March 2019

White Paper on Science, Technology and Innovation

Science, technology and innovation enabling inclusive and sustainable South African development in a changing world

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

2030 NDP

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"Scientific inventions, at all conceivable levels, should enrich human life ..."

Chief Albert Luthuli (first African winner of the Nobel Peace Prize)
Oslo, December 1961

MINISTER'S FOREWORD

Since the adoption of the White Paper on Science and Technology in 1996, shortly after the advent of democracy, the South African government has been committed to using science, technology and innovation (STI) to develop the country and overcome the legacy of apartheid.

Recent reviews show that the South African national system of innovation (NSI) made significant progress between 1996 and 2016. For instance, the STI institutional landscape has expanded and the number of publications has grown threefold. The participation of black people and women in the research and development (R&D) workforce has increased considerably, and doctoral graduation rates have risen.

There are, however, still challenges. The NSI is not yet fully inclusive, and since 1996, South Africa's innovation performance (measured in patents and products) has been relatively flat. Moreover, the world is continuously changing in significant ways due to rapid technological change, geopolitical shifts like the rise of India and China as economic superpowers, rapid urbanisation, and the growing proportion of young people in South Africa, coupled with very high youth unemployment – to name a few. The Fourth Industrial Revolution (4IR), with its attendant risks and opportunities, is also upon us. South Africa therefore needs updated policy responses to expand the role that STI can play in, for instance, re-industrialisation, service delivery, modernising the agricultural sector and mitigating environmental degradation.

The National Development Plan (NDP) has identified STI as primary drivers of economic growth, job creation and socio-economic reform. It is therefore with great pleasure that I introduce the 2019 White Paper on Science, Technology and Innovation, which sets out government's long-term policy approach for the STI sector. This White Paper, which was approved by Cabinet, has been based on extensive reviews of various aspects of the NSI, as well as consultation with a wide range of role players such as relevant government departments, civil society, business and academia.

The 2019 White Paper on Science, Technology and Innovation emphasises the core themes of inclusivity, transformation, and partnerships. Proposals are made to address policy coherence, the development of human capabilities, knowledge expansion, innovation performance and increased investment. The aim is to build on our successes and adopt new approaches where required, so as to foster an NSI in which creativity, learning and entrepreneurship can flourish. The White Paper will be implemented through a series of decadal plans, which will also be developed in partnership with the relevant role players in industry, academia, civil society and government.

The extent to which we thrive as a country will depend on accelerating the South African development project, an endeavour that will be influenced by how we ready ourselves for the dramatic changes coming to the world we know. Science, technology and innovation are at the heart of these preparations. The 2019 White Paper on Science, Technology and Innovation further proceeds from the starting point that, as Africans, we share a common history, and as humankind, a common future.

MS MT KUBAYI-NGUBANE, MP
MINISTER OF SCIENCE AND TECHNOLOGY

DEPUTY MINISTER'S FOREWORD

Since the advent of democracy, a number of policies and planning frameworks have been developed to shape the growth and development trajectory of South Africa. While government has made significant progress in improving the socio-economic conditions of South Africans, the inter-linked challenges of unemployment, poverty and inequality remain.

On the science, technology and innovation (STI) front, the 1996 White Paper on Science and Technology was introduced. More than 20 years have passed since then, and the global and local economies have seen major shifts. Rapid technological advancement and the Fourth Industrial Revolution (4IR) require updated STI policy responses for South Africa to thrive in this changing environment.

The 2019 White Paper on Science, Technology and Innovation is therefore intended to position the national system of innovation (NSI) to increase the contribution of STI to addressing the socio-economic challenges faced by South Africa.

I am confident that, through efficient implementation of this new STI policy by various stakeholders in the public and private sector, the lives of our people and the fortunes of our communities will be transformed through STI.

MS ZANELE kaMAGWAZA-MSIBI, MP
DEPUTY MINISTER OF SCIENCE AND TECHNOLOGY

REMARKS BY THE DIRECTOR-GENERAL

The 2019 White Paper on Science, Technology and Innovation sets the long-term policy direction for the South African government to ensure a growing role for science, technology and innovation (STI) in a more prosperous and inclusive society. It focuses on using STI to help South Africa benefit from developments such as rapid technological advancement and geopolitical and demographic shifts, as well as responding to the threats associated with some of these global trends. In particular, the White Paper engages with the significant changes that are associated with the Fourth Industrial Revolution (4IR).

We do, however, not start from a blank slate. Since the adoption of the 1996 White Paper on Science and Technology, just after the attainment of democracy, the National System of Innovation (NSI) has shown good progress. Recent reviews indicate that challenges remain, resulting in South Africa not yet fully benefiting from the potential of STI to help address our socio-economic problems. Policy on STI is still fragmented across government, and partnerships with business, academia and civil society can be expanded. The NSI is significantly underfunded, and the participation of black people and women at the highest levels (e.g. as professors) remains too low – to name but a few of the remaining challenges.

To maximise the considerable potential of STI to help South Africa thrive in a challenging and changing environment, the 2019 White Paper on Science, Technology and Innovation, while drawing from what has worked in the past, introduces a number of policy shifts. Inter alia, these relate to:

- Increasing the focus on inclusivity, transformation and linkages in the NSI
- Enhancing the innovation culture in society and government
- Improving policy coherence and budget coordination across government
- Developing a more enabling environment for innovation
- Developing local innovation systems
- Supporting social and grassroots innovation
- Expanding the research system
- Developing human capabilities
- Accelerating the implementation of the pan-African STI agenda
- Increasing investment in the NSI

In the spirit of co-learning, as well as to garner support for this ambitious agenda, the White Paper has been based on extensive independent reviews of the South African NSI. Additionally, the Department of Science and Technology (DST) received detailed technical input from relevant government departments, business, civil society, academia and STI experts, based both locally and abroad.

A Decadal Plan for STI will be developed to serve as an implementation plan for the White Paper. This decadal plan will take into consideration not only the policy intents of the White Paper, but also the review of the Ten-year Innovation Plan (2008–2018) and of the National Research and Development Strategy (2002), both of which have seen the attainment of significant milestones. Furthermore, the results of the National Advisory Council on Innovation's (NACI's) 2019 foresight exercise, as well as the priority outcomes of government, will lend context to the decadal plan.

With the release of the 2019 White Paper on Science, Technology and Innovation, I am confident that South Africa will reap even more benefits from STI to help realise the objectives of the National Development Plan (NDP). Furthermore, I am excited at the potential for African development embodied by STI as presented in this White Paper.

DR PHIL MJWARA
DIRECTOR-GENERAL, DEPARTMENT OF SCIENCE AND TECHNOLOGY

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ABBREVIATIONS

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
ASSAf	Academy of Science of South Africa
AU	African Union
BRICS	Brazil, Russia, India, China and South Africa
CoC	Centre of Competence
CoE	Centre of Excellence
CPSI	Centre for Public Service Innovation
DHET	Department of Higher Education and Training
DIRISA	Data-intensive Research Initiative of South Africa
DPME	Department of Planning, Monitoring and Evaluation
DST	Department of Science and Technology
DTPS	Department of Telecommunications and Postal Services
FAIR	Findable, Accessible, Interoperable and Reusable
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
HEI	Higher Education Institution
ICT	Information and Communications Technology
IDC	Industrial Development Corporation
IP	Intellectual Property
IPR	Intellectual Property Rights
IPR Act	Intellectual Property Rights from Publicly Financed Research and Development Act
IPAP	Industrial Policy Action Plan
M&E	Monitoring and Evaluation
NACI	National Advisory Council on Innovation
NDP	National Development Plan
NIPMO	National Intellectual Property Management Office
NRF	National Research Foundation
NSI	National System of Innovation
OECD	Organisation for Economic Cooperation and Development
R&D	Research and Development
RDI	Research, Development and Innovation
RRI	Responsible Research and Innovation
SADC	Southern African Development Community
SANSA	South African National Space Agency
SARChI	South African Research Chairs Initiative
SDGs	Sustainable Development Goals
SET	Science, Engineering and Technology
SKA	Square Kilometre Array
SME	Small and Medium Enterprise
SOE	State-owned Entity
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
STIIL	Science, Technology and Innovation Institutional Landscape
the dti	Department of Trade and Industry
TIA	Technology Innovation Agency
TVET	Technical and Vocational Education and Training

GLOSSARY OF TERMS

Black people: According to the Department of Labour, black people are defined as follows:

African, coloured and Indian persons who are natural persons and:

- are citizens of the Republic of South Africa by birth or descent; or
- are citizens of the Republic of South Africa by naturalisation before the commencement date of the Constitution of the Republic of South Africa Act of 1993; or
- became citizens of the Republic of South Africa after the commencement date of the Constitution of the Republic of South Africa Act of 1993, but who, had it not been for the apartheid policy, would have qualified for naturalisation before then.

The definition of "black people" now includes South African Chinese people as per the Pretoria High Court ruling on 18 June 2008.

Centre of Competence: A Centre of Competence (CoC) is envisaged as a collaborative entity or instrument, preferably led by industry, that is resourced by highly qualified researchers associated with Public Research Institutions who are empowered to undertake market-focused strategic research and technology development for the benefit of industry and the economy at large. CoCs are therefore intended to provide a formal, and as far as possible contractually secure, physical or virtual platform upon which to establish collaborative technology innovation and commercialisation partnerships between government, industry, universities and Public Research Institutions, with the explicit aim of technology commercialisation.

Centre of Excellence: A Centre of Excellence (CoE) is a physical or virtual centre of research that concentrates existing research excellence, capacity and resources to enable researchers to collaborate across disciplines and institutions on long-term projects that are locally relevant and internationally competitive in order to enhance the pursuit of research excellence and capacity development. The five key performance areas of Centres of Excellence are: research/knowledge production, education and training, information brokerage, networking and service rendering.

Circular economy: Looking beyond the current "take, make and dispose" extractive industrial model, the circular economy is designed to restore and regenerate. Underpinned by a transition to renewable energy sources and system-wide innovation, it aims to redefine products and services to reduce waste and negative impacts.

Data-intensive Research Initiative of South Africa (DIRISA): This is the newest of the country's national cyber infrastructure initiatives. Shortly after the launch of the Centre for High Performance Computing and the South African National Research Network (SANReN), it was recognised that there would soon be a need to manage very large datasets. The technical requirements of efficiently and reliably storing these datasets are a huge challenge in themselves; however, the need for data-intensive research goes beyond the physical storage requirements to issues such as curation, provenance, trust, digital preservation and analytical techniques.

Emerging researchers: People who are generally younger than 40 years and have not yet completed their PhDs or established themselves as active researchers, although they are employed in knowledge-based institutions.

Established researchers: People who have established themselves as independent researchers and have an active research track record. They produce the bulk of the research output and play an important role in training and mentoring younger and less experienced researchers.

Fourth Industrial Revolution: The Fourth Industrial Revolution (4IR) has been defined as technological developments that blur the lines between the physical, digital and biological spheres. It integrates cyber-physical systems and the Internet of Things, big data and cloud computing, robotics, artificial intelligence (AI)-based systems and additive manufacturing. Compared to previous industrial revolutions, this one is evolving at an exponential rather than a linear pace, with potentially significant impacts on work, services, education and leisure.

Grassroots innovation: Grassroots innovation covers a diverse set of activities in which networks of neighbours, community groups and activists work with people to generate bottom-up solutions for sustainable development, in the form of novel solutions that respond to local situations and the interests and values of the communities involved, and where those communities have control over the process and outcomes.

Human capabilities: This implies a non-instrumental notion of human development, where developing the knowledge and skills of people has intrinsic value and goes beyond the narrowly defined science, engineering and technology (SET) skills required for the National System of Innovation (NSI).

