South African rand as follows:

- Assets and liabilities, including goodwill and fair value adjustments on acquisition, at rates of exchange ruling at the reporting date.
- Revenue, expenditure and cash flow items at the average rates of exchange during the relevant financial year (the average rates approximate exchange rates at the various dates).

Differences arising on translation are recognised in other comprehensive income and presented in equity as non-distributable reserves called a foreign currency translation reserve (FCTR). When a foreign operation is disposed of, in part or in full, the relevant amount in the FCTR is transferred to profit or loss.

Foreign exchange gains and losses arising from a monetary item receivable from or payable to a foreign operation, the settlement

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

of which is neither planned nor likely in the foreseeable future, are considered to form part of a net investment in a foreign operation and are recognised directly in other comprehensive income and presented in equity in the FCTR.

Foreign currency transactions and balances

Transactions in foreign currencies are converted to South African rand at the rate of exchange ruling at the date of the transactions. Monetary assets and liabilities denominated in foreign currencies are translated into South African rand using the rates of exchange ruling at the reporting date. The resulting exchange differences are recognised in profit or loss. Non-monetary assets and liabilities measured at fair value are translated at foreign exchange rates ruling at the date the fair value was determined.

1.4 Property, plant and equipment

Owned assets

Land is stated at cost less accumulated impairment losses. Buildings, equipment and vehicles are stated at cost less accumulated depreciation and accumulated impairment losses. Cost includes expenditure directly attributable to acquisition.

The cost of self-constructed assets includes the cost of materials, direct labour, the initial estimate, where relevant, of the costs of dismantling and removing the items and restoring the site on which these are located and an appropriate proportion of production overheads.

Where parts of an item of property, plant and equipment have different useful lives, these are accounted for as separate items (major components) of property, plant and equipment.

Gains and losses on disposal of an item of property, plant and equipment are determined by comparing proceeds from disposal with the carrying amount of property, plant and equipment and are recognised in profit or loss.

Subsequent costs

The Group recognises in the carrying amount of an item of property, plant and equipment, the cost of replacing a part of such an item when that cost is incurred, if it is probable that the future economic benefits embodied in the item will flow to the Group and the cost of the item can be measured reliably. The carrying amount of the replaced part is derecognised. The costs of the day-to-day servicing of property, plant and equipment are recognised in profit or loss as incurred.

Depreciation

Depreciation is based on cost less residual value and is calculated on the straight-line method from the day the assets are available for use, at rates considered appropriate to write off carrying values over the estimated useful lives of the assets, except for assets specifically acquired for a contract, which are depreciated over the life of the contract. Land is not depreciated.

The estimated lives of the main categories of property, plant and equipment for the current and comparative period are as follows:

Land: Indefinite
Buildings: 40 years
Equipment: 3 to 10 years
Vehicles: 10 years

Depreciation methods, useful lives and current residual values, if not insignificant, are reassessed annually.

1.5 Intangible assets

Research and development

Expenditure on research activities, undertaken with the prospect of gaining new scientific or technical knowledge and understanding, is recognised in profit or loss when incurred. Development activities involve a plan or design for the production of new or substantially improved products and processes. Development expenditure is capitalised only if development costs can be measured reliably, the product or process is technically and commercially feasible, future

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

economic benefits are probable, and the Group intends to and has sufficient resources to complete development and to use or sell the asset. The expenditure capitalised includes the cost of materials, direct labour and overhead costs that are directly attributable to preparing the asset for its intended use. Other development expenditure is recognised in profit or loss when incurred.

Capitalised development expenditure is measured at cost less accumulated amortisation and accumulated impairment losses.

Subsequent costs
Subsequent expenditure on capitalised intangible assets is capitalised only when it increases the future economic benefits embodied in the specific asset to which it relates. All other expenditure, including expenditure on internally generated goodwill and brands, is expensed as incurred.

Amortisation
Amortisation is based on cost and calculated on the straight-line method at rates considered appropriate to write off carrying values over the estimated useful lives of the intangible assets with definite useful lives. Intangible assets are amortised from the day they are available for use.

The estimated lives of intangible assets with definite useful lives are as follows:

Investment in technology: 3 to 10 years

Amortisation methods, useful lives and residual values are reviewed at each reporting date and adjusted if appropriate.

1.6 Impairment

Financial assets
A financial asset not classified at fair value through profit or loss is assessed at each reporting date to determine whether there is any objective evidence that it is impaired. A financial asset is considered to be impaired if objective evidence indicates that one or more events have had a negative effect on the estimated future cash flows of that asset.

An impairment loss in respect of a financial asset measured at amortised cost is calculated as the difference between its carrying amount, and the present value of the estimated future cash flows discounted at the original effective interest rate.

Individually-significant financial assets and those that have been identified as impaired are tested for impairment on an individual basis. The remaining financial assets are assessed collectively in groups that share similar credit risk characteristics.
All impairment losses are recognised in profit or loss.

An impairment loss is reversed if the reversal can be related objectively to an event occurring after the impairment loss was recognised. For financial assets measured at amortised cost the reversal is recognised in profit or loss.

Non-financial assets
The carrying amounts of the Group's non-financial assets, other than inventories and deferred tax assets, are reviewed at each reporting date to determine whether there is any indication of impairment. If any such indication exists then the asset's recoverable amount is estimated. For goodwill arising from the acquisition of subsidiaries and intangible assets that have indefinite lives or that are not yet available for use, the recoverable amount is estimated at each reporting date.

An impairment loss is recognised if the carrying amount of an asset or its cash-generating unit exceeds its recoverable amount. A cash-generating unit is the smallest identifiable asset group that generates cash flows that are largely independent from other assets and groups. Impairment losses are recognised in profit or loss. Impairment losses recognised in respect of cash-generating units are allocated first to reduce the carrying amount of any goodwill allocated to the units and then to reduce the carrying amount of the other assets in the unit (group of units) on a pro rata basis.

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

The recoverable amount of an asset or cash-generating unit is the greater of its value in use and its fair value less costs of disposal. In assessing value in use, the estimated future cash flows are discounted to their present value using a pre-tax discount rate that reflects current market assessments of the time value of money and the risks specific to the asset.

An impairment loss in respect of goodwill is not reversed. In respect of other assets, impairment losses recognised in prior periods are assessed at each reporting date for any indications that the loss has decreased or no longer exists. An impairment loss is reversed if there has been a change in the estimates used to determine the recoverable amount. An impairment loss is reversed only to the extent that the asset's carrying amount does not exceed the carrying amount that would have been determined, net of depreciation or amortisation, if no impairment loss had been recognised.

1.7 Short-term employee benefits

Short-term employee benefit obligations are measured on an undiscounted basis and are expensed as the related service is provided. A liability is recognised for the amount expected to be paid under short-term cash bonus if the Group has a present legal or constructive obligation to pay this amount as a result of past service provided by the employee, and the obligation can be estimated reliably.

1.8 Retirement benefits

Pension fund

The Group operates a defined contribution plan, the assets of which are held in a separate trustee-administered fund. The benefits payable by the fund in the future, due to retirements and withdrawals from the fund, are contributions to the fund together with fund interest at a rate determined by the valuator with the consent of the trustees. The rate is so determined that the value of the total of the fund shall not exceed the value of the total assets of the fund.

Post-retirement benefits other than pensions

The Group provides post-retirement medical benefits to qualifying employees, which is deemed to be a defined benefit plan. The expected costs of these benefits are determined using the projected unit credit method, with actuarial valuations being carried out at each reporting date. Contributions are made to the relevant funds over the expected service lives of the employees entitled to those funds. The estimated cost of providing such benefits is charged to profit or loss on a systematic basis over the employees' working lives within the Group.

Actuarial gains and losses are recognised in other comprehensive income in the year when actuarially determined. The amount recognised in the statement of financial position represents the present value of the post-retirement medical fund benefit obligation. Any asset resulting from this calculation is limited to actuarial losses and the present value of available refunds and reductions in future contributions to the plan.

1.9 Inventory and contracts in progress

Inventory is measured at the lower of cost and net realisable value. Cost of inventory is determined by the weighted average method. In the case of work in progress, cost includes an appropriate share of production overheads based on normal operating capacity. Net realisable value represents the estimated selling price less all estimated costs to completion and costs to be incurred in selling.

Contracts in progress are stated as a percentage of the sales value of work completed, after provision for losses relating to the stage of completion and any foreseeable losses to completion of the contract, less progress billings.

1.10 Income tax

The CSIR is exempt from South African income tax. The income tax expense of subsidiary companies is reflected on Group level.

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

Income tax expense comprises current and deferred tax. The current tax charge is based on the profit or loss for the year as adjusted for items that are non-taxable or disallowed. It is calculated using tax rates that have been enacted or substantially enacted at the reporting date. Income tax expense is recognised in profit or loss except to the extent that it relates to items recognised directly in other comprehensive income or equity, in which case it is recognised in other comprehensive income or equity.