Innovation: An innovation is the implementation of a new or significantly improved product (good or service) or process, or a new marketing method, or a new organisational model in business practice, workplace organisation or external relations.

Megatrends: Global megatrends are social, economic, technological, environmental or geostrategic forces that are shaping our world in profound ways. The implications of these forces are broad and varied, and present tremendous opportunities and risks.

National Development Plan: The National Development Plan (NDP) is a long-term South African development plan, developed by the National Planning Commission in collaboration with South Africans from all walks of life. It serves as an action plan for securing the future of South Africans as charted in the Constitution. It is founded on six pillars that represent the plan's broad objectives to eliminate poverty, reduce inequality and ensure a decent standard of living for all South Africans by 2030.

National Facilities: The National Facilities of the National Research Foundation (NRF) are research institutions centred on substantial instrumentation, equipment or skills bases. The National Facilities constitute unique and indispensable infrastructure platforms that provide the enabling environment for advancing research areas of strategic importance in South Africa. The National Facilities further create the foundation for South African researchers to compete at the forefront of discovery, as well as to train highly skilled postgraduate students.

National System of Innovation: There is no single accepted definition of a National System of Innovation. What is important is the web of interaction in the system, as underscored in the following two quotations: "The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies"; and "that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such, it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies".

Office of Technology Transfer: An Office of Technology Transfer tends to be located at a university or science council and is focused on facilitating the identification, protection and use of intellectual property (IP) that emanates from research and development (R&D) for social and/or economic benefit. Researchers are the creators of this IP. By managing and protecting it appropriately, the technology transfer function helps researchers to translate their IP into useful and innovative products and services, creating an additional layer of impact for their research. It also gives industry access to this IP to further develop and use it commercially or otherwise.

Open innovation: The basic premise of open innovation is to introduce more actors into the innovation process so that knowledge can circulate more freely and be transformed into products and services that create new markets, fostering a stronger culture of entrepreneurship and encouraging firms to use external and internal ideas, and internal and external paths to market, as they look to advance their technologies

Open science: Open science refers to an approach to research based on greater access to public research data enabled by information and communications technology (ICT) tools and platforms, broader collaboration in science – including the participation of non-scientists – and the use of alternative copyright tools for diffusing research results.

Policy coherence: Achieving policy coherence involves the systematic promotion of mutually reinforcing policies across government departments in order to create synergies towards achieving agreed objectives and to avoid or minimise duplication and negative spill-overs in other policy areas.

Policy coordination: Policy coordination involves the alignment of programmes and activities across various role players in order to give effect to policy objectives.

Policy nexus: New institutional arrangements to facilitate collaboration in specific areas. Arrangements are based on written agreements that specify how to harmonise policy and coordinate the implementation of action plans.

Public Research Institutions: This refers to a heterogeneous group of research organisations with varying degrees of governmental influence on their research activities and funding. Different Public Research Institutions, depending on their particular profile, perform a variety of roles. These include basic and applied research, policy support, training, knowledge and technology transfer, service provision, research funding, operating technological facilities, and standardisation and certification.

Research and development: R&D comprises creative and systematic work undertaken to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.

R&D tax incentive: The South African government offers the R&D tax incentive under section 11D of the Income Tax Act, 1962 (Act No. 58 of 1962) in order to promote private sector R&D investment in the country. The incentive allows any company undertaking scientific and/or technological R&D in the country to deduct 150% of its R&D spending when determining the taxable income. The incentive is available to businesses of all sizes and in all sectors of the economy. The Department of Science and Technology (DST) shares responsibility for the delivery of the incentive with the South African Revenue Service and National Treasury. The incentive is part of a package of policy instruments to promote R&D and innovation in the country.

Research infrastructures: Research infrastructures are facilities, resources and services used by the science community to conduct research and foster innovation.

Responsible Research and Innovation: Responsible Research and Innovation (RRI) is concerned with producing ethically acceptable, sustainable and socially desirable research and innovation outcomes. RRI is underpinned by the principle that research and innovation need to be responsive to a wide range of stakeholders and societal grand challenges, and be sensitive to the values, needs and expectations of South Africans.

Sector-specific science councils: Providing scientific and technological support to government entities requires organisations with a suite of special characteristics. These include being seen as impartial and trustworthy, being at the forefront of a range of applicable technologies, and being familiar with the user's application domain (e.g. mining, health care, social sciences), terminology and culture. These attributes require a stable body of professional scientists and engineers who have made their careers in the application domain, which in turn calls for a reliable and sustained source of funding, coupled with a carefully crafted mechanism to provide strategic direction and prioritisation of projects. Organisations that provide this kind of support – e.g. the South African Medical Research Council, the Council for Scientific and Industrial Research, the Human Sciences Research Council, and Mintek – are termed "sector-specific science councils".

Science diplomacy: Science diplomacy refers to scientific cooperation and engagement with the explicit intent of building positive relationships with other governments and societies. The Royal Society and the American Association for the Advancement of Science identify three main types of activities related to science diplomacy:

- Science in diplomacy: informing foreign policy objectives with scientific advice
- Diplomacy for science: facilitating international science cooperation
- Science for diplomacy: using scientific cooperation to improve relations between countries

Social entrepreneurship: The underlying drive of social entrepreneurship is the creation of social value as opposed to personal or shareholder wealth. Social entrepreneurship involves identifying a problem-solving opportunity to meet a social need. The crux is the application of entrepreneurial characteristics to a type of mission that is not solely focused on financial profit.

Social innovation: Social innovation is a sub-set of innovation that is cross-sectoral and distinct from business or technological innovation. Social innovation is context-specific, is underpinned by values, leads to specific outcomes that are a measurable improvement on existing practices, changes social relations with regard to governance, and empowers beneficiaries by increasing their socio-political capabilities and access to resources.

South African Research Chairs Initiative: The South African Research Chairs Initiative (SARChI) was established in 2006. It is designed to attract and retain excellence in research and innovation at South African public universities through the establishment of research chairs with a long-term investment trajectory of up to 15 years. The main goal of SARChI is to strengthen and improve the research and innovation capacity of public universities for producing high-quality postgraduate students and research and innovation outputs.

Technology Balance of Payments: The Technology Balance of Payments is a subdivision of the balance of payments that is used to collate invisible transactions relating to trade in technical knowledge and technology-related services between partners in different countries. It registers the commercial transactions related to international technology and technological know-how transfers. It consists of money paid or received for the use of patents, licences, know-how, trademarks, patterns, designs and technical services (including technical assistance), and for industrial R&D carried out abroad, among other things.

Technology Localisation Programme: The Technology Localisation Programme provides technological assistance to local firms in an effort to increase their competitiveness and to help ensure that greater use is made of local production and services, specifically in instances where government or its state-owned entities (SOEs) are procuring capital or operational goods. The Technology Localisation Programme's primary aim is to support the Competitive Supplier Development Programme and other government procurement programmes and initiatives, e.g. the Strategic Infrastructure Programmes. The Technology Localisation Programme is implemented by the Technology Localisation Implementation Unit, which is hosted by the Council for Scientific and Industrial Research.

Technology Stations Programme: The Technology Stations Programme was established to enable universities of technology to provide technology development services to small and medium enterprises (SMEs). The technology stations provide innovative SET solutions for complex engineering challenges within the relevant industrial sectors that are aimed at supporting government's socio-economic priorities.

Transdisciplinarity: Transdisciplinary research is defined as research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological and translational innovations that integrate and move beyond discipline-specific approaches in order to address a common problem. A critical defining characteristic of transdisciplinary research is the inclusion of stakeholders in defining needs and hence research objectives and strategies.

EXECUTIVE SUMMARY

This White Paper, which is based on extensive review of the National System of Innovation (NSI), sets the long-term policy direction for the South African government to ensure a growing role for science, technology and innovation (STI) in a more prosperous and inclusive society. It focuses on using STI to accelerate inclusive economic growth, make the economy more competitive, and improve people's daily lives. It aims to help South Africa benefit from global developments such as rapid technological advancement and geopolitical and demographic shifts, as well as respond to the threats associated with some of these global trends.

Chapter 1: Introduction

More than 20 years after the adoption of the 1996 White Paper on Science and Technology, South Africa needs an updated STI policy – for two main reasons. Firstly, while reviews show good progress in the implementation of the 1996 White Paper, South Africa has not yet fully benefited from the potential of STI to advance the objectives of the National Development Plan (NDP). To illustrate, the STI institutional landscape has been expanded and there has been a threefold increase in publications, significant growth in the participation of black people and women in the research and development (R&D) workforce, and a rise in doctoral graduation rates. However, challenges remain. The NSI is still not fully inclusive, and since 1996, South Africa's innovation performance (measured in patents and products) has been relatively flat. Secondly, as the world is rapidly becoming more technologically advanced, new STI policy approaches are required to respond to the opportunities (such as rapid economic growth) and threats (such as the loss of some traditional jobs) of such change.

According to recent reviews, the main factors constraining the performance of the NSI are the inadequate and non-collaborative means of STI agenda setting for the country, insufficient policy coherence and coordination, weak partnerships between NSI actors (particularly the inadequate involvement of business and civil society), inadequate monitoring and evaluation (M&E), inadequate high-level science, engineering and technology (SET) and technical skills for the economy, an undersized research system, a poor environment for innovation, and significant levels of underfunding. If these constraining factors can be addressed, it will be possible to increase the impact of STI in South Africa. STI can be instrumental in improving public service delivery and decision making for public policy, thereby improving the quality of life of South Africans, particularly in poor communities. For instance, educational outcomes can be improved through equipping children with the thinking skills they will need in a technologically advanced world. STI can also help in increasing the competitiveness of existing firms; forming new technology-based firms; modernising existing industries such as agriculture and mining; and developing emerging industries such as those linked to the Fourth Industrial Revolution (4IR), thereby exploiting new sources of economic growth while promoting environmental custodianship to safeguard the future.

Since 1996, a solid foundation has been laid to achieve the ambitions outlined in this White Paper. To take this progress further and to realise the full potential of STI in South Africa, the vision of this White Paper is "science, technology and innovation enabling inclusive and sustainable South African development in a changing world". The White Paper has three high-level goals, namely, to take advantage of opportunities presented by megatrends and technological change; to expand policy approaches that have worked and propose new approaches where necessary; and to promote a more inclusive economy at all levels.

This White Paper is not an implementation plan. The policy actions proposed here will be implemented according to decadal plans informed by technology foresight studies and consultation with all implementation partners (across government, business, academia and civil society) to ensure policy coherence and certainty. The decadal plans will detail technology focus areas, programmes to be initiated, institutional arrangements and funding required for these programmes, and ways to evaluate their performance. They will be reviewed and updated every five years, or as deemed appropriate by the Department of Science and Technology (DST).

Chapter 2: Looking to the future

The world is changing rapidly and fundamentally. Drivers of global change are socio-economic and geopolitical (e.g. demographic shifts, urbanisation, rising inequality and youth unemployment, and the rise of China and India as economic powers), scientific and technological (e.g. the blurring of lines between the physical and digital spheres as a result of information and communication technologies and the 4IR), and environmental (with climate change having serious consequences for the world's most vulnerable people).

These global changes have profound implications for the NSI. To illustrate, inter- and transdisciplinary knowledge is increasingly important, and research is becoming increasingly data-driven. This means that an open science approach is required to enable greater access to existing information. The success of South Africa's response to the 4IR, which will include ensuring that people are not left behind as society and the economy become more technologically driven, will depend on how well we exploit the pivotal role of information and communication technology (ICT) and harness the potential of big data. Furthermore, STI have a fundamental role to play in achieving the Sustainable Development Goals (SDGs). South Africa's future is inextricably linked to that of the rest of the African continent, and therefore the potential of STI for African development and continental integration needs to be fully exploited.

To address the challenges and opportunities discussed above, the White Paper proposes several policy shifts, which are summarised below.

Chapter 3: A coherent, inclusive National System of Innovation

In addition to measures to support partnerships among NSI actors at all levels, interventions aimed at improving the policy coherence and coordination, as well as the governance, of the NSI will be introduced. Among these will be the establishment of a Ministerial STI Structure under the guidance of the Minister of Science and Technology, which will set the STI agenda across government and commit public resources to priority STI programmes. The Ministerial STI Structure will be informed by an annual STI Plenary involving government, business, academia and civil society, to be convened by the Presidency. The National Advisory Council on Innovation (NACI) will be strengthened to advise the Ministerial STI Structure. Policy approaches are introduced to increase coherence in critical areas such as education and skills development, the economy, and social development. Sector coordination will be improved through the adoption of collaborative sector R&D planning, as well as Sector Innovation Funds to concentrate resources on priority sectors.

To fully exploit the potential of STI in South Africa, the STI institutional landscape will be expanded in line with the findings of the STI Institutional Landscape Review, and the governance of NSI institutions will be strengthened (including clarifying the mandates of government departments regarding public research organisations, and improving coordination across research institutions and funding agencies). Finally, policy approaches to enhance the M&E capacity of the NSI will be introduced, for instance, conducting regular foresight exercises and developing a new M&E framework for the NSI, with NACI being upgraded so that it can undertake this role.

Chapter 4: An enabling innovation environment in South Africa

To improve the environment for South African innovation, a number of policy approaches will be introduced, such as moving beyond R&D to a broader conceptualisation of innovation, and supporting a whole-of-society approach to innovation (the so-called innovation compact) to ensure that all policies related to innovation (e.g. trade, competition, education and procurement policies) work together to support innovation in South Africa. Various mechanisms will be introduced to strengthen support to business (with a focus on small and medium enterprises (SMEs)) as well as to revitalise the role of state-owned entities (SOEs) in innovation. This White Paper further supports an enabling legislative framework, for instance, in the area of intellectual property rights (IPRs) from publicly funded R&D, and to increase the uptake of locally developed technologies through

government procurement. The White Paper introduces policy approaches to develop local innovation ecosystems (e.g. integrating support for local and grassroots innovators into local economic development planning, and establishing more incubation facilities and local walk-in centres for innovation). To bolster innovation for inclusive development, the White Paper introduces a significant policy shift in including civil society in STI planning at all levels, and devoting resources to supporting grassroots and other neglected innovators.

The White Paper further focuses on the exploitation of new sources of growth such as the 4IR (a collaborative national platform will be established to respond to the risks and opportunities this brings), the circular economy and ICTs. The role of government as an enabler of innovation will be strengthened, e.g. through programmes to build an innovation mindset from primary school level, to celebrate entrepreneurs and innovation role models, and to adopt innovative approaches throughout government operations.

Chapter 5: Expanded capabilities to support the knowledge enterprise

To exploit the full potential of scientific knowledge, this White Paper aims to expand research outputs and transform the research institutional landscape, for instance, through programmes to improve the performance of historically disadvantaged universities. Furthermore, building on and expanding successful approaches over the past two decades, the profile of the researcher base will be transformed (for instance by activating the PhD-qualified "silent majority", who do little research). The research system's output of human resources will be improved (for instance through developing the human resource pipeline, providing increased support for students, increasing supervisory capacity, and transforming the demographics of the professoriate). In addition to a focus on academic outputs and PhDs, the White Paper supports a diversity of post-secondary education opportunities and the prioritisation of the development of technical skills for the economy, including a focus on education and training for a future of digital jobs.

To respond to a changing world, policy approaches are introduced to ensure an open, responsive and diverse knowledge system. These include adopting an open science paradigm, supporting a diversity of knowledge fields, and a greater focus on inter- and transdisciplinary research and the contribution of the humanities and social sciences to addressing complex societal problems. The selection process of research focus areas will be institutionalised, and the focus areas will be aimed at opportunities to meet the NDP's objectives. There will be an enhanced focus on knowledge diffusion. The envisaged expansion and transformation of the research system will be further supported through policy approaches to upgrade and expand research infrastructure, including cyberinfrastructure (e.g. through the establishment of a knowledge infrastructure fund at National Treasury).

The realisation of the ambitions of this White Paper will in part depend on building an innovation culture in society and developing a science-literate and -aware citizenry. The White Paper therefore pays attention to skills and institutional arrangements to support and coordinate science engagement initiatives in South Africa. Finally, building on South Africa's strong record in developing international STI partnerships, the White Paper introduces a systematic approach to expanding the internationalisation of STI and science diplomacy – with a strong focus on the African continent to support a pan-African agenda.

Chapter 6: Financing science, technology and innovation

Very few of the ambitions of this White Paper will be realised without adequate funding and the productive deployment of funding. The White Paper therefore recommits the government to increasing the levels of R&D investment in the economy so that gross expenditure on R&D (GERD) reaches 1.5 per cent of gross domestic product (GDP) in the next decade. To achieve this target, provincial and local governments will actively contribute more to STI funding, and national STI-intensive government departments will set appropriate targets for STI in their budgets. Furthermore, the mandates of development finance institutions will be expanded to scale up funding for industrial innovation activities. International investments in STI will be appropriately positioned in South African trade and investment initiatives to attract STI-linked foreign direct investment, targeting multinational companies. As there is a specific need for increased commercialisation funding, a sovereign innovation fund will be set up to leverage co-investment by the public and private sectors.

To ensure that public STI funding is deployed productively, an STI investment framework will be institutionalised, under the auspices of the Ministerial STI Structure, to serve as a mechanism for prioritising and allocating funds. This will involve collaboration between the DST, National Treasury and the Department of Planning, Monitoring and Evaluation (DPME). Finally, to improve funding efficiencies, the mandates and funding instruments and incentives of institutions such as the Technology Innovation Agency (TIA), the National Intellectual Property Management Office (NIPMO), parts of the Industrial Development Corporation (IDC) and parts of the National Research Foundation (NRF) will be harmonised, and the administrative capabilities of the relevant institutions improved (e.g. through simplified application procedures, improved turnaround times and standardised evaluation approaches, where appropriate).

Chapter 7: Concluding remarks

For South Africa to become a winning nation in the field of STI, and for STI to realise its potential as a driver of economic growth and social development, this White Paper introduces a number of policy shifts. The White Paper will be implemented through successive decadal plans. The indicators to measure the achievement of the policy intents expressed in the White Paper will be included in these decadal plans. To realise the intended impacts of STI in terms of sustainable and inclusive development (as envisaged in the SDGs and the NDP), progress will be measured in inputs (e.g. investment in STI), outputs (e.g. increases in graduates, publications and patents) and outcomes (e.g. improved partnerships between NSI actors and increased policy coherence, yielding improved innovation performance).

CHAPTER 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

Science, technology and innovation (STI) embody some of the best qualities of humanity, such as curiosity, creativity and aspirational thinking. Moreover, economists associate the competitiveness and long-term economic growth of nations with technological progress. Societies that value STI and invest in STI to support health and education, for instance, can vastly improve the quality of life of citizens and support socio-economic progress. Being such powerful drivers of change across society, STI have to be developed through partnerships between business, government, academia and civil society.

> *"No modern society has scaled the heights of social progress without science and technology … Harnessing the force of science and technology to meet South Africa's developmental needs is among the surest ways out of the current quagmire of underdevelopment … Research has shown that nations such as Japan, South Korea and Germany put science, technology and innovation in the service of their societies, with commendable results."*
>
> Kgalema Motlanthe, former President of South Africa, addressing the 2013 South African Science, Technology and Innovation Summit

In 1996, with the adoption of the White Paper on Science and Technology, the first democratic South African government committed to using STI to support the development of the country and to help overcome the legacy of apartheid. Twenty-three years later, building on STI-related achievements since 1996 and using South Africa's abundant resources, STI can significantly contribute to realising the National Development Plan's (NDP's) Vision 2030. The Fourth Industrial Revolution (4IR) and attendant rapid technological changes are creating opportunities for improved quality of life and increased national competitiveness, but are also putting some traditional jobs at risk.

Not only is South Africa a small, open economy influenced by these changes, but we are also a society constrained by high levels of poverty, unemployment (particularly among the youth) and inequality. Furthermore, some of the biggest risks facing nations over the near future are related to the environment, for instance climate change, drought and loss of biodiversity. South Africa therefore urgently needs to expand its STI capabilities, including its research competence and high-level skills (not limited to PhDs) to support the attainment of national development priorities in the context of environmental risks and rapid technological change.

This White Paper sets the medium- to long-term policy direction for government to ensure a growing role for STI in a prosperous and inclusive society in which the potential of all South Africans is realised. It proceeds from the starting point that, as Africans, we share a common history and, as humankind, a common future.

1.1 The policy context

1.1.1 South Africa's socio-economic landscape

Social issues

Over the past two decades, South Africa has seen significant social progress[1]. Near universal basic education coverage was achieved, with enrolment reaching 99 per cent in 2005. Furthermore, the National School Nutrition Programme is benefitting 9 million learners (out of 12 million). Health indicators such as Life Expectancy (which increased from 54 years in 2005 to 64.2 years in 2018) and Infant Mortality Rate (which decreased significantly from 53.2 deaths per 1 000 live births in 2002 to 45 deaths per 1 000 live births in 2018) would seem to indicate that the health of South Africans has vastly improved over the past two decades. The Social Wage for indigent people provides free electricity, water and sanitation, as well as social assistance to 17.4 million beneficiaries.

However, poverty and unemployment still afflict many South Africans. South Africa has among the highest inequality rates in the world. In 2014, 21.5 per cent of South Africans lived below the poverty line. Black South Africans, particularly black women, continue to bear the brunt of poverty. Unemployment remains racially skewed. Youth unemployment is also of concern given that it increased from 30 per cent in 1994 to 40 per cent in 2013, leaving many young people, most of them black, on the margins of society[2]. Finally, a report by the

Human Sciences Research Council (HSRC) shows that South Africans continue to underperform in mathematics and science compared with other countries[3, 4].

Economic issues

On the economic front, there has also been good progress in a number of areas over the past two decades. For instance, despite external factors (e.g. the price of oil) putting immense upward pressure on domestic inflation, the South African Reserve Bank has, since 2002, maintained inflation within the target range of 3 to 6 per cent. Furthermore, there has been strong fixed-investment activity over the past 20 years with a 6.2 per cent average annual growth rate. The private sector accounted for about 68 per cent of overall real fixed investment over the past decade, although its share had declined from 74.4 per cent in 2005 to 63 per cent by 2012.

South Africa is a small open economy that has been impacted on by, inter alia, the end of the commodity boom in 2011 and an uneven global recovery after the 2008/09 economic crisis. Furthermore, the South African economy is also constrained by structural problems such as infrastructure backlogs, concerns over water and energy security, and poor education outcomes in certain areas. Although economic growth has not reached the NDP target of 5 per cent, the World Bank[5] indicates a positive growth trend going forward. In addition, in 2018, the Organisation for Economic Cooperation and Development (OECD)[6] forecast a recovery of both investment and demand from 2019 onwards.

The decreasing contribution of the productive sectors to South Africa's gross domestic product (GDP) is balanced by a shift towards services – a global phenomenon. However, it remains necessary over the short to medium term for South Africa to modernise and strengthen productive sectors such as manufacturing, mining and agriculture to absorb larger numbers of low-skilled workers. Increasing mechanisation and technological development run counter to this goal, presenting a complex techno-socio-economic problem.