Deferred tax is recognised in respect of temporary differences arising from differences between the carrying amounts of assets and liabilities in the financial statements and the corresponding tax basis used in the computation of the taxable profit.

Where the tax effects of temporary differences, including those arising from tax losses, give rise to a deferred tax asset, the asset is recognised only if it is probable that future taxable profits will be sufficient to allow the tax benefit of the loss to be realised. Deferred tax assets are reviewed at each reporting date and are reduced to the extent that it is no longer probable that the related tax benefit will be realised. Deferred tax is not recognised for the following temporary differences: the initial recognition of assets or liabilities in a transaction that is not a business combination and that affects neither profit or loss, and differences relating to investments in subsidiaries, associates and jointly controlled entities to the extent that it is probable that they will not reverse in the foreseeable future.

Deferred tax assets and liabilities are offset when there is a legally enforceable right and when these relate to income taxes levied by the same taxation authority and the Group intends to settle its current tax assets and liabilities on a net basis.

1.11 Provisions

Provisions are recognised when the Group has a present legal or constructive obligation as a result of past events, for which it is probable that an outflow of economic benefits will be required to settle the obligation, and a reliable estimate can be made of the amount of the obligation. Provisions are measured at the present value of the expenditures expected to be required to settle the obligation using a pre-tax rate that reflects current market assessments of the time value of money and the risks specific to the obligation. The increase in the provision due to passage of time is recognised as interest expense.

A provision for onerous contracts is recognised when the expected benefits to be derived by the Group from a contract are lower than the unavoidable cost of meeting its obligations under the contract. The provision is measured at the present value of the lower of the expected cost of terminating the contract and the expected net cost of continuing with the contract. Before a provision is established, the Group recognises any impairment loss on the assets associated with that contract.

1.12 Government grants

Government grants that compensate the Group for expenses incurred are recognised as income on a systematic basis over periods necessary to match the assistance with the related expenses it is intended to compensate.

Grants that compensate the Group for the cost of an asset are deducted in arriving at the carrying amount of the acquired asset.

1.13 Revenue recognition

Revenue from the sale of goods is measured at the fair value of the consideration received or receivable, net of returns and allowances, trade discounts and volume rebates. Revenue is recognised when the significant risks and rewards of ownership have been transferred to the buyer, recovery of the consideration is probable, the associated costs and possible return of goods can be estimated reliably and there is no continuing management involvement with the goods, and the amount of revenue can be measured reliably.

Revenue from services rendered is recognised in profit or loss in proportion to the stage of completion of the transaction at the reporting date. The stage of completion is assessed by reference to work performed as at the reporting date.

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

Contract revenue includes the initial amount agreed in the contract plus any variations in contract work, claims and incentive payments to the extent that it is probable that these will result in revenue and can be measured reliably. As soon as the outcome of a contract can be estimated reliably, contract revenue and expenses are recognised in profit or loss in proportion to the stage of completion of the contract.

The stage of completion is assessed by reference to work performed as at reporting date. When the outcome of a contract cannot be estimated reliably, contract revenue is recognised only to the extent of contract costs incurred that are likely to be recoverable. An expected loss on a contract is recognised immediately in profit or loss.

Royalties are accrued based on the stipulations of the applicable contracts.

1.14 Finance income/expense

Finance income/expense comprises interest receivable on funds invested, dividend income, fair value adjustments on investments and interest payable on borrowings. Interest income is recognised in profit or loss as it accrues, using the effective interest rate method. Dividend income is recognised in profit or loss on the date that the entity's right to receive payments is established (which is when the dividend is declared). Interest payable on borrowings is calculated using the effective interest rate method.

1.15 Expenses

Operating lease payments

Leases in which a significant portion of the risks and rewards of ownership are retained by the lessor are classified as operating leases. Payments made under operating leases are recognised in profit or loss on a straight-line basis over the term of the lease. Lease incentives received are recognised in profit or loss as an integral part of the total lease expense, over the term of the lease.

Finance lease payments

Leases of property, plant and equipment where the Group has substantially all the risks and rewards of ownership are classified as finance leases. Minimum lease payments are apportioned between the finance charge and the reduction of the outstanding liability. The finance charge is allocated to each period during the lease term so as to produce a constant periodic rate of interest on the remaining balance of the liability.

1.16 Financial instruments

Financial instruments are initially measured at fair value plus, for instruments not at fair value through profit or loss, any directly attributable transaction costs, when the Group has become a party to contractual provision of the instrument. Subsequent to initial recognition, these instruments are measured as set out as follows:

Loans and receivables

Trade and other receivables

Trade receivables are subsequently measured at amortised cost using the effective interest method less any impairment losses, which approximate the fair value of these due to the short-term nature thereof.

Loans

Loans are measured at amortised cost using the effective interest method less any impairment losses if they have a fixed maturity, or at cost if there is no fixed maturity.

Cash and cash equivalents

Cash and cash equivalents are measured at amortised cost, which is their fair value. Cash and cash equivalents comprise fixed deposits, call deposits, bank balances, cash on hand and cash deposits.

Financial assets at fair value through profit or loss

Forward exchange contracts

Forward exchange contracts are fair valued and gains and losses are recognised in profit or loss. Hedge accounting is not applied.

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

Available-for-sale financial assets

Available-for-sale financial assets are subsequently carried at fair value. Changes in the fair value of available-for-sale financial assets are recognised in other comprehensive income. When available-for-sale financial assets are sold or impaired, the accumulated fair value adjustments recognised in equity are included in profit or loss.

Financial liabilities at amortised cost

Trade and other payables and advances received

Trade and other payables and advances received are stated at amortised cost, which approximates the fair value of these due to the short-term nature thereof.

De-recognition

Financial assets (or a portion thereof) are de-recognised when the Group realises the rights to the benefits specified in the contract, the rights expire or the Group surrenders or otherwise loses control and does not retain substantially all risks and rewards of the asset. On de-recognition, the difference between the carrying amount of the financial asset and proceeds receivable is included in profit or loss.

Financial liabilities (or a portion thereof) are de-recognised when the obligation specified in the contract is discharged, cancelled or expires. On de-recognition, the difference between the carrying amount of the financial liability and the amount paid for it is included in profit or loss.

1.17 Related parties

The Group operates in an economic environment currently dominated by entities directly or indirectly owned by the South African government. As a result of the constitutional independence of all three spheres of government in South Africa, only parties within the national sphere of government will be considered to be related parties.

Key management is defined as being individuals with the authority and responsibility for planning, directing and controlling the activities of the entity. All individuals from the level of Group Executive up to the Board of Directors are regarded as key management.

Close family members of key management are considered to be those family members who may be expected to influence, or be influenced by key management individuals or other parties related to the entity.

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

1.18 Standards and interpretations issued, not yet effective

At the date of authorisation of the financial statements of the Group for the year ended 31 March 2016, the following standards and interpretations were in issue but not yet effective:

Standard/ Interpretation	Description	Effective date
Amendments to IFRS 10, 'Consolidated financial statements' and IAS 28, 'Investments in associates and joint ventures' on sale or contribution of assets	This amendment was issued to eliminate the inconsistency between IFRS 10 and IAS 28. If the non-monetary assets sold or contributed to an associate or joint venture constitute a 'business', then the full gain or loss will be recognised by the investor. A partial gain or loss is recognised when a transaction involves assets that do not constitute a business, even if these assets are housed in a subsidiary. – This amendment is not expected to affect the Group's results.	Annual periods beginning on or after 1 January 2016
Amendments to IFRS 10, 'Consolidated financial statements' and IAS 28, 'Investments in associates and joint ventures' on applying the consolidation exemption	The amendments clarify the application of the consolidation exception for investment entities and their subsidiaries. – These amendments will not affect the Group's results.	Annual periods beginning on or after 1 January 2016
Amendment to IFRS 11, 'Joint arrangements' on acquisition of an interest in a joint operation	This amendment adds new guidance on how to account for the acquisition of an interest in a joint operation that constitutes a business. The amendments specify the appropriate accounting treatment for such acquisitions. – The impact of this amendment on the Group's results cannot be determined at this stage.	Annual periods beginning on or after 1 January 2016
IFRS 14 – Regulatory deferral accounts	IFRS 14, 'Regulatory deferral accounts' was issued specific to first time adopters as an interim standard on the accounting for certain balances that arise from rate-regulated activities (regulatory deferral accounts). Rate regulation is a framework where the price that an entity charges to its customers for goods and services is subject to oversight and/or approval by an authorised body. – This standard will not affect the Group's results.	Annual periods beginning on or after 1 January 2016
Amendments to IAS 1, 'Presentation of financial statements' disclosure initiative	These amendments were issued to clarify guidance in IAS 1 on materiality and aggregation, the presentation of subtotals, the structure of financial statements and the disclosure of accounting policies. – The impact of these amendments on the Group's results cannot be determined at this stage.	Annual periods beginning on or after 1 January 2016

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

Standard/ Interpretation	Description	Effective date
Amendment to IAS 16, 'Property, plant and equipment' and IAS 38, 'Intangible assets', on depreciation and amortisation	This amendment clarifies that the use of revenue based methods to calculate the depreciation of an asset is not appropriate because revenue generated by an activity that includes the use of an asset generally reflects factors other than the consumption of the economic benefits embodied in the asset. It has also clarified that revenue is generally presumed to be an inappropriate basis for measuring the consumption of the economic benefits embodied in an intangible asset. – This amendment will not affect the Group's results.	Annual periods beginning on or after 1 January 2016
Amendments to IAS 16, 'Property, plant and equipment' and IAS 41, 'Agriculture' on bearer plants	In this amendment to IAS 16 bearer plants have been scoped in, but the produce on bearer plants have not been scoped in. It explains that a bearer plant not yet in the location and condition necessary to bear produce is treated as a self-constructed asset. In this amendment to IAS 41, the definition of a bearer plant has been adjusted to include examples of non-bearer plants and to remove current examples of bearer plants from IAS 41. – These amendments will not affect the Group's results.	Annual periods beginning on or after 1 January 2016
Amendments to IAS 27, 'Separate financial statements' on equity accounting	In this amendment the option to use the equity method to account for investments in subsidiaries, joint ventures and associates in an entity's separate financial statements has been restored. – This amendment will not affect the Group's results.	Annual periods beginning on or after 1 January 2016
IFRS 16 – 'Leases'	This standard replaces the current guidance in IAS 17. Under IAS 17, lessees were required to make a distinction between a finance lease and an operating lease. IFRS 16 now requires lessees to recognise a lease liability reflecting future lease payment and a 'right-of-use asset' for virtually all lease contracts. There is an optional exemption for certain short-term leases and leases of low-value assets which can be applied by lessees. Lessors will be affected by the new standard as the guidance on the definition of a lease has been updated. – The impact of this standard on the Group's results cannot be determined at this stage.	Annual periods beginning on or after 1 January 2016
Amendments to IAS 12 - 'Income taxes' on recognition of deferred tax assets for unrealised losses	These amendments on the recognition of deferred tax assets for unrealised losses clarify how to account for deferred tax assets related to debt instruments measured at fair value. – These amendments are not expected to affect the Group's results.	Annual periods beginning on or after 1 January 2017

1. PRINCIPAL ACCOUNTING POLICIES (CONTINUED)

Standard/ Interpretation	Description	Effective date
IFRS 15 – 'Revenue from contracts with customers'	The converged standard on revenue recognition has been issued. It is a single, comprehensive revenue recognition model for all contracts with customers to achieve greater consistency in the recognition and presentation of revenue. This standard requires entities to recognise revenue to depict the transfer of promised goods or services to customers in an amount that reflects the consideration to which the entity expects to be entitled in exchange for those goods or services. – The impact of this standard on the Group's results cannot be determined at this stage.	Annual periods beginning on or after 1 January 2018
IFRS 9 – 'Financial instruments' (2009 & 2010) • Financial liabilities • Derecognition of financial instruments • Financial assets • General hedge accounting	IFRS 9 addresses classification and measurement of financial assets and replaces the multiple classification and measurement models in IAS 39 with a single model that has only two classification categories: amortised cost and fair value. IFRS 9, 'Financial instruments' has been updated to include guidance on financial liabilities and derecognition of financial instruments. The accounting and presentation for financial liabilities and for derecognising financial instruments has been relocated from IAS 39, 'Financial instruments: Recognition and measurement', without change, except for financial liabilities that are designated at fair value through profit or loss. – The impact of this standard on the Group's results cannot be determined at this stage.	Annual periods beginning on or after 1 January 2018
Amendment to IFRS 9 – 'Financial instruments', on general hedge accounting	IFRS 9 has been amended to align hedge accounting more closely with an entity's risk management. The revised standard also establishes a more principles-based approach to hedge accounting and addresses inconsistencies and weaknesses in the current model in IAS 39. – This amendment will not affect the Group's results.	Annual periods beginning on or after 1 January 2018
Annual improvements 2014	In September 2014 the annual improvements for the 2012 to 2014 cycle was issued, which contains five amendments to four standards, excluding consequential amendments: • IFRS 5, 'Non-current assets held for sale and discontinued operations' • IFRS 7, 'Financial instruments; Disclosures' • IAS 19, 'Employee benefits' and • IAS 34, 'Interim financial reporting'. – The impact of these amendments on the Group's results cannot be determined at this stage.	Annual periods beginning on or after 1 January 2016

The Group has not early-adopted any of the above guidance.

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

2. REVENUE

	GROUP				CSIR			
	2016 R'000	%	2015 R'000	%	2016 R'000	%	2015 R'000	%
Parliamentary Grant	680 485	25	675 340	29	680 485	25	675 340	29
Parliamentary Grant received	649 704	24	657 819	28	649 704	24	657 819	28
Less:								
Grant received for projects started before year-end but not completed	(23 526)	(1)	(54 307)	(2)	(23 526)	(1)	(54 307)	(2)
Add:								
Grant received in prior year for projects completed in this year	54 307	2	71 828	3	54 307	2	71 828	3
Contract R&D income	1 965 007	75	1 677 766	71	1 966 748	75	1 679 430	71
Local private sector	172 348	7	161 604	7	172 154	6	161 265	7
Local public sector	1 643 863	62	1 329 039	56	1 645 798	63	1 331 042	56
International sector (including Africa)	148 796	6	187 123	8	148 796	6	187 123	8
Royalties	5 249	-	9 070	-	5 249	-	8 674	-
	2 650 741	100	2 362 176	100	2 652 482	100	2 363 444	100

Contract R&D income is disclosed after taking into account the effect of the time value of money (the value of discounting) in terms of SAICA's Circular 9 of 2006: Transactions giving rise to adjustments to revenue/purchases. The value is R12,09 million (2015: R13,07 million) and is included in finance income (note 4).

Included in public sector contract R&D income is R68,12 million (2015: R93,93 million) ring-fenced allocation from the Department of Science and Technology for specific initiatives managed through memorandums of agreement.

Included in contract R&D income is rental income amounting to R44,80 million (2015: R35,56 million) and revenue of R32,14 million (2015: R36,81 million) earned by the CSIR International Convention Centre.

Estimates on Parliamentary Grant recognition are based on cost to completion, budgets and percentage of completion.

3. PROFIT BEFORE INCOME TAX

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Profit before income tax is arrived at after taking the following items into account:				
Audit fees	5 658	6 251	5 658	6 251
Fees for services	9 868	6 224	9 764	6 127
Patent costs	8 387	4 813	8 283	4 716
Legal costs	1 481	1 411	1 481	1 411
Operating leases	4 781	5 240	4 745	5 150
Buildings	1 685	1 287	1 649	1 197
Equipment	1 841	2 259	1 841	2 259
Vehicles	1 255	1 694	1 255	1 694
Net realised foreign exchange gain	(55 544)	(14 322)	(55 544)	(14 322)
Net unrealised foreign exchange loss/(gain)	14 145	(5 097)	14 145	(5 097)
Board members' and Executive Management's renumeration (note 18)	25 663	23 850	25 663	21 698
Impairments/(reversals of impairments)	10 339	(10 064)	1 811	(10 351)
Impairment/(reversal of impairment) on subsidiaries, joint ventures and associates	63	(5 873)	(8 465)	(6 037)
Impairment /(reversal of impairment) on trade receivables	10 276	(4 314)	10 276	(4 314)
Impairment on intangible assets	-	123	-	-
Profit on sale of associate*	(1 834)	-	-	-
Bad debt written off	2 278	302	2 278	302
Profit on disposal and write-off of property, plant and equipment	(1 459)	(321)	(1 459)	(330)
Lost and/or stolen equipment and vehicles**	759	488	759	488
Losses incurred	767	488	767	488
Losses recovered	(8)	-	(8)	-

* Refer to note 26.1.

** These are losses incurred in the normal course of the CSIR's business and are covered by the CSIR's insurance policy. The net losses incurred on these are included in the profit on disposal and write-off of property, plant and equipment amounts.

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

4. FINANCE INCOME/EXPENSE

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Finance income	48 781	65 688	48 341	64 570
Interest on bank balances and investments	36 693	52 613	36 253	51 495
Adjustment on initial recognition of contract R&D income*	12 088	13 075	12 088	13 075
Finance expense	(8 371)	(6 952)	(8 371)	(6 952)
Adjustment on initial recognition of operating expenses*	(8 371)	(6 952)	(8 371)	(6 952)
	40 410	58 736	39 970	57 618

* These adjustments are due to the effect of the time value of money (the value of discounting) in terms of SAICA's Circular 9 of 2006: Transactions giving rise to adjustments to revenue/purchases.