There is potential to increase the productivity of the South African economy through skills development, innovation, regulatory reform, investment in infrastructure, and information and communications technology (ICT). Greening the economy will be an important adjunct to such efforts.

1.1.2. The National Development Plan

The National Development Plan (Vision 2030) was introduced in 2011 to serve as South Africa's long-term planning framework. At the heart of the NDP lies the vision of creating a "virtuous cycle of growth and development", with success "measured by the degree to which the lives and opportunities of the poorest South Africans are transformed in a sustainable manner". The NDP envisages STI playing an important role in achieving its vision for 2030[7].

The role of STI in South Africa's National Development Plan

The NDP sets out to address a set of core outcomes covering the following 14 focus areas: education, health, safety and security, economic growth and employment, skills development, infrastructure, rural development, human settlements, local government, environment, international relations, public sector, social protection, and nation-building and social cohesion. As will be evident from this White Paper, science, technology and innovation are key enablers that cut across all these focus areas.

Subject to conditions such as social stability, investment in STI, education and skills development, science, technology and innovation are one way of feeding a virtuous cycle of economic growth and employment in the country. It is for this reason that the NDP includes targets for PhDs and makes specific reference to the need to ensure more research, the productivity of STI investment, and the efficiency of STI institutions.

Furthermore, effective STI policies and programmes will help ensure that gains made in addressing the NDP's core outcomes will not be reversed by the impact of the Fourth Industrial Revolution, which is already fundamentally altering the nature of societies and business across the globe.

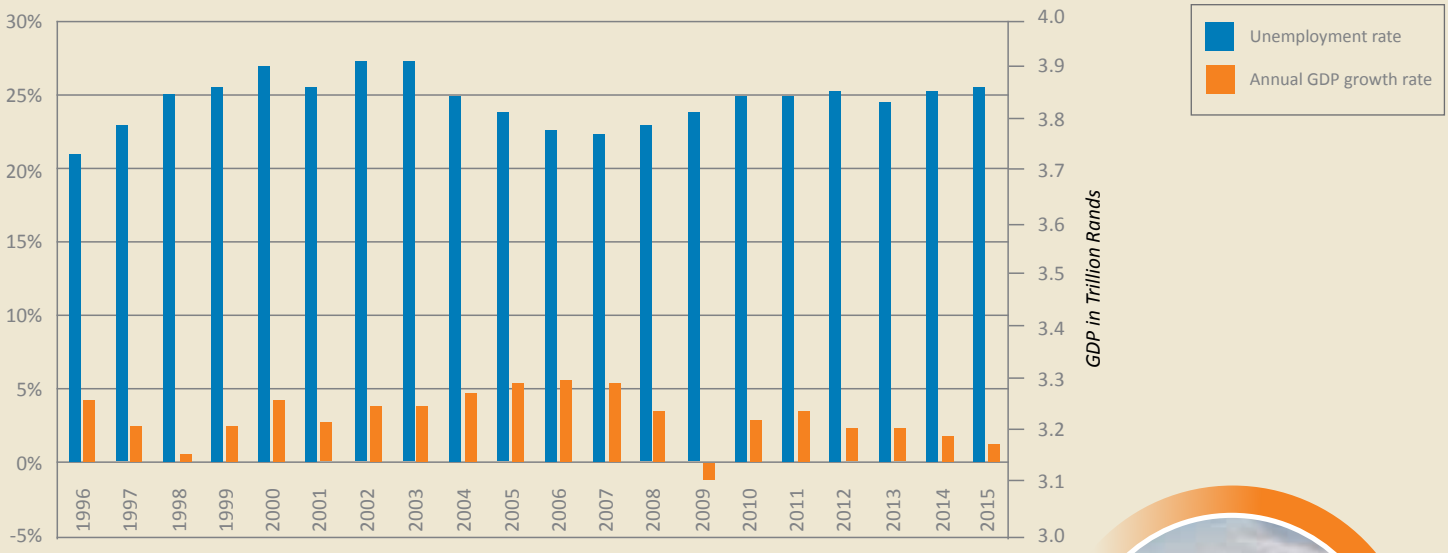
The South African socio-economic landscape

The South African socio-economic landscape is considered in relation to the following*:

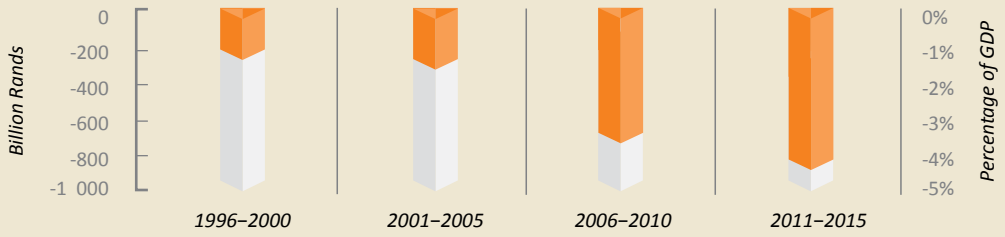
- Economic factors
- Social factors
- Environmental factors

ECONOMIC FACTORS

Unemployment and GDP growth 1996–2015



Ratio of current account balances to the GDP



Telecommunications

Mobile broadband coverage for 3G is at 99% of the population, and for 4G at 77% of the population, but South African data prices are the highest among Africa's largest economies. South African data cost is around $7.6/GB, Kenya at $4.9/GB and Egypt (the lowest) at $1.2/GB.

Youth business ownership

Business ownership for the youth stands at a low 33%, of which 43% venture into business because of unemployment, rather than a market opportunity.

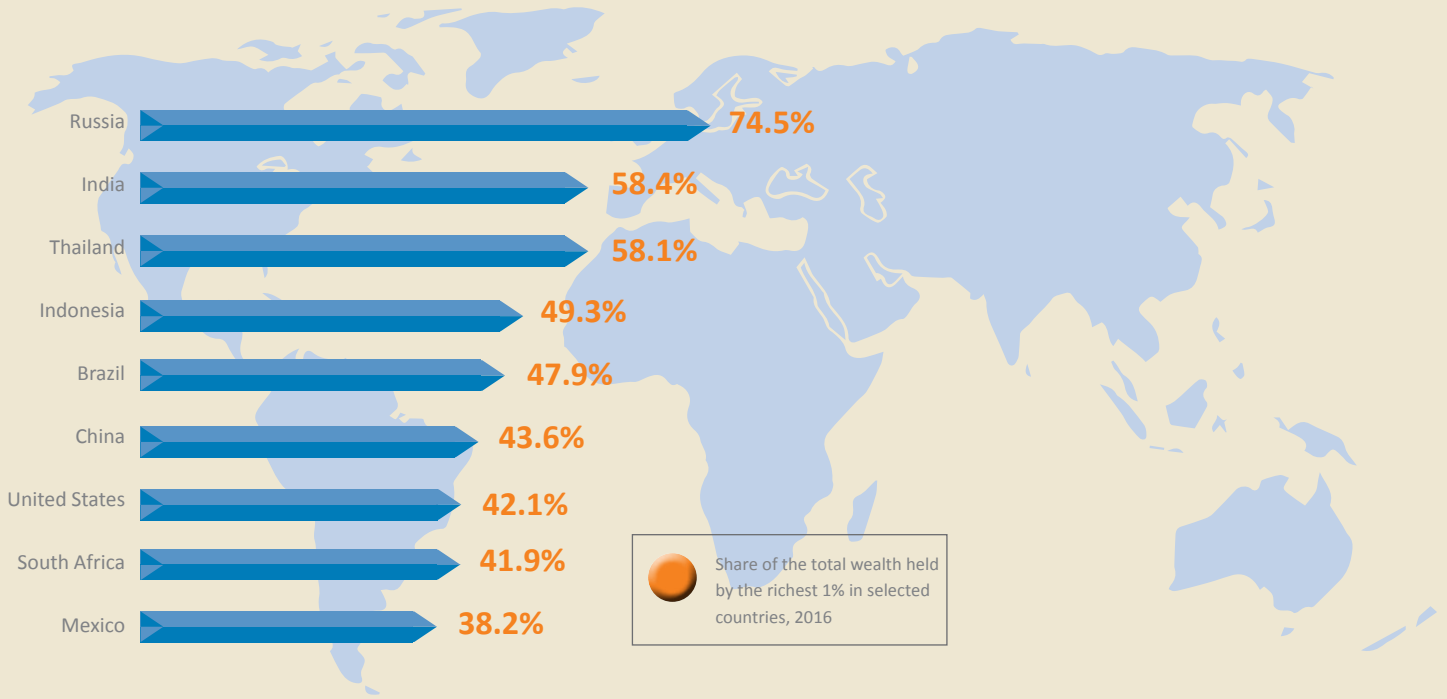
Per capita GDP

From 1996 to 2016 South Africa's real GDP/capita increased 27% from R44 177 to R 56 304.

**Data provided by the South African Reserve Bank, STATS SA[2], and NACI[8]*

SOCIAL FACTORS

South Africa remains one of the most unequal societies globally



Water & Sanitation:
From 2002 to 2015, the % of population with access to an improved water source increased from 87.4% to 93.2%, and over the same period, the % of population with access to improved sanitation facilities increased from 58.5% to 66.4%.

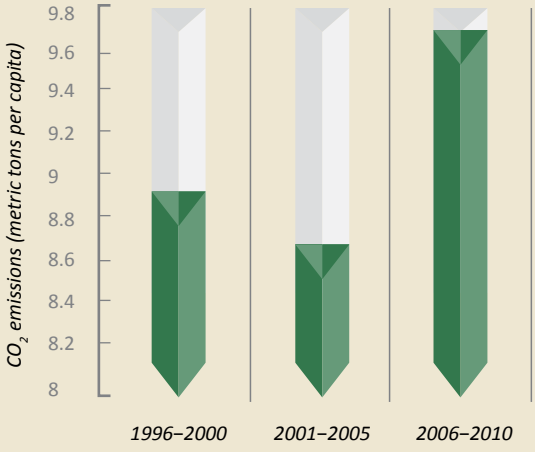
Health:
From 2002 to 2015, life expectancy at birth increased from 55.2 years to 62.1 years, but over the same period HIV prevalence increased from 10.3% to 12.5%.

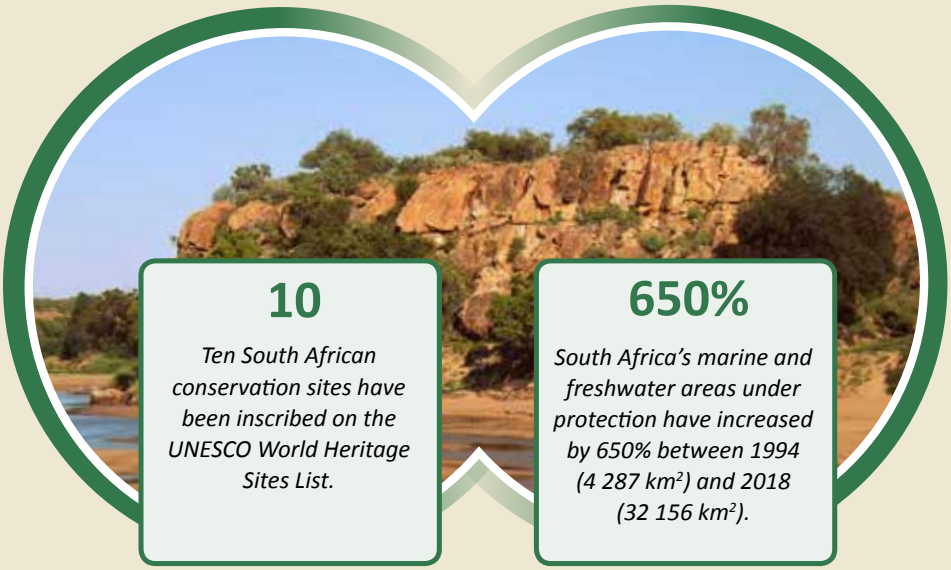
Literacy rate:
From 2002 to 2015, the youth literacy rate improved from 93.9% to 99%, and over the same period the adult literacy rate improved from 82.4% to 94.6%.