5. INCOME TAX EXPENSE

The CSIR is exempt from South African income tax in terms of section 10 (1) (t) (i) of the Income Tax Act, Act No 58 of 1962.

South African normal taxation due by subsidiaries	1 554	-
Current taxation	1 554	-
	1 554	-
	%	%
South African normal rate of taxation	28%	28%
Profit attributable to tax exempt entities	(21%)	(28%)
Assessed loss (refer note 13)	(1%)	1%
Share of profit of joint ventures and associates	(1%)	(1%)
Non taxable portion of capital gain on sale of associate	(2%)	0%
Current and deferred taxation - effective rate	3%	0%

6. PROPERTY, PLANT AND EQUIPMENT

	2016			2015		
	Cost	Accumulated depreciation	Carrying value	Cost	Accumulated depreciation	Carrying value
	R'000	R'000	R'000	R'000	R'000	R'000
Group						
Land	125 435	-	125 435	143 587	-	143 587
Buildings	459 237	64 291	394 946	442 570	68 480	374 090
Equipment	449 576	288 689	160 887	408 685	266 890	141 795
ICT equipment	167 674	102 318	65 356	155 210	85 371	69 839
Furniture and fittings	14 356	9 184	5 172	12 933	8 127	4 806
Vehicles	7 825	5 884	1 941	7 318	5 403	1 915
	1 224 103	470 366	753 737	1 170 303	434 271	736 032
CSIR						
Land	125 435	-	125 435	143 587	-	143 587
Buildings	459 237	64 291	394 946	442 570	68 480	374 090
Equipment	449 576	288 689	160 887	408 685	266 890	141 795
ICT equipment	167 627	102 283	65 344	155 163	85 347	69 816
Furniture and fittings	14 356	9 184	5 172	12 933	8 127	4 806
Vehicles	7 825	5 884	1 941	7 318	5 403	1 915
	1 224 056	470 331	753 725	1 170 256	434 247	736 009

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

6. PROPERTY, PLANT AND EQUIPMENT (CONTINUED)

	Land	Buildings	Equipment	ICT Equipment	Furniture and fittings	Vehicles	Total
	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Group							
Carrying value 31 March 2014	143 587	338 816	126 573	38 667	5 153	1 880	**654 676**
Additions	-	35 492	45 678	47 962	773	607	**130 512**
Disposals and write-offs	-	-	(228)	(256)	(20)	-	**(504)**
Depreciation	-	(218)	(30 228)	(16 534)	(1 100)	(572)	**(48 652)**
Carrying value 31 March 2015	143 587	374 090	141 795	69 839	4 806	1 915	**736 032**
Additions	-	25 549	55 317	17 491	1 529	657	**100 543**
Disposals and write-offs	-	-	(178)	(585)	(11)	-	**(774)**
Depreciation	-	(219)	(31 295)	(21 341)	(1 152)	(507)	**(54 514)**
Transfer to non-current assets classified as held for sale	(18 152)	(4 474)	(4 752)	(48)	-	(124)	**(27 550)**
Carrying value 31 March 2016	125 435	394 946	160 887	65 356	5 172	1 941	753 737
CSIR							
Carrying value 31 March 2014	143 587	338 816	126 573	38 637	5 153	1 880	**654 646**
Additions	-	35 492	45 678	47 932	773	607	**130 482**
Disposals and write-offs	-	-	(228)	(247)	(20)	-	**(495)**
Depreciation	-	(218)	(30 228)	(16 506)	(1 100)	(572)	**(48 624)**
Carrying value 31 March 2015	143 587	374 090	141 795	69 816	4 806	1 915	**736 009**
Additions	-	25 549	55 317	17 491	1 529	657	**100 543**
Disposals and write-offs	-	-	(178)	(585)	(11)	-	**(774)**
Depreciation	-	(219)	(31 295)	(21 330)	(1 152)	(507)	**(54 503)**
Transfer to non-current assets classified as held for sale	(18 152)	(4 474)	(4 752)	(48)	-	(124)	**(27 550)**
Carrying value 31 March 2016	125 435	394 946	160 887	65 344	5 172	1 941	753 725

Land and buildings are unencumbered and full details of the titles are available at the registered office of the CSIR.

A change in the depreciation estimate due to a change in the useful lives of equipment, ICT equipment, furniture and fittings and vehicles, resulted in a R4,9 million (2015: R2,2 million) decrease in the depreciation amount for the current financial year.

During the current financial year, assets to the value of R207,5 million (2015: R79,2 million) were purchased with Government grant funds. At year-end the cumulative value of assets purchased with Government grant funds and shown at a nil cost is R664,6 million (2015: R469,1 million).

6. PROPERTY, PLANT AND EQUIPMENT (CONTINUED)

6.1 Non-current assets held for sale

Property, plant and equipment transferred to non-current assets classified as held for sale amounts to R27,6 million (carrying value) and relates to land, buildings, equipment, ICT equipment and vehicles. The property, plant and equipment has been presented as held for sale following the events detailed below.

The CSIR and Nelson Mandela Metropolitan University (NMMU) are finalising an agreement to transfer Erf 1281 Summerstrand to NMMU. The transfer, subject to the required approval, is expected to be finalised within 12 months.

The CSIR has reached an agreement to sell certain laboratory assets. The contract of sale has been approved and concluded with the effective date being subject to certain suspensive conditions being met.

7. INTANGIBLE ASSETS

	2016			2015		
	Cost	Accumulated amortisation and impairment	Carrying value	Cost	Accumulated amortisation and impairment	Carrying value
	R'000	R'000	R'000	R'000	R'000	R'000
Group						
Investments in technology	10 862	10 862	-	10 862	10 862	-

	GROUP R'000
Carrying value 31 March 2014	-
Additions	123
Impairment*	(123)
Carrying value 31 March 2015	-
Carrying value 31 March 2016	-

* There are no guarantees of future cash flows and therefore the intangible assets have been impaired. This impairment is not material for the Group.

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

8. INTEREST IN JOINT VENTURES AND ASSOCIATES

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Cost of investments less impairment losses	1	1	1	1
Loans to joint ventures and associates	27 937	29 187	27 937	27 937
Share of post-acquisition losses of joint venture	(23 432)	(23 554)	-	-
Share of post-acquisition gains of associate	-	7 694	-	-
Share of pre-acquisition gains of associate	-	151	-	-
	4 506	13 479	27 938	27 938
Impairment of joint ventures and associates	(3 068)	(3 005)	(26 514)	(26 574)
	1 438	10 474	1 424	1 364

The loans to joint ventures and associates are interest free, unsecured and have no fixed terms of repayment. In substance, they form part of the Group's net investment in joint ventures and associates.

Agreements have been entered into between the CSIR and certain joint ventures and associates to subordinate the loans made to those joint ventures and associates. The subordination agreements will remain in force for as long as the liabilities of the relevant joint ventures or associates exceed their assets, fairly valued.

Details of the joint ventures and associates at 31 March 2016 are as follows:

Name of joint venture/associate	Place of incorporation	Portion of ownership interest	Portion of voting power held	Principal activity	Carrying value		Financial year-end
					2016 R'000	2015 R'000	
Joint ventures							
Sera (Pty) Ltd	South Africa	50%	50%	Commercialisation and licensing of patents	3 068	3 005	31 March
Ellipsoid Technology (Pty) Ltd	South Africa	50%	50%	Development of encapsulation technology	1 438	1 378	31 March
Associates							
Uvirco Technologies (Pty) Ltd*	South Africa	-	45%	Manufacturing of high technology cameras	-	9 096	31 March
					4 506	13 479	

* Refer to note 26.1.

8. INTEREST IN JOINT VENTURES AND ASSOCIATES (CONTINUED)

The following are details of the significant joint ventures' and associates' assets, liabilities, income and expenses:

	Joint ventures Group		Associates Group	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Current assets	7 482	7 321	-	24 945
Non-current assets	33 665	33 665	-	2 759
Current liabilities	53 433	53 518	-	10 068
Non-current liabilities	36 232	36 232	-	-
Income	377	972	34 780	35 078
Expenses	130	611	30 180	30 088

9. INTEREST IN SUBSIDIARIES

	CSIR	
	2016 R'000	2015 R'000
Shares at cost less impairment losses	4 650	4 650
Indebtedness	11 403	2 999
- by subsidiaries	19 500	19 500
- impairment of loans	(8 097)	(16 501)
	16 053	7 649

Details disclosed in Addendum A.

The loans to subsidiaries are interest free, unsecured and have no fixed terms of repayment.

Agreements have been entered into between the CSIR and certain subsidiaries to subordinate the loans made to those subsidiaries. The subordination agreements will remain in force for as long as the liabilities of the relevant subsidiaries exceed their assets, fairly valued.