Multidimensional poverty:
From 2001 to 2011, the % of people suffering from multidimensional poverty decreased from 17.9% to 8%, and subsequently from 8% to 7% in 2016, as a result of the government's progressive social wage.

ENVIRONMENTAL FACTORS

CO_2 emissions, 1996–2010





10

Ten South African conservation sites have been inscribed on the UNESCO World Heritage Sites List.

650%

South Africa's marine and freshwater areas under protection have increased by 650% between 1994 (4 287 km²) and 2018 (32 156 km²).

The NDP acknowledges that economic development takes time and that innovation should grow in importance in years to come. In the first phase of implementation of the NDP (2012–2017), the focus should be on "intensifying research and development (R&D) spending, emphasising opportunities linked to existing industries". In the second phase (2018–2023), the country "should lay the foundations for more intensive improvements in productivity" and "innovation across state, business and social sectors should start to become pervasive". Finally, as 2030 approaches, "the emphasis should be on consolidating the gains of the second phase, with greater emphasis on innovation, improved productivity, more intensive pursuit of a knowledge economy, and better utilisation of comparative and competitive advantages in an integrated continent".

1.1.3 The evolution of the global STI policy environment

South Africa must take cognisance of the changing global STI environment. Policy trends across OECD countries have various implications for South African STI policy. Foremost among these is that OECD countries are shifting the composition of their STI funding by increasing public financial support to firms (at the expense of public research), amid a projected stabilisation of public R&D budgets. The OECD group is focusing on immediate economic priorities and policy efficiency gains (such as public research capacity, business innovation and entrepreneurship, governance, and improving framework conditions for innovation) rather than long-term issues (such as structural adjustment, sustainability and green growth). The OECD group is further setting up an agenda to advance Responsible Research and Innovation (RRI).

A South African focus on RRI would help local researchers to collaborate and compete with their foreign counterparts in a world where ethical concerns (such as fair trade) and environmental concerns (such as emission standards) are increasingly influencing competitiveness.

Access to R&D funding has become increasingly competitive and countries are developing their research systems accordingly. South Africa will have to follow suit. Any strategy to attract foreign R&D funding would have to take the shifting patterns of global funding into account, particularly the increasing role of large firms in the national R&D effort (meaning that international collaborative efforts will have to shift to firms). South Africa needs to concentrate on increasing the research capacity of domestic firms and strengthening their competitiveness in global value chains.

1.1.4. Looking to the future

Various megatrends (such as population growth and urbanisation) and technological advances are increasing uncertainty. These changes present opportunities and threats (e.g. a changing manufacturing environment can lead to economic growth but also to the loss of traditional jobs). These intersecting megatrends span the geopolitical, economic, social, technological and environmental spheres. Innovation is required to address needs arising from these megatrends, such as protecting the environment and improving service delivery.

The lines between physical, digital and biological systems are becoming blurred, and governments around the world are planning for the 4IR. In particular, it is necessary to prepare for the ways in which artificial intelligence (AI) and advances in ICT will change the way society and the economy function. Already, traditional jobs are being lost to automation, and traditional commerce is being disrupted by the move to online and the development of fast, personalised services and products. At the same time, these changes are creating new opportunities, including new market opportunities. For example, the growth of a middle class in emerging economies, and the high proportion of young people in national populations (the so-called "youth bulge") in Africa, are stimulating manufacturing, widening markets for mobile telephones, and creating ICT-enabled job opportunities for young entrepreneurs in the services sector. South Africa can benefit from these emerging market opportunities by using technology to modernise sectors such as agriculture and mining, and increase exports to growing markets in Africa and other emerging economies. Furthermore, tapping into the international trend for outsourcing presents a significant opportunity for South Africa to host the R&D centres of large multinational companies, reaping the concomitant benefits of job creation and foreign investment.

The possibilities are exciting and the implications vast. Only countries that are prepared for these changes will thrive, and STI lie at the heart of this preparation.

The NSI from 1996 to 2016 at a glance

The pre-1994 STI system was small, exclusive and aligned to the narrow agenda of the apartheid state, rather than oriented towards inclusive sustainable development and social equity. Since the 1996 White Paper on Science and Technology, the national system of innovation (NSI) has seen significant progress. However, challenges remain that constrain the contribution of the NSI to South Africa's national priorities.

	NSI AS A WHOLE	KNOWLEDGE AND HUMAN CAPABILITIES	INNOVATION PERFORMANCE	FINANCING
+	New institutions e.g. TIA, SANSA and NIPMO. Deeper linkages e.g. DST/dti . Business support increased e.g. Sector Innovation Fund.	Publications increased. Increased participation of women and black people.	Growing uptake of STI. More tech start-ups. Grassroots focus.	Up to 2015, business funding increased. Public funding increased.
−	NSI fragmentation. Business linkages insufficient. Systemic M&E lacking.	Transformation incomplete. Infrastructure backlogs. Research focus insufficient.	No over-arching innovation policy. Innovation mostly flat.	GERD largely stagnant. Funding uncoordinated.

Indigenous knowledge provides business opportunities: Legislation has been drafted to protect, promote, develop and manage South Africa's Indigenous Knowledge Systems.

Unravelling the universe: South Africa was awarded the bulk of the Square Kilometre Array (SKA) project, the largest radio telescope in the world, and the biggest science infrastructure on the African continent.

350%

Doctoral awards *more than doubled between 2002 and 2014; and PhD enrollment increased by 350% between 1996 and 2014.*

44.3%

Women researchers *made up 44.3% of all researchers in 2014/15 – a higher participation rate than in many developed countries.*

32%

Share of scientific outputs by black authors *increased from 10% in 1998 to 32% in 2014.*

279%

Between 1996 and 2016, SA ***Web of Science*** *articles increased from 3 233 to 12 251.*

POLICY DEVELOPMENT

1996 — ***White Paper on Science and Technology***

2002 — ***National Research and Development Strategy***

2008 — ***Ten-Year Innovation Plan***

1.2 The evolution and performance of the National System of Innovation, 1996 to 2016[8]

1.2.1. South African STI policy since 1996

In 1994, the newly elected government inherited a fractured society, a fiscally drained state and an unsustainable, resource-intensive economic growth path. The pre-1994 STI system was small, exclusive and in line with the agenda of the apartheid state, rather than oriented towards inclusive, sustainable economic development and social equity.

The democratic government began a period of comprehensive STI policy development. It adopted the 1996 White Paper on Science and Technology, the 2002 National Research and Development Strategy, and the Ten-year Innovation Plan for South Africa (2008–2018). Various sectoral and cross-cutting STI strategies were also adopted for areas such as advanced manufacturing technology, biotechnology and human resource development. The organising framework for the 1996 White Paper, as well as the STI policies following on the 1996 White Paper, was that of a National System of Innovation (NSI) – guided by prevailing global approaches to enhancing innovation performance. The 1996 White Paper conceptualised the NSI as "a set of functioning institutions, organisations and policies that interact constructively in the pursuit of a common set of social and economic goals and objectives"[8].

The aim of early post-1994 STI policy development was (i) to transform the STI system to serve all South Africans; (ii) to counter STI policy fragmentation; (iii) to expand and transform human capabilities; (iv) to provide more support for research; (v) to build the required STI institutions; (vi) to increase innovation to support economic growth and socio-economic development; and (vii) to increase the financial resources for the system. Progress on these seven objectives can be traced throughout the discussion below on the high-level performance of the NSI.

1.2.2. High-level overview of the performance of the National System of Innovation, 1996 to 2016

Developing the National System of Innovation

As stated above, the 1996 White Paper adopted the concept of the NSI as an organising framework for STI policy and implementation. Since then, progress has been made in developing the required NSI institutions, such as the Technology Innovation Agency (TIA) and the National Research Foundation (NRF) (see Chapter 3 for more detail). Linkages have been strengthened, and public support to business is growing (e.g. through the R&D tax incentive, the Sector Innovation Funds and other public-private partnerships). Science, technology and innovation are increasingly being incorporated into government plans, countering policy fragmentation to some degree. The most significant indication that STI is being integrated into government planning is the central role of STI in the NDP. While challenges remain – for example, South Africa's NSI is still too small and STI programmes are still fragmented – the government's effort in setting up institutions, building NSI relationships and facilitating the coherence of STI programmes is beginning to show results.

Expanding the research system, and developing and transforming high-level human capabilities

Various instruments have been introduced to expand the research system, including the South African Research Chairs Initiative (SARChI) and the Centres of Excellence. Among the beneficial effects of these instruments is that they have enabled the concentration of investment in South African research in areas of strategic importance.

South African researchers have established productive international networks. Between 1996 and 2014, although the number of university research staff did not increase, research output trebled[8]. PhD student enrollment increased[8] by 350 per cent, which is encouraging, although it does strain supervisory capacity.

The participation of black people and women in the research system has grown substantially. In 2013/14, including doctoral and postdoctoral students, women comprised 44 per cent of R&D personnel, and black people 52 per cent. However, significant inequality persists, especially at the higher levels. Black women and men make up less than 5 per cent and 20 per cent of professors respectively[8].

Advancing South Africa's innovation performance

The 2016 Global Innovation Index[9] showed that South Africa is strong in market sophistication and investment, and aspects of knowledge absorption and knowledge impact. Patent cooperation treaty applications have doubled, and South Africa's registration of plant cultivars is the highest in Africa and ranks 14th globally. The Technology Balance of Payments shows that South Africa remains a net importer of technology – a fact that is not necessarily negative as it points to enhanced absorptive capacity in the economy, and an increased demand for technology. Moreover, there are large revenue flows from South African firms trading abroad in retail, financial services, communications, leisure, construction and logistics. However, despite these positive trends, South Africa's innovation performance has remained relatively flat since 1996, pointing to unharnessed potential and hence exciting opportunities to grow a strong and inclusive economy. In fact, in 2018 the World Bank[5] stated that innovation is one of the keys to taking the South African economy to a new level.

Increasing the financial resources of the NSI

Since 1996, public resources for both public and private sector STI have increased significantly (the Department of Science and Technology's (DST's) expenditure alone has increased nine-fold). Furthermore, over the past decade, a number of provincial growth and development strategies have recognised innovation as an important driver of social and economic wellbeing and provinces have invested resources in innovation hubs, ICT infrastructure and science park-type developments. However, there is potential to do much more. Although gross expenditure on R&D (GERD) as a percentage of GDP has not yet reached the 1.5 per cent target level, it has held steady at about 0.7 per cent in a challenging economic environment, with the beginnings of a possible long-term upward trend apparent.

Closing remarks

The above analysis clearly illustrates the significant progress in the South African NSI over the past two decades. The foundation has been laid for South Africans to tap into the full potential of STI to help change the growth and development trajectory of the economy, in the process contributing to the alleviation of poverty and inequality. In particular, the role of STI speaks, both directly and indirectly, to the three pillars of the NDP, namely:

- Developing a strong and inclusive economy
- Increasing the capabilities of South Africans
- Developing a capable state

To unleash the significant potential of STI, the South African NSI needs to address the challenges shown in the box below.