10. AVAILABLE-FOR-SALE FINANCIAL ASSET

	% held	Number of shares held		Class of shares	GROUP		CSIR	
		2016	2015		2016 R'000	2015 R'000	2016 R'000	2015 R'000
Unlisted shares								
Persomics AB*	12.53%	9 497	7 250	Ordinary	6 177	5 409	6 177	5 409
					6 177	5 409	6 177	5 409

* Country of incorporation is Sweden

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

11. TRADE AND OTHER RECEIVABLES

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Trade receivables	191 811	226 752	193 517	226 740
Prepaid expenditure	48 305	36 870	48 295	36 870
Other receivables*	12 339	703	554	577
	252 455	264 325	242 366	264 187
Less non current portion: other receivables*	(1 750)	-	-	-
Current portion	250 705	264 325	242 366	264 187

Trade receivables are shown net of impairment losses. Refer to note 21 for more detail on trade receivables.

*Included in other receivables is an amount of R11,75 million (2015: R nil) for the sale of an associate (refer to note 26.1). The initial payment of R10 million was received in April 2016 with the balance of R1,75 million being payable by 30 June 2019.

12. INVENTORY AND CONTRACTS IN PROGRESS

Contracts in progress less provision for losses	104 184	101 409	104 184	101 409
Raw materials and consumables	1 782	1 492	1 782	1 492
	105 966	102 901	105 966	102 901

Estimates on contract in progress recognition are based on cost to completion, budgets and percentage of completion.
The cost of inventories recognised as an expense amounted to R10,9 million (2015: R12,2 million).

13. DEFERRED TAX

A subsidiary (2015: two subsidiaries) in the Group is in an assessed loss position and no deferred tax asset was raised for the assessed loss due to the uncertainty of the recoverability in future periods in respect of the carry forward of unused tax losses.

Opening balance	7 966	6 131
Assessed tax loss (utilised)/generated for the year	(513)	1 835
Assessed tax loss carried forward	7 453	7 966

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
14. ADVANCES RECEIVED				
Advances on contracts received from clients and stakeholders	800 202	767 209	800 202	767 209
15. TRADE AND OTHER PAYABLES				
Accounts payable and accruals	259 356	288 368	259 531	288 458
Salary related accruals	159 384	157 718	159 384	157 718
Forward exchange contracts	58	-	58	-
	418 798	446 086	418 973	446 176
16. OPERATING LEASE COMMITMENTS				
Financial commitments under non-cancellable operating leases will result in the following payments falling due:				
Within one year:	1 874	1 972	1 874	1 957
Land and buildings	1 104	1 051	1 104	1 036
Vehicles	770	921	770	921
Within two to five years:	1 669	850	1 669	850
Land and buildings	858	236	858	236
Vehicles	811	614	811	614

Agreements relating to operating lease payments for vehicles vary from 36 to 48 months and payments are fixed for the term of the agreements.

The CSIR leases buildings under operating leases. The lease periods vary from 12 to 36 months. Lease payments are increased with a fixed annual escalation percentage to reflect market rentals. None of the leases include contingent rentals.

The CSIR leases a number of properties at nominal rental amounts. The lease periods vary from 25 to 99 years.

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

17. RETIREMENT BENEFITS OF EMPLOYEES

17.1 CSIR Pension Fund

The fund is registered in terms of the Pension Funds Act, 1956, and is a defined contribution plan. The CSIR's liability to the fund was limited to paying the employer contributions up until 29 February 2016. The impact of the tax reform effective from 1 March 2016 was that the CSIR package structure was changed to reflect all retirement fund contributions as employee contributions. All the CSIR's permanent employees are members of the fund. Employer contributions of R92,3 million (2015: R91,1 million) and employee contributions of R68,4 million (2015: R53,4 million) were expensed during the year.

17.2 Associated Institutions Pension Fund (AIPF)

The fund is a defined benefit plan. The formula used to determine pensions is based on the pensionable earnings of the final year, and the aggregate period of uninterrupted membership.

The CSIR has one employee (2015: one employee) who is a member of the AIPF as at 31 March 2016. The fund is controlled by the state, which has assumed responsibility for the unfunded portions of these funds. Employer contributions of R6 460 (2015: R6 506) and employee contributions of R5 016 (2015: R4 066) were expensed during the year.

17.3 Post-retirement medical benefits

The CSIR has a post-retirement medical benefit obligation to certain qualifying retired CSIR employees (pensioners) that joined the CSIR prior to 30 September 1996. An offer was made to qualifying pensioners in December 2005 to accept an annuity, payable from an independent source, equivalent to the value of their medical subsidy. The pensioners who accepted the offer are no longer entitled to a subsidy from the CSIR.

The accumulated benefit obligation and the annual cost of accrual of benefits are assessed by independent, qualified actuaries using the projected unit credit method. The estimated present value of the anticipated expenditure for the remaining 18 continuation members (2015: 18 continuation members) was recalculated by the actuaries as at 31 March 2016 and will be funded through cash and cash equivalents. These cash and cash equivalents have not been set aside specifically for this benefit.

17. RETIREMENT BENEFITS OF EMPLOYEES (CONTINUED)

The amount included in the statement of financial position arising from the CSIR's obligation in respect of post-retirement medical benefits is as follows:

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Present value of obligations	10 695	10 614	10 695	10 614
Net liability on statement of financial position	10 695	10 614	10 695	10 614

Amounts recognised in the statement of comprehensive income in respect of the scheme are as follows:

Interest cost	785	850	785	850
Actuarial gain recognised during the year	(704)	(8)	(704)	(8)
	81	842	81	842

Movement in the net liability recognised in the statement of financial position is as follows:

Net liability at the beginning of the year	10 614	9 772	10 614	9 772
Movement for the year	81	842	81	842
Net expense recognised in the statement of comprehensive income	81	842	81	842
Net liability at the end of the year	10 695	10 614	10 695	10 614

Principal actuarial assumptions at the reporting date:

Discount rate at 31 March	9.30%	7.40%	9.30%	7.40%
Medical inflation costs	8.30%	6.40%	8.30%	6.40%

The above results are sensitive to changes in the assumed future rate of medical inflation.

The effect of a one percent increase in the assumed future rate of medical inflation would have the following effects:				
Effect on defined benefit obligation	689	722	689	722
The effect of a one percent decrease in the assumed future rate of medical inflation would have the following effects:				
Effect on defined benefit obligation	(626)	(653)	(626)	(653)

The above sensitivity analyses are based on a change in an assumption while all other assumptions are assumed to remain unchanged. This may not always be realistic as some of the assumptions tend to be correlated. When calculating the sensitivity of the defined benefit obligation to significant actuarial assumptions the same method (present value of the defined benefit obligation calculated with the projected unit credit method at the end of the reporting period) has been applied as when calculating the liability recognised within the statement of financial position.

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

17. RETIREMENT BENEFITS OF EMPLOYEES (CONTINUED)

Historical information:	2016	2015	2014	2013	2012
Present value of the defined benefit obligation	10 695	10 614	9 772	10 347	8 260
Deficit in the plan	10 695	10 614	9 772	10 347	8 260

The average term (undiscounted) of the defined benefit obligation is 10.5 years (2015: 10.1 years) and the average duration (discounted) of the defined benefit obligation is 6.8 years (2015: 7.1 years).

18. BOARD MEMBERS, DIRECTORS AND EXECUTIVE MANAGEMENT'S REMUNERATION

2016			Managerial services				
	Entity	Fees for services as director R'000	Basic salary R'000	Bonuses and performance-related payments R'000	Retirement fund and medical aid contributions* R'000	Sale of accrued leave** R'000	Total R'000
Board members and Executive Directors							
Dr SP Sibisi	CSIR	-	3 877	2 035	581	-	6 493
Non-executive Board members							
Adv. G Badela	CSIR	157	-	-	-	-	157
Ms P Baleni	CSIR	-	-	-	-	-	-
Dr PH Goyns	CSIR	153	-	-	-	-	153
Dr A Llobell	CSIR	61	-	-	-	-	61
Professor T Majozi	CSIR	135	-	-	-	-	135
Dr R Masango	CSIR	92	-	-	-	-	92
Ms M Maseko	CSIR	75	-	-	-	-	75
Mr J Netshitenzhe	CSIR	92	-	-	-	-	92
Ms A Noah	CSIR	51	-	-	-	-	51
Professor M Phakeng	CSIR	167	-	-	-	-	167
Executive Management							
Dr RK Chikwamba	CSIR	-	2 176	716	145	-	3 037
Mr JPL Cloete	CSIR	-	2 356	754	164	66	3 340
Ms GA Huma (from May 2015)	CSIR	-	1 904	-	154	-	2 058
Dr M Motuku	CSIR	-	2 325	554	184	-	3 063
Mr CR Sturdy	CSIR	-	2 249	1 007	360	-	3 616
Mr RM Zondo	CSIR	-	2 212	660	201	-	3 073
Subsidiaries							
Non-executive Board member: Mr M Sibanda (until October 2015)	Technifin SOC Ltd	-	-	-	-	-	-
2016		983	17 099	5 726	1 789	66	25 663