Overview of NSI challenges

According to recent reviews[8, 10, 11, 12], the main factors constraining NSI performance are the following:

- Inadequate and non-inclusive means of agenda setting
- A lack of policy coherence and coordination
- Inadequate mechanisms for policy learning
- Insufficient involvement of business and civil society
- Inadequate high-level SET and technical skills for the economy
- A research system that, although productive, is small
- An environment that does not sufficiently enable innovation
- Significant levels of underfunding

1.3 Why a new White Paper on STI?

There are two reasons for South Africa to renew its STI policy. Firstly, the STI system inherited in 1994 has seen significant changes over the past two decades, as has the global STI technology environment with the advent of the 4IR. Global megatrends such as demographic and geopolitical shifts, as well as environmental degradation, render even the near future uncertain. Therefore, South Africa requires new STI policy approaches to respond to the changing environment.

Secondly, as indicated above, based on recent reviews, there are a number of challenges constraining the contribution that the NSI can make to the attainment of South Africa's NDP objectives. Building on progress in South African STI over the past two decades, the 2019 White Paper on Science, Technology and Innovation aims to help realise the potential of STI to address the country's challenges.

"We stand on the brink of a technological revolution that will fundamentally alter the way we live, work and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before.

"We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society."

Klaus Schwab, Founder and Chairman of the Word Economic Forum, 2016

1.4 The vision, objectives, approach and theory of change of the White Paper

Vision

Science, technology and innovation enabling inclusive and sustainable South African development in a changing world

Objectives:

- Improved coherence and coordination
- Increased NSI partnering between business, academia, government and civil society
- Strengthened and transformed NSI institutions
- Increased human capabilities
- Expanded research enterprise
- Enhanced enabling environment for innovation
- Improved funding across the NSI

Approach followed:

In pursuing these objectives, the approach will be to:

- ensure full alignment with the NDP objectives;
- expand what has worked and propose new approaches where necessary;
- take advantage of opportunities presented by megatrends and
- promote transformation and inclusivity.

The theory of change of the White Paper

The White Paper proposes policy actions to achieve its vision according to the following conceptual logic:

- The premise of this White Paper is that STI, being significant contributors to inclusive and sustainable development, can shape a different South Africa.
- It is through partnerships between business, government, academia and civil society that the potential contribution of STI to addressing South Africa's socio-economic development challenges will be realised.
- The success of these partnerships will require a coherent whole-of-society STI agenda, the collaboration of all NSI partners in pursuing this agenda, and for all NSI partners to regularly reflect on and learn from the implementation of STI initiatives.
- Specific STI-related challenges, such as insufficient skills and funding, as well as constraints in the business environment for innovation, will also need to be addressed for the partnerships to have an optimal impact.
- To make all of the above possible, society will need to value science, appreciate the impact of innovation on development, and anticipate and plan for change. A society that is permeated by a culture of creativity, learning and entrepreneurship will provide a fertile environment for harnessing the potential of STI.

1.5 Implementation of the White Paper: the role of decadal plans

This White Paper sets the medium- to long-term policy direction for the NSI. It is informed by analysis of the evidence from a number of reviews of the NSI, experience gained in the implementation of STI policy over the past 20 years, and consultation with NSI partners – including both state actors such as STI-intensive government departments, universities and science councils, and non-state actors such as civil society, labour and business.

The White Paper is not an implementation plan. Rather, the implementation of the White Paper will be directed through successive decadal plans. To ensure policy coherence and maximum responsiveness to the needs of society, these decadal plans will be developed in partnership with the relevant NSI actors. The decadal plans will be informed by analysis, foresight, and government's priority outcomes as captured in the NDP and the Medium-term Strategic Framework (MTSF).

The decadal plans will be reviewed every five years, or as deemed appropriate by the DST.

The role of the decadal plans in implementation and technology choices

It is the function of policy to set medium- to long-term government policy direction, as in this White Paper. It is not the function of policy to present a detailed implementation plan or to prescribe specific technology choices. However, policy without a detailed, and evolving, implementation plan will have little impact.

The decadal plans will provide guidance on the following:

- Suggested technology focus areas
- Priority initiatives
- Required institutional arrangements, including partnerships
- Funding required and proposals for sourcing funding
- Timelines
- Indicators to measure progress

CHAPTER 2

LOOKING TO THE FUTURE

CHAPTER 2: LOOKING TO THE FUTURE

The world is rapidly changing and countries are grappling with how to use scientific advances to meet new challenges and build resilience in a fragile world. The potential of STI lies in helping South Africa and its NSI respond, not only to current problems, but also to opportunities offered by a changing, increasingly connected and globalised environment. The next section (Section 2.1) briefly examines the drivers of change, leading to a discussion of the implications of these drivers for the NSI (Section 2.2).

2.1 Drivers of global change

Social	• Exponential population growth will see the global population reaching ~11 billion by 2100, increasing competition for resources. • According to the World Health Organisation, by 2050, 80% of older people will live in the developing world. • The youth "bulge" in Africa, coupled with high youth unemployment, drives inequality and social instability. • Africa has one of the highest burdens of infectious diseases in the world, which climate change and African land-use patterns will continue to influence. The potential to address this infectious disease threat exists, but is not currently fully utilised. • By 2050, the northern regions will be 84% urbanised and Africa 62% urbanised, which has potential for economic growth, but may also expose people to marginalisation, conflict and exploitation. • Increasing uncontrolled migration from war-torn and poverty-stricken regions to developed countries is already leading to social instability. • The international mobility of highly educated individuals, supported by digital technologies, is driving global knowledge circulation. However, higher mobility also means higher competition for these human resources, with its attendant risks such as an African brain drain. • Slow progress on the gender agenda in many countries has the effect of stifling socio-economic growth.
Scientific and technological	• Modern science and data are expanding exponentially, and scientists have access to an increasing range of data from multiple sources with variable quality. • Rapid change in and between disciplines is happening, science breakthroughs come about more quickly, and are translated into innovations faster. • The 4IR is blurring lines between the physical and digital spheres, with legal, ethical and socio-economic consequences. The 4IR further has consequences for public services, and the way we work, learn, produce, consume and interact.
Economic	• In 2017, 70% of the global population was living in countries where income inequality is increasing, stifling economic growth, health and education outcomes, as well as stability. • Young people are increasingly exposed to income inequality, thereby squandering the demographic dividend of countries with large young populations. • Technological change can promote social inclusion and economic growth, but can also cause the loss of many traditional jobs – a dire prospect, given South Africa's high unemployment and high proportion of unskilled workers. • A growing middle class and increasing consumerism in emerging economies will increase the demand for goods and services worldwide. • Despite a backlash against the disruptive effects of globalisation, analysts do not foresee the large-scale retreat of globalisation. Instead of protective policies, a concerted effort towards more sustainable governance of the global economy would be the answer.

Environmental	• The challenges of climate change, and the degradation of the natural environment, e.g. biodiversity loss, will increasingly shape policies. The concept of a circular economy will likely come to dominate future growth discourse. • New environmental policies will require new technologies, processes, services and business models.
Geopolitical	• The axis of the world's economic and geopolitical power is shifting from west and north, to east and south, and the international landscape is increasingly multipolar. • These geopolitical shifts will create opportunities for South Africa and the African continent as a whole, provided inclusive long-term modernisation of the continent takes place and infrastructure investment is increased, e.g. in broadband.
National and global policies	• The Sustainable Development Goals (SDGs), representing opportunities for transformative social, economic, environmental and institutional change. • The South African NDP, providing a guide for planning up to 2030. • Various policy commitments in terms of global treaties and goals.

It is imperative, therefore, that the South African STI policy not only responds to future risks and opportunities, but also helps shape the future.

2.2 Implications of the drivers of change for science, technology and innovation in South Africa

The drivers of global change have significant implications for South Africa's STI policy. The remainder of this chapter defines the main ways in which policy should respond to these changes. It thus serves as background for the rest of the White Paper.

2.2.1 Thinking in terms of socio-technical systems

Current innovation thinking does not adequately respond to a world in rapid transition[a]. A shift is required from thinking about systems in isolation to considering entire socio-technical systems and the values underlying them.[1]

In South Africa, which is still grappling with the legacies of its apartheid past, a focus on the evolution of socio-technical systems and their underlying values is acutely relevant. For example, apartheid spatial development patterns continue to obstruct the development of inclusive systems of mobility. These insights have profound implications for South African STI policy, how programmes are conceived and implemented, as well as how impacts are evaluated.

2.2.2 Significantly expanding human STI capabilities

The dearth of STI human capabilities severely hampered society's ability to solve problems. The need for long-term investment in individuals and institutions by society to develop the knowledge, skills and resources to address South African developmental needs cannot be overemphasised. While a broad base of STI human capabilities is desirable, research capabilities have emerged to occupy the centre stage in the activities of developing nations.

Universities will continue to play a leading central role in research in South Africa. However, in line with global trends, other organisations such as science councils, non-governmental organisations, state-owned entities (SOEs) and other privately funded institutions are increasingly becoming sites of research and innovation activities. Furthermore, with the thrust of training the next generation of human STI capabilities vesting with universities, South African universities in particular must tackle the challenges of making the STI workforce diverse and inclusive to address the discriminatory vestiges of the past.

a The current focus is on individual systems, for instance, a transport system. However, because of increasing inter-connectedness, this focus should shift from individual systems to entire socio-technical systems, e.g. a system of mobility (rather than a transport system). A socio-technical system links any number of related individual systems, e.g. fuel infrastructure, vehicle production, cultural practices and norms regarding public transport, infrastructure and traffic systems, maintenance and distribution systems, and industry.

2.2.3 Embracing transdisciplinary approaches

Interdisciplinary research teams, and the integration of knowledge from different disciplines, as well as from users, are necessary to deal with complex problems. Increasingly scholars and policy makers are viewing such approaches as "science for the future", and as an opportunity to strengthen the relationship between science and society by putting social concerns at the core of scientific research. Open science is one avenue to realise the benefits of collaborative, transdisciplinary approaches to knowledge development.

2.2.4 Strengthening knowledge networks

As the leading STI countries around the globe are all expanding their scientific bases in order to remain at the forefront of knowledge development, the competition for high-level skills and for investment in science projects will increase exponentially. Expanding and supporting knowledge networks will be important in tapping into global knowledge development and investment.

South Africa's diaspora scientists remain a vastly untapped resource. Hence, South Africa needs to look beyond the "brain drain" and take advantage of its overseas community by strengthening international networks of diaspora scientists. Knowledge networks through which diaspora scientists can organise scientific exchanges, educational programmes, and other opportunities to build capacity and encourage innovation and knowledge production, need to be supported, both at home and in their host countries. Properly leveraged, these "brain circulation" networks could help drive innovation and knowledge generation in South Africa, and improve science diplomacy between countries.

2.2.5 Increasing investment

Increased investment in STI is important, since it is investment in science that has enabled knowledge breakthroughs in, for example, biotechnology, AI, nanotechnology, synthetic biology and the basic sciences more broadly. Furthermore, investment in innovation such as in innovation infrastructure is necessary to translate knowledge advances into products and services for the financial and social markets. Moreover, benefiting from technological change and the megatrends described in this chapter requires the scientific knowledge base of the NSI to be expanded across all scientific disciplines.

Basic research is essential for building the South African economy and keeping it competitive globally – thus giving effect to the basic social contract between science and society. Currently, South Africa has to compete with comparable countries across the globe that have been pouring resources into their science systems, and have adopted long-term planning and funding horizons. If we want to craft an innovative edge, we must make funding for scientific research a national priority.