18. BOARD MEMBERS, DIRECTORS AND EXECUTIVE MANAGEMENT'S REMUNERATION (CONTINUED)

2015							
			Managerial services				
	Entity	Fees for services as director	Basic salary	Bonuses and performance-related payments	Retirement fund and medical aid contributions*	Sale of accrued leave**	Total
		R'000	R'000	R'000	R'000	R'000	R'000
Board members and Executive Directors							
Dr SP Sibisi	CSIR	-	3 594	1 791	597	-	5 982
Non-executive Board members							
Mr P Benadè (until Dec 2014)	CSIR	107	-	-	-	-	107
Professor TE Cloete (until Dec 2014)	CSIR	78	-	-	-	-	78
Ms M Mabitje-Thompson (until Dec 2014)	CSIR	-	-	-	-	-	-
Professor TA Nyokong (until Dec 2014)	CSIR	-	-	-	-	-	-
Professor FW Petersen (until Dec 2014)	CSIR	104	-	-	-	-	104
Mr M Sibanda (until Dec 2014)	CSIR	84	-	-	-	-	84
Ms BS Tshabalala (until Dec 2014)	CSIR	107	-	-	-	-	107
Professor MJ Wingfield (until Dec 2014)	CSIR	68	-	-	-	-	68
Adv. G Badela	CSIR	107	-	-	-	-	107
Ms P Baleni (from Jan 2015)	CSIR	-	-	-	-	-	-
Dr PH Goyns	CSIR	-	-	-	-	-	-
Dr A Llobell (from Jan 2015)	CSIR	-	-	-	-	-	-
Professor T Majozi (from Jan 2015)	CSIR	33	-	-	-	-	33
Dr R Masango (from Jan 2015)	CSIR	19	-	-	-	-	19
Ms M Maseko (from Jan 2015)	CSIR	19	-	-	-	-	19
Mr J Netshitenzhe (from Jan 2015)	CSIR	19	-	-	-	-	19
Ms A Noah (from Jan 2015)	CSIR	19	-	-	-	-	19
Professor M Phakeng (from Jan 2015)	CSIR	10	-	-	-	-	10
Executive Management							
Dr RK Chikwamba	CSIR	-	1 803	630	132	-	2 565
Mr JPL Cloete (from Nov 2014)	CSIR	-	2 018	622	155	-	2 795
Dr M Motuku	CSIR	-	2 124	853	189	-	3 166
Mr CR Sturdy	CSIR	-	2 081	886	369	-	3 336
Mr RM Zondo	CSIR	-	2 061	813	206	-	3 080
Subsidiaries							
Non-executive Board member:							
Mr M Sibanda	Technifin SOC Ltd	51	-	-	-	-	51
Executive Management:							
Mr JG Hattingh (until Feb 2015)***	Technifin SOC Ltd	-	2 101	-	-	-	2 101
2015		825	15 782	5 595	1 648	-	23 850

* The impact of the tax reform effective from 1 March 2016 was that the CSIR package structure was changed to reflect all retirement fund contributions as employee contributions. From 1 March 2016 all retirement fund contributions are thus included in the basic salary category for disclosure purposes.

** The approved changes to the CSIR conditions of service, effective 1 April 2013, resulted in amendments to leave days and the accumulation of leave. Leave accrued as at 1 April 2013 had to be utilised or sold within 2 years.

*** Including severance

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000

19. CONTINGENT LIABILITIES AND FACILITIES

Local and foreign payment and performance guarantees issued as at 31 March	13 684	7 984	13 684	7 984

The CSIR has a borrowing plan approved by the Minister of Finance to issue performance bonds, local and foreign advance payment guarantees and carnets.

Legal costs and litigation

In the nature of the CSIR's business, agreements with complex deliverables may be entered into. All necessary steps are taken to manage the risks inherent to these transactions. If and when it is evident that there is a reasonable probability that a dispute on a transaction could lead to costs against the CSIR, such costs will be disclosed.

20. CAPITAL COMMITMENTS

Property, plant and equipment	37 608	70 720	37 608	70 720

This capital expenditure is to be financed from internal sources.

21. FINANCIAL INSTRUMENTS

The Group has exposure to the following risks from its use of financial instruments:

- market risk
- credit risk
- liquidity risk.

This note presents information about the Group's exposure to each of the above risks and the Group's objectives, policies and processes for measuring and managing risk. Further quantitative disclosures are included throughout these consolidated financial statements.

The Board has overall responsibility for the establishment and oversight of the Group's risk management framework.

The Group's risk management policies are established to identify and analyse the risks faced by the Group, to set appropriate risk limits and controls, and to monitor risks and adherence to limits. Risk management policies and systems are reviewed regularly to reflect changes in market conditions and the Group's activities. The Group, through its training and management standards and procedures, aims to develop a disciplined and constructive control environment in which all employees understand their roles and obligations.

21. FINANCIAL INSTRUMENTS (CONTINUED)

The Audit and Risk Committee oversees how management monitors compliance with the Group's risk management policies and procedures and reviews the adequacy of the risk management framework in relation to the risks faced by the Group. The Group Audit and Risk Committee is assisted in its oversight role by Internal Audit. Internal Audit undertakes both regular and ad hoc reviews of risk management controls and procedures, the results of which are reported to the Audit and Risk Committee.

21.1 Market risk

Market risk is the risk that changes in market prices, such as foreign exchange rates and interest rates will affect the Group's income or the value of its holdings of financial instruments. The objective of market risk management is to manage and control market risk exposures within acceptable parameters, while optimising the return.

Foreign currency risk

The Group is exposed to currency risk on sales and purchases that are denominated in a currency other than the respective functional currency of the Group entities.

The Group enters into forward exchange contracts to buy specified amounts of foreign currencies in the future at a predetermined exchange rate.

Forward exchange contracts are entered into mainly to cover import orders. The Group has no policy to enter into forward exchange contracts for anticipated foreign receipts. The Group does not use derivative financial instruments for speculative purposes.

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

21. FINANCIAL INSTRUMENTS (CONTINUED)

The Group's exposure to foreign currency risk was as follows:

	31 March 2016					
	Total R'000	ZAR R'000	EURO R'000	USD R'000	GBP R'000	Other R'000
Available-for-sale financial asset	6 177	-	-	-	-	6 177
Trade receivables	191 811	163 048	206	27 457	922	178
Bank accounts	187 442	49 525	17 788	100 287	9 676	10 166
Trade and other payables	(418 798)	(409 196)	(5 903)	(965)	(2 062)	(672)
Gross statement of financial position exposure	(33 368)	(196 623)	12 091	126 779	8 536	15 849
Forward exchange contracts	(6 941)	-	(6 941)	-	-	-
Net exposure	(40 309)	(196 623)	5 150	126 779	8 536	15 849

	31 March 2015					
	Total R'000	ZAR R'000	EURO R'000	USD R'000	GBP R'000	Other R'000
Available-for-sale financial asset	5 409	-	-	-	-	5 409
Trade receivables	226 752	179 926	354	44 311	2 161	-
Bank accounts	167 829	96 213	5 750	55 390	4 939	5 537
Trade and other payables	(446 086)	(443 224)	(1 672)	(988)	(202)	-
Gross statement of financial position exposure	(46 096)	(167 085)	4 432	98 713	6 898	10 946
Forward exchange contracts	-	-	-	-	-	-
Net exposure	(46 096)	(167 085)	4 432	98 713	6 898	10 946

21. FINANCIAL INSTRUMENTS (CONTINUED)

	GROUP	
	2016	2015
The following significant exchange rates applied during the year:	R	R
Average rate of forward exchange contracts: Euro	16.8579	-
Year-end spot rate:		
Euro	16.8338	13.1191
USD	14.8208	12.0907
GBP	21.2941	17.9367

Sensitivity analysis

A 10% strengthening of the rand against the following currencies at 31 March would have decreased profit or loss by the amounts shown below. This analysis assumes that all other variables remain constant. The analysis is performed on the same basis for 2015.

	R'000	R'000
Euro	(515)	(443)
USD	(12 678)	(9 871)
GBP	(854)	(690)
Other	(1 585)	(1 095)

A 10% weakening of the rand against the above currencies at 31 March would have had the equal but opposite effect on the above currencies to the amounts shown above, on the basis that all other variables remain constant.

Interest rate risk

Interest rate exposure and investment strategies are evaluated by management on a regular basis. Interest-bearing investments are held with several reputable banks in order to minimise exposure.