2.2.6 Facilitating open science and open innovation

Open science and open innovation represent significant opportunities for growing STI output and impact. Open science is a practice in which research and other data, including laboratory notes and other research processes, are made freely available under terms that allow people to re-use, redistribute and reproduce research and its underlying data and methods[13]. Increasing access to public science has the potential to make the entire research system more effective, participative and productive by reducing duplication and the costs of creating, transferring and re-using data.

Fostering digitally enabled open and collaborative innovation is also key. The basic premise of open innovation is to make the innovation process accessible to all active players so that knowledge can circulate more freely. Open innovation represents, at least in part, a reinvention of the organisational models that we have come to take for granted. In a networked world, it is no longer possible to ring-fence what we know or have invented and create new value through internal means alone. What is novel in collaborative innovation is the greater use of the internet, digital technologies and social networks to foster learning, enable the co-creation of (codified) knowledge, and provide wide access to tools, data and resources.

2.2.7 Exploiting the pivotal role of ICT

South Africa will need to exploit the increasing convergence, sophistication and reach of ICT. The NDP, in particular, sees ICT underpinning a dynamic, inclusive and prosperous knowledge economy, in which seamless information infrastructure and systems will meet the needs of citizens, business and the public sector. Such a situation, in which advances in ICT are used to strengthen economic competitiveness, generate youth employment and enable an enhanced quality of life, can be described as a "digital advantage". The attainment of digital advantage is crucial if South Africa is to participate effectively in the 4IR.

ICT is already playing an important role in transforming the educational system. More changes are expected in terms of new models for open-access, mobile, lifelong and ubiquitous learning beyond the traditional classroom. Integrating digital technologies into the provision of government services (e-government) and the management of cities (smart cities) has the potential to transform the scope and efficiency of public services.

More than ever before, research is data-driven. This not only means that the volume of data available to conduct research is growing exponentially, but also that research subjects, methods and practices, and visibility are changing irrevocably. New research fields will develop around data mining, machine learning, privacy and database interoperability to enable big data science. Big data analytics will open new research avenues and create new business models.

2.2.8 Harnessing the potential of big data

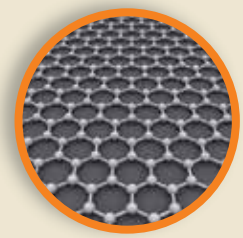
Advances in digital technology are making it possible to collect, store and process ever-expanding amounts of data generated through a wide range of systems and from a multiplicity of sources. "Big data" refers to extremely large and/or complex data sets that can be analysed computationally to reveal patterns, trends and associations, especially relating to human behaviour and interactions.

Whether it is geographical information, statistics, weather data, research data, transport data, energy consumption data, biometric or health data, the need to make sense of big data is leading to technological innovations and the development of new tools and skills. Improved analytics and processing of data will, for instance, make it possible to transform South Africa's service industries, increase the productivity of all sectors, and achieve cost reductions through more personalised services and increases in efficiency.

The challenge is to harness the power of big data to enhance the quality of the evidence, insight and analysis that inform and shape our views. Big data presents a challenge to policy makers because it can offer real-time results that require rapid, adaptive policies in return. One of the important policy questions relates to the right trade-off between privacy, property rights and security, on the one hand, and allowing society to benefit from data-driven innovations and better ways of living, on the other hand.

South Africa is a rich source of research data and has made substantial investments in cyberinfrastructure, as well as in the acquisition and generation of data across a number of domains. Driven by initiatives such as the Square Kilometre Array (SKA), these commitments are set to greatly increase in the future and uniquely position South Africa to derive substantial benefits from big data. South Africa, however, should not just be a collector of data. The economic, social, scientific and industrial beneficiation potential of big data for South Africa must rather be realised.

Emerging fields of knowledge, technologies and materials that will shape the near future



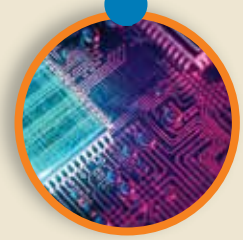
Graphene: This special form of carbon is very versatile. It is light and strong, and can conduct heat and electricity better than any other material. It can be used in bioelectric sensory devices to monitor glucose levels, cholesterol and even DNA sequencing. It is flexible and thin, so graphene-based photovoltaic cells can be used in clothing, to help recharge mobile devices and even in curtains to help power a home.

Regenerative medicine: Research in tissue engineering and molecular biology holds the promise of stimulating the body's own repair mechanisms to heal previously irreparable tissue and organs. It also has the possibility of growing tissues and organs in the laboratory and implanting them into the body so that it can heal itself.

Carbon capture and storage: This is the process of capturing waste carbon dioxide from large point sources, such as fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere – normally in an underground geological formation. Such geoscience-based technologies can mitigate the contribution of fossil fuel emissions to global warming and ocean acidification.

Modelling, simulation and gaming: Modelling and simulation is a substitute for experimentation where computers calculate the results of physical phenomena. It is important in research as it represents real systems through mathematical models that simulate the dynamics of the system. This makes it possible to explore system behaviour in ways that are often not possible, too risky or too expensive in real life. Gaming technology refers to a range of technologies used in computer games such as facial and voice recognition, gesture control, artificial intelligence, and virtual and augmented reality.

Artificial intelligence and virtual reality: The creation of algorithms that can learn, understand language and mimic some aspects of the human mind have led to huge advances. The ultimate goal is artificial general intelligence, which can outperform humans across a wide range of disciplines. Virtual reality (VR) will transform the nature of both entertainment and education. Applications include gaming, fully immersive VR movies and training pilots and surgeons. In the case of medical training, fully interactive, accurately modelled specimens that suffer from various ailments and need surgery can be modelled using a VR interface.



Quantum computing: Quantum computers will revolutionise the future of computing. Quantum computers, algorithms and principles differ from computing based on digital circuits as they can process much more information much faster. Potential societal applications include the protection of low-lying areas from flooding, encryption for communication technology, and robust and efficient aircraft with low noise and CO_2 emissions.

Medical geology: This globally emerging discipline explores the connection between human and animal health, and rocks and minerals. An environment's geology influences the chemical make-up – and health – of the life within it. People who live on impoverished soils lack essential trace minerals, which triggers various diseases, while excess chemicals, such as arsenic and fluoride, can cause serious illnesses. Where people live in close contact with the physical environment, medical geology provides a new way of understanding and solving health problems.

2.2.9 Instilling a Responsible Research and Innovation approach to support environmental sustainability and ethical STI

STI can help build a basis for a knowledge-based society and a healthy economy, but it can also cause harm. South Africans should develop a shared normative understanding of what is appropriate for our reality. A South African RRI approach would rest on the following pillars**,** based on the European Union's RRI framework: (i) engagement of all societal actors throughout the process of framing societal challenges and developing joint solutions; (ii) addressing racial and gender transformation to unlock the full potential of South African society; (iii) improving the educational and skills profile of South Africans; (iv) increasing open access to STI; (v) maintaining a high level of ethics in terms of the relevance and acceptability of STI to society and environmental sustainability; and (vi) developing the required governance framework to drive the RRI agenda across the NSI.

2.2.10 Harnessing the Fourth Industrial Revolution

The 4IR is based on three sets of megatrends – physical, digital and biological[14] – and involves a convergence of technologies and disciplines that is having a multisystem impact. Understanding the likely impact of the 4IR, both positive and negative, and preparing for these collectively and strategically will be key to South Africa's future resilience.

For instance, digitisation is expected to change the work environment in innovative ways, as online jobs, crowd sourcing and the ability of general workers and specialists to choose when, where and how long they work, might replace traditional employment models. Technological progress might also leave many people behind, increasing the premium for present and future workers to acquire special skills or education. Retraining and educating today's workers will be crucial to prevent skills mismatches, mass unemployment and growing inequality. Increased investment will be required to drive STI in response to these changes.

2.2.11 Achieving the Sustainable Development Goals

The 17 SDGs adopted by the United Nations General Assembly on 25 September 2015 outline steps to promote economic, environmental and social wellbeing. The ambitious agenda of the goals presents an opportunity to experiment with and foster new forms of innovation for sustainable development. STI plays three main roles in the achievement of the SDGs. First, STI is a goal in itself as a driver of economic growth and job creation. Second, STI is central to the implementation of other goals; e.g. new technological solutions can help address challenges around energy and food security. Third, scientific knowledge can help to both translate the targets associated with the SDGs into national policies and evaluate their impact.

2.2.12 Adopting a circular-economy approach

The idea of a circular economy is linked to the SDGs, but is mentioned separately for its particular relevance as a source of new growth across the globe. The concept implies systemic change and a shift to a low- or zero-waste, resource-efficient society, and entails major changes to methods of production and consumption.[15] Beyond the potential to reduce the use of materials and leave a smaller footprint on the environment, a circular economy would create economic opportunities as new services and business models emerge, transforming the relationship between producer and consumer, and products and their users.

Support for the circular economy would further imply that the environmental impacts of technological developments are understood and taken into consideration in decisions around support for these developments. The environmental footprint of STI-based products and services is also increasingly a factor in consumer's spending decisions, therefore the footprint of STI initiatives should be contained.

Support for the transition to a circular economy in addition to addressing the SDGs will place the country on a development pathway that avoids getting locked-in to resource-intensive industries and practices. This is especially important as we try to balance increased mining efforts with a transition to a more circular economy over the next two decades. A stronger evidence base is required to understand the opportunities that this transition will yield for increased industrialisation.

2.2.13 Deepening African collaboration

The Southern African Development Community (SADC) and African Union (AU) strategies highlight the potential role of STI in achieving the goals of SADC and the broader objective of pan-Africanism. South Africa's linkages with the rest of Africa present opportunities to build and consolidate national, regional and continental systems of innovation. South Africa's cooperation strategies in Africa should therefore prioritise efforts to strengthen its own and partner countries' STI systems. The aim should be to promote and facilitate cross-border research networks, shared technology innovation platforms, mutual learning, an integrated African STI agenda that encourages development and competitiveness, as well as funding partnerships.

South Africa's strategic science diplomacy focus has already recognised STI as an important means of driving the developmental agendas of the AU and SADC. For instance, major minerals beneficiation projects, as highlighted in the SADC Industrialisation Strategy and Roadmap, will depend on cross-border cooperation in energy and transport infrastructure and input supply, and on the development of globally competitive industry sectors.

CHAPTER 3

A COHERENT AND INCLUSIVE NATIONAL SYSTEM OF INNOVATION

CHAPTER 3: A COHERENT AND INCLUSIVE NATIONAL SYSTEM OF INNOVATION

The NSI is central to South Africa's preparation for the future. This chapter focuses on how to improve the coherence and inclusiveness of the NSI, thereby realising its potential to transform society and shape a bright future for all South Africans.

3.1 Progress, gaps and focus areas in developing the NSI

The 1996 White Paper conceptualised the NSI as a "set of functioning institutions, organisations, and policies that interact constructively in the pursuit of a common set of social and economic goals and objectives". It adopted the NSI approach to provide a coherent and integrated framework for national activities, with a focus on innovation rather than just research.

3.1.1 Progress in building the NSI and remaining gaps

Over the past two decades, meaningful progress has been made in establishing a range of institutions that are required for a functional system of innovation, such as the DST, the NRF, the National Advisory Council on Innovation (NACI), the South African National Space Agency (SANSA), TIA and the National Intellectual Property Management Office (NIPMO). Furthermore, legislation governing intellectual property (IP) that emanates from publicly funded R&D has been promulgated.

However, the 2012 Report of the Ministerial Review Committee on the STI Landscape in South Africa found, among others, that the NSI is too small and not yet fully transformed, and that new governance approaches are required to address aspects such as the fragmentation of the STI effort across the NSI, and the aligning of the mandates of Public Research Institutions to national priorities.

Although there has been progress in building government-business collaboration – for example, through increased support for industry via the R&D Tax Incentive and the Sector Innovation Funds – the level of collaboration between all NSI actors needs to increase. In particular, civil society has to be brought into the formal NSI structures and networks, and support for and collaboration with business must be enhanced. A nuanced approach is required to address the unique needs of business sectors, and small and large firms, as well as to create linkages with SOEs.

Relationships between STI-intensive departments have been strengthened. For example, the DST is working closely with the Department of Higher Education and Training (DHET) on human capabilities development, and with the Department of Trade and Industry (*the dti*) on the inclusion of STI in government's plans to re-industrialise the South African economy. However, there is room for improving the incorporation of STI in the strategies of lead departments.

3.1.2 Approach to developing the NSI

South Africa was one of the first emerging countries to formally adopt the NSI approach as a way of thinking more holistically about innovation. However, the 2012 Report of the Ministerial Review Committee found that the NSI concept had not gained sufficient support across government, nor across the NSI. The NSI remains a valuable organising concept, but strong advocacy is required for it to become a shared goal. To this end, steps will be taken to enhance the inclusion of all innovation actors, with an emphasis on mutual learning, policy coherence and collaboration.

Actions in this White Paper to improve the functioning of the NSI relate to the following:

- Bringing more and different actors across society into the NSI fold to make it more inclusive
- Intensifying interactions and partnerships, and enhancing coherence among NSI actors' agendas
- Improving the governance of STI institutions
- Strengthening the monitoring, evaluation and policy learning function

Institutional development highlights

2014 — South African Bioeconomy Strategy

2008 — Space Agency Act, Act 36 of 2008, paving the way for the South African National Space Agency (SANSA)

2008 — technology innovation agency

2008 — Intellectual Property Rights from Publicly Financed Research, Act 51 of 2008, paving way for the National Intellectual Property Management Office (NIPMO)

2008 — TEN-YEAR INNOVATION PLAN

2006 — SA Research Chairs Initiative (SARChI)

2006 — Youth into Science Strategy

2006 — CHPC COMPUTING

2005 — Meraka Open Source Centre, at the CSIR

2005 — SA National Energy Research Institute (SANERI)

2004 — National Strategy for Mathematics, Science and Technology Education

2004 — Indigenous Knowledge Systems (IKS) Policy

2004 — science & technology Department: Science and Technology REPUBLIC OF SOUTH AFRICA

2003 — Advanced Manufacturing Technology Strategy (AMTS)

2003 — SACNASP South African Council for Natural Scientific Professions

2002 — Human Resource Development Strategy

2002 — African Coelecanth Ecosystem Programme (ACEP)

2002 — NATIONAL RESEARCH AND DEVELOPMENT STRATEGY

2001 — SEDA Technology Programme

2001 — Integrated Manufacturing Strategy

2001 — Strategic Plan for SA Agriculture

2001 — National Biotechnology Strategy

2000 — NACI

2000 — African Laser Centre

1999 — NRF National Research Foundation

1998 — Council on Higher Education (CHE)

1996 — WHITE PAPER ON SCIENCE AND TECHNOLOGY

3.2 Policy intent: Improve inclusion and build more linkages across the NSI

> *"We look at science as something very elite, which only a few people can learn. That's just not true. You just have to start early and give kids a foundation. Kids live up, or down, to expectations."*
>
> Mae Jemison (first black woman in space)

The themes of inclusivity and interactivity pervade this White Paper and are addressed in various ways in each chapter. A number of overarching issues are highlighted below.

3.2.1 Inclusion

The NSI concept will be retained as an organising framework, and interactions and partnerships will be encouraged between business, government (including Public Research Institutions), higher education institutions (HEIs) and civil society.

In particular, civil society is recognised as a potential link between the formal and informal parts of the NSI. Civil society serves to strengthen and incentivise collaboration with and between non-governmental organisations, public benefit organisations, publicly funded R&D institutions and science councils in identifying, developing, piloting and disseminating technology for public use. The White Paper will therefore more explicitly bring civil society into the NSI fold.

In further pursuit of an inclusive NSI, and to build on the progress of the past 20 years, improving the representation of black people and women, as well as people with disabilities, will remain a priority at all levels – among undergraduates, people in management positions in research programmes, those in new technology-based firms, and among the professoriate (see Chapters 4 and 5).

Specific measures will be introduced to address the equality and empowerment of women, and to increase cooperation between relevant stakeholders, particularly involving the Department of Women and civil society.

These will include the following:

- Improving gender representation in NSI institutions
- Ensuring gender-sensitive research agendas
- Providing targeted support to women researchers and techno-entrepreneurs
- Developing gender-sensitive monitoring and evaluation mechanisms
- Putting in place mechanisms to unearth bias against women in the NSI and to develop appropriate responses – for instance, to address the risk of gender biases being perpetuated through incorporation into AI applications.

3.2.2 Linkages and partnerships

To increase interactions and collaboration, a more open approach to science, data and innovation will be adopted (see Chapter 5). Formal mechanisms (e.g. sector-based planning instruments) will also be institutionalised to improve interaction among actors. Furthermore, where necessary, effort will be directed at strengthening collaborative R&D instruments such as Centres of Competence, and Sector Innovation Funds.

The partnership objective is mainstreamed in this White Paper to ensure that partnerships permeate the NSI. Requirements for interaction and collaboration will also be built explicitly into the mandates of science councils and HEIs. Additional support for the business sector will be provided to improve collaboration with government (see Chapters 4 and 6).

3.3 Policy intent: Enhance policy coherence and programme coordination in the NSI

3.3.1 Coherence of the NSI at the system level: a Ministerial Structure on STI

A standing ministerial-level STI Structure, chaired by the Minister of Science and Technology, will be established. The Ministerial STI Structure will comprise the relevant STI-intensive departments, the chairpersons of the government clusters, National Treasury and the Department of Planning, Monitoring and Evaluation (DPME). The committee will focus on setting a high-level public agenda for the NSI, approving decadal plans on innovation for South Africa, committing public resources to research and innovation, and reviewing reports on the performance of the NSI over three-year cycles.

Furthermore, the Ministerial STI Structure will lead government in ensuring that the environment for innovation is optimal. Key requirements for building an enabling environment for innovation fall within the ambit of various government departments, such as those dealing with trade and competition policy, immigration and labour, procurement policies and STI. To facilitate policy coherence (and certainty), and thereby encourage long-term private sector investment, all of these departments need to commit to supporting innovation in their policies and programmes. Under the guidance of the Ministerial STI Structure, a whole-of-society innovation approach will be adopted to ensure that the various policies that affect innovation are aligned – establishing, in effect, a South African innovation compact.

The DST will work with the Presidency and National Treasury to facilitate the integration of the STI agenda and plans into government planning, under the auspices of the Ministerial STI Structure.

3.3.2 Ensuring that STI enjoys support at the highest levels of government and business: an annual STI Plenary

To ensure that STI enjoys the required support and stature across government and society, an annual STI Plenary will be convened by the Presidency. The STI Plenary will include business, government, academia and civil society.

The STI Plenary will serve as a collaborative platform. The Ministerial STI Structure will present its high-level STI plans and broad investment strategy for South Africa, as well as report on progress with priority national STI initiatives, for discussion with the NSI partners brought together by the Plenary. Importantly, business will also present its STI requirements and initiatives to the Plenary. The NSI partners will use the STI Plenary to collaboratively reflect on progress with STI initiatives, strategise to address challenges, make recommendations on actions required, and jointly commit resources for the recommended initiatives.

3.3.3 Ensuring that STI agenda setting and planning are based on ongoing stakeholder consultation and expert analysis: a strengthened National Advisory Council on Innovation

To support the Ministerial STI Structure in carrying out its mandate, government recognises that, in addition to the STI Plenary discussed above, there is a need for ongoing stakeholder engagement. NACI will be strengthened to facilitate such engagement, for example, by following up on matters discussed at the STI Plenary. Policy advice from relevant NSI institutions and think-tanks, for instance the Academy of Science of South Africa (ASSAf), the HSRC and the Centres of Excellence, will also be used.

Furthermore, the Ministerial STI Structure will require expert studies and up-to-date performance and environmental information to support its decisions. To advise the Ministerial STI Structure, a strengthened NACI will undertake such studies, and will also function as a monitoring and evaluation (M&E) institution for the NSI.

As part of this expanded mandate, NACI will work with the DST to develop an annual high-level STI investment framework to support the commitment of public resources for STI by the Ministerial STI Structure. It will also do regular environmental scanning to support the agenda-setting function of the Ministerial STI Structure. To help expand its capacity, NACI will work with other sources of technical expertise and data in the NSI, such as the Centres of Excellence and Research Chairs.

Appropriate links will also be established between NACI and the DPME to help integrate STI into transversal government planning by the DPME, and to support funding prioritisation by the DPME and National Treasury (e.g. via the annual Budget Mandate Paper). For instance, based on its new M&E function and on regular environmental scanning, NACI will prepare reports on the implications of geopolitical and demographic shifts, technological changes, environmental sustainability imperatives and other megatrends for government STI planning.

The NACI legislation will be amended to allow for this new role.

3.3.4 Building STI coherence through shared values

Coherence is strengthened when values, information and competencies are shared. To this end, several additional initiatives (discussed throughout the White Paper) will be launched. Examples include e-government, experimentation, upskilling officials in how to facilitate innovation, and increasing the mobility of employees among government, business, science councils and HEIs.

3.3.5 Coherence in critical policy areas

There are areas where it is particularly important to build policy coherence and strong collaborative STI relationships. As recommended by the 2012 Report of the Ministerial Review Committee on the STI Landscape, a number of well-functioning "core" policy nexuses will be established to harmonise and coordinate implementation plans – while taking account of the functions and roles of relevant government clusters. These policy nexuses include the following:

- **Education and skills development:** This nexus will focus on education and training involving the DHET, the DST, the Department of Social Development, the Department of Basic Education and the Department of Labour.
- **Economy:** This nexus will focus on business and enterprise development, involving at least the DST and the departments of Trade and Industry, Economic Development, and Public Enterprises.
- **Social:** The focus of this nexus will be on social development and innovation for inclusive development, involving the DST and departments concerned with social and rural development, and the social security-health-education nexus.

3.3.6 Horizontal and sector/thematic coordination

Innovation has the potential to further modernise sectors of South Africa's economy that can absorb significant labour and contribute to exports. Examples are manufacturing, agriculture and mining, as well as the integrated value chains that link these to the services sector. Therefore, integrated STI planning for priority sectors will be adopted (as was done for Operation Phakisa), resulting in the development of sector STI plans. These will be used to coordinate the research effort across industry, science councils and universities, and to concentrate funding on priority initiatives.

The development and implementation of the sector STI plans will be driven by a committee involving all stakeholders, specifically business and industry associations. The DST, in collaboration with the relevant line department, will manage this committee. The sector STI plans will be supported by financial and non-financial instruments. Sector Innovation Funds, which have been introduced mainly in the agriculture and mining sectors, will be enhanced and expanded to include other priority sectors. Government instruments that are aimed at coordination, such as interministerial committees, the cluster system and memorandums of agreement, will also be employed where appropriate to ensure coherent action across sectors to implement the sector STI plans.

Sector science councils will continue to report to their line departments. This will allow councils to conduct research and promote innovation to further modernise and enhance the competitiveness of relevant sectors. The science councils will increasingly help the country to translate research into products and services, demonstrate the use of knowledge in transforming society, and inform government policy related to their respective sectors.

All STI-intensive departments will be encouraged