At the reporting date the interest rate profile of the Group's interest-bearing financial instruments was as follows:

	R'000	R'000
Fixed rate instruments: carrying amount		
Financial assets: Fixed deposits	764 940	750 032

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

21. FINANCIAL INSTRUMENTS (CONTINUED)

The Group does not account for any fixed rate financial assets and liabilities at fair value through profit or loss, and the Group does not designate derivatives as hedging instruments under a fair value hedge accounting model. Therefore, a change in interest rates at the reporting date would not affect profit or loss.

	GROUP	
	2016 R'000	2015 R'000
Variable rate instruments: carrying amount		
Financial assets: Call deposits	58 000	63 000
Financial assets: Bank balances	187 442	167 829
	245 442	230 829

Sensitivity analysis

An increase of 100 basis points in interest rates at the reporting date would have increased equity and profit and loss by the amounts shown below. This analysis assumes that all other variables, in particular foreign currency rates, remain constant. The analysis is performed on the same basis for 2015.

Variable rate instruments	2 454	2 308

A decrease of 100 basis points would have had the equal but opposite effect to the amounts shown above.

21.2 Credit risk

Credit risk is the risk of financial loss to the Group if a customer or counterparty to a financial instrument fails to meet its contractual obligations, and arises principally from the Group's bank balances and deposits, trade and other receivables and loans to joint ventures, associates and subsidiaries.

Trade and other receivables and loans to joint ventures, associates and subsidiaries

Trade and other receivables and loans to joint ventures, associates and subsidiaries are presented net of impairment losses. Credit risk with respect to trade receivables is limited due to the large number of customers comprising the Group's customer base and their dispersion across different industries and geographical areas.

Bank balances and deposits

The Group's bank balances and cash are placed with high credit, quality financial institutions with no significant exposure to any one financial institution.

Guarantees

Refer to note 19 for details on bank guarantees issued with respect to facilities.

21. FINANCIAL INSTRUMENTS (CONTINUED)

	GROUP	
	2016 R'000	2015 R'000
Exposure to credit risk		
The carrying amount of financial assets represents the maximum credit exposure.		
The maximum exposure to credit risk at the reporting date was:		
Available-for-sale financial asset	6 177	5 409
Current fixed deposits	764 940	750 032
Call deposits	58 000	63 000
Bank balances	187 442	167 829
Cash on hand and cash deposits	2 497	3 054
Trade and other receivables	252 455	264 325
Contracts in progress less provision for losses	104 184	101 409
	1 375 695	1 355 058
The maximum exposure to credit risk for trade receivables at the reporting date by type of customer was:		
Local public sector	127 151	139 419
Local private sector	32 511	39 852
International sector	32 149	47 481
	191 811	226 752

The Group's most significant customers are various local public sector customers.

The aging of the Group's trade receivables at the reporting date was:

	2016		2015	
	Gross R'000	Impairment R'000	Gross R'000	Impairment R'000
Not past due	113 416	3 007	162 352	1 040
Past due 0 - 30 days	49 383	770	28 555	77
Past due 31 - 120 days	28 666	2 534	28 016	648
Past due more than 120 days	26 127	19 470	23 334	13 740
	217 592	25 781	242 257	15 505

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

21. FINANCIAL INSTRUMENTS (CONTINUED)

	GROUP	
	2016 R'000	2015 R'000
The movement in the allowance for impairment in respect of trade receivables during the year was as follows:		
Balance at 1 April	15 505	19 819
Movement for the year	10 276	(4 314)
Recoveries	(4 403)	(6 332)
Utilisation	(3 805)	(8 826)
New impairment allowances	18 484	10 844
Balance at 31 March	25 781	15 505

The allowance account in respect of trade receivables is used to record impairment losses unless the Group is satisfied that no recovery of the amount owing is possible; at that point the amount considered irrecoverable is written off against the financial asset directly.

The fully performing trade receivables are considered to be of high credit quality.

21.3 Liquidity risk

Liquidity risk is the risk that the Group will not be able to meet its financial obligations as these fall due. The Group's approach to managing liquidity is to ensure, as far as possible, that it will always have sufficient liquidity to meet its liabilities when due, under both normal and stressed conditions, without incurring unacceptable losses or risking damage to the Group's reputation.

The Group monitors its cash flow on a daily basis. Typically, the Group ensures that it has sufficient cash on demand to meet expected operational expenses for a period of 60 days, including the servicing of financial obligations; this excludes the potential impact of extreme circumstances that cannot be predicted reasonably, such as natural disasters.

21. FINANCIAL INSTRUMENTS (CONTINUED)

The following are the contractual maturities of financial liabilities, including interest payments and excluding the impact of netting agreements for the Group:

	2016			2015		
	Carrying amount	Contractual cash flows		Carrying amount	Contractual cash flows	
		6 months or less	6 - 12 months		6 months or less	6 - 12 months
	R'000	R'000	R'000	R'000	R'000	R'000
Non-derivative financial liabilities						
Trade and other payables	(418 740)	(418 740)	-	(446 086)	(446 086)	-
Derivative financial liabilities						
Forward exchange contracts	(58)	(6 999)	-	-	-	-
	(418 798)	(425 739)	-	(446 086)	(446 086)	-

	2016	2015
	R	R
Rate of forward exchange contracts:		
Euro	16.9994	-

21.4 Fair values

At 31 March 2016 the carrying amount of bank balances and cash, deposits, trade and other receivables, contracts in progress and trade and other payables approximated their fair values due to the short-term maturities of these assets and liabilities.

Basis for determining fair values

Interest free employee loans

The fair value of interest free employee loans is calculated based on the present value of future cash flows, discounted at the market rate of interest at the reporting date.

Trade and other receivables and trade and other payables

The fair value of trade and other receivables and trade and other payables is calculated based on the present value of future cash flows, discounted at the average return on investment rate at the reporting date.

NOTES TO THE
Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

21. FINANCIAL INSTRUMENTS (CONTINUED)

Forward exchange contracts

The fair value of forward exchange contracts is determined using forward exchange rates at the Statement of Financial Position date, with the resulting value discounted back to present value.

21.5 Fair value hierarchy

The table below analyses financial instruments carried at fair value, by valuation method. The different levels have been defined as follows:

Level 1: quoted prices (unadjusted) in active markets for identical assets or liabilities

Level 2: inputs other than quoted prices included within Level 1 that are observable for the asset or liability, either directly (as prices) or indirectly (derived from prices)

Level 3: inputs for the asset or liability that are not based on observable market data (unobservable inputs).

	Level 1	Level 2	Level 3	Total
31 March 2016				
Forward exchange contracts	-	(58)	-	(58)
31 March 2015				
Forward exchange contracts	-	-	-	-

22. RECONCILIATION OF OPERATING PROFIT TO CASH GENERATED FROM OPERATING ACTIVITIES

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Operating profit for the year before taxation	52 736	52 812	58 982	52 387
Adjusted for:				
Profit on disposal of interest in associate	(1 834)	-	-	-
Depreciation and amortisation	54 514	48 652	54 503	48 624
Net unrealised foreign exchange loss/(gain)	14 145	(5 097)	14 145	(5 097)
Net finance income	(40 410)	(58 736)	(39 970)	(57 618)
Post-retirement medical benefits	785	850	785	850
Straight-lining adjustment of operating leases	(18)	25	(18)	25
Leave accrual and warranty provision	3 421	8 617	3 421	8 617
Impairments	10 339	(10 064)	1 811	(10 351)
Profit on disposal and write-off of property, plant and equipment	(1 459)	(321)	(1 459)	(330)
Share of profit of joint ventures and associates	(2 193)	(2 426)	-	-
Bad debt written off	2 511	677	2 511	677
Available-for-sale financial asset	-	(3 704)	-	(3 704)
Operating profit before changes in working capital	92 537	31 285	94 711	34 080
Decrease in trade and other receivables	9 075	65 456	7 276	65 545
Increase in inventory and contracts in progress	(509)	(18 917)	(509)	(18 917)
Increase/(decrease) in advances received	28 314	(11 642)	28 314	(11 642)
Decrease in trade and other payables	(30 721)	(86 315)	(30 663)	(85 542)
Net working capital changes	6 159	(51 418)	4 418	(50 556)
Cash generated/(utilised) from operating activities	98 696	(20 133)	99 129	(16 476)

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000

23. CASH AND CASH EQUIVALENTS

Fixed deposits	764 940	750 032	761 000	745 000
Call deposits	58 000	63 000	56 000	61 000
Bank balances	187 442	167 829	185 744	166 898
Cash on hand and cash deposits	2 497	3 054	2 497	3 054
	1 012 879	983 915	1 005 241	975 952

24. RELATED PARTY TRANSACTIONS

The CSIR is a schedule 3B National Government Business Enterprise in terms of the Public Finance Management Act, Act 1 of 1999 as amended by Act 29 of 1999, and therefore falls within the national sphere of government. As a consequence, the CSIR has a significant number of related parties, being entities that fall within the national and provincial sphere of government. Amounts due from/to these entities are subject to the same terms and conditions as normal trade receivables and trade payables. For detail on individually significant transactions refer to notes 2 and 3.

In addition, the CSIR has a related party relationship with its subsidiaries (see Addendum A) and joint ventures and associates (see note 8). Unless specifically disclosed, these transactions are concluded at arm's length and the Group is able to transact with any entity.

24. RELATED PARTY TRANSACTIONS (CONTINUED)

24.1 Transactions with related parties

The following is a summary of transactions with related parties during the year and balances due at year-end:

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Constitutional institutions				
Services received	5	-	5	-
Major public entities				
Services rendered	369 137	335 898	369 137	335 898
Services received	192 269	162 202	192 269	162 202
Amount due from	19 806	39 134	19 806	39 134
National public entities				
Services rendered	135 517	102 347	135 517	102 347
Services received	15 340	13 479	15 340	13 479
Amount due from	13 065	6 010	13 065	6 010
National government business enterprises				
Services rendered	5 311	4 944	5 311	4 944
Services received	4 629	5 043	4 629	5 043
Amount due from	557	684	557	684

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

24. RELATED PARTY TRANSACTIONS (CONTINUED)

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Provincial public entities				
Services rendered	1 136	528	1 136	528
Amount due from	-	500	-	500
Provincial government business enterprises				
Services rendered	2 886	7 408	2 886	7 408
Services received	30	28	30	28
Amount due from	2 538	3 427	2 538	3 427
Government departments				
Services rendered	1 764 009	1 505 593	1 764 009	1 505 593
Services received	2 665	404	2 665	404
Amount due from	71 889	66 673	71 889	66 673
Subsidiaries				
Services rendered	-	-	1 997	2 033
Services received	-	-	92	218
Amount due from/(to)	-	-	1 454	(8)
Joint ventures and associates				
Services rendered	2 322	2 393	2 099	2 046
Services received	1 032	563	970	477
Amount due to	-	(395)	-	(332)

24.2 Transactions with key management

Total remuneration of key management is included in employees' remuneration (refer to note 18 for Executive Management's remuneration).

25. IRREGULAR EXPENDITURE

	GROUP		CSIR	
	2016 R'000	2015 R'000	2016 R'000	2015 R'000
Opening balance	117	-	117	-
Irregular expenditure relating to the current year:				
- Administrative error in assessing supplier	-	117	-	117
Amounts condoned	(117)	-	(117)	-
Irregular expenditure awaiting condonation	-	117	-	117

NOTES TO THE

Annual financial statements

FOR THE YEAR ENDED 31 MARCH 2016

26. DISPOSAL OF INTEREST IN ASSOCIATE AND DEREGISTRATION OF SUBSIDIARIES

	GROUP 2016 R'000
26.1 Uvirco Technologies (Pty) Ltd	
The Group held 45% of the issued share capital in Uvirco Technologies (Pty) Ltd. The shares held were sold effective 15 March 2016.	
Carrying amount of Uvirco Technologies (Pty) Ltd on date of disposal	9 916
Profit on disposal	1 834
Proceeds on disposal	11 750
26.2 Citizens Information Services (Pty) Ltd	
The Group held 100% of the issued share capital in Citizens Information Services (Pty) Ltd. The company was deregistered on 16 September 2015.	
The net assets of Citizens Information Services (Pty) Ltd on deregistration were as follows:	
Net asset value disposed	120
Loss on deregistration	(120)
Total consideration	-
Net cash outflow arising on deregistration of interest in subsidiary	
Bank balance and cash disposed	-

26. DISPOSAL OF INTEREST IN ASSOCIATE AND DEREGISTRATION OF SUBSIDIARIES (CONTINUED)

	GROUP 2016 R'000
26.3 Ulwazi Biotech (Pty) Ltd	
The Group held 100% of the issued share capital in Ulwazi Biotech (Pty) Ltd. The company was deregistered on 10 March 2016.	
The net assets of Ulwazi Biotech (Pty) Ltd on deregistration were as follows:	
Net asset value disposed	-
Total consideration	-
Net cash outflow arising on deregistration of interest in subsidiary	
Bank balance and cash disposed	-

ADDENDUM A

Interest in subsidiaries

31 MARCH 2016

Consolidated subsidiaries	Interests of the CSIR						
	Country of incorporation	Issued capital	Effective holding		Financial year-end	Shares at cost less accumulated impairment losses	
		R'000	2016 %	2015 %		2016 R'000	2015 R'000
Direct investments							
Technology Finance Corporation SOC Ltd (Technifin)	South Africa	5 200	100	100	31 March	4 650	4 650
Technovent SOC Ltd	South Africa	5 000	100	100	31 March	-	-
						4 650	4 650

The Group has an interest in one dormant company. Details of this interest is available at the CSIR's registered office.

Interests of the CSIR				
Net indebtedness less accumulated impairment losses by subsidiaries		Net investment		General nature of business
2016 R'000	2015 R'000	2016 R'000	2015 R'000	
-	-	4 650	4 650	The commercialisation of patents, which are being developed at the CSIR, and on which royalties are earned based on the utilisation of the rights by external companies, either local or international.
11 403	2 999	11 403	2 999	The provision of financial services to the CSIR subsidiaries and joint ventures.
11 403	2 999	16 053	7 649	

Abbreviations

3D	Three-dimensional
AfCAP	African Community Access Programme
AIPF	Associated Institutions Pension Fund
AISI	Aerospace Industry Support Initiative
AMD	Acid mine drainage
ARC	Agricultural Research Council
ARTIST	Adaptive Real-Time Internet Streaming Technology
B-BBEE	Broad-based Black Economic Empowerment
BIDC	Biomanufacturing Industry Development Centre
BITRI	Botswana Institute for Technology Research and Innovation
BTRI	Biomedical Translational Research Initiative
BPO	Business Process Outsourcing
CERN	European Organization for Nuclear Research
CHPC	Centre for High Performance Computing
CMIP6	Coupled Model Intercomparison Project six
CSIR	Council for Scientific and Industrial Research
DEFTED	Defence Transformative Enterprise Development
DIVA	Differentiating Infected from Vaccinated Animals
DoD	Department of Defence
DoH	Department of Health
DSIDE	Data Science for Impact and Decision Enhancement
DST	Department of Science and Technology
EIA	Environmental Impact Assessment
ENRM	Environmental and Natural Resource Management
EPO	European Patent Office
EPR	Extended Producer Responsibility
ERT	Electrical Resistance Tomography
FCTR	Foreign currency translation reserve
FLOPS	Floating point operations per second
FMPPI	Framework for managing programme performance information
FPAs	Fire Protection Associations
GBP	Great British Pound
GWh	Gigawatt hour
H3Africa	Human Heredity and Health in Africa
HIV	Human Immunodeficiency Virus
IAS	International Accounting Standards
IASB	International Accounting Standards Board
ICT	Information and Communications Technology
IEE	Industrial Energy Efficiency
IFRS	International Financial Reporting Standards
KRA	Key Results Area
KPI	Key Performance Indicator
kWh	Kilowatt-hour
MEME	Micro-Enterprise Media Engine
MHSC	Mine Health and Safety Council
MoU	Memorandum of Understanding
mIPTV	Mobile Internet Protocol Television
NCPC-SA	National Cleaner Production Centre of South Africa
NDP	National Development Plan
NFkB	Nuclear factor kappa-light-chain-enhancer of activated B cells
NHI	National Health Insurance
NICIS	National Integrated Cyber Infrastructure system
PAA	Public Audit Act
PFMA	Public Finance Management Act
PhD	Doctor of Philosophy
PV	Photovoltaic
PVC	Polyvinyl chloride
R&D	Research and Development
RDI (also RD&I)	Research, Development and Innovation
RIA	Research Impact Area
SAICA	South African Institute of Chartered Accountants
SAN	South African Navy
SANBio	Southern Africa Network for Biosciences
SANDF	South African National Defence Force
SANParks	South African National Parks
SAR	Satellite Aperture Radar
SDP	Science Data Processing
SET	Science, engineering and technology
SKA	Square Kilometre Array
SMME	Small, Medium and Micro Enterprise
SMS	Short message service
SOC	State-owned company
the dti	Department of Trade and Industry
TACC	Texas Advanced Computing Center
TENET	Tertiary Education and Research Network of South Africa
UAV	Unmanned aerial vehicle
UK	United Kingdom
USA	United States of America
USD	United States Dollar
UV	Ultraviolet

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PO Box 395, Pretoria, 0001
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Published by: CSIR Strategic Communication

Enquiries: Tel +27 12 841 2911
Email: query@csir.co.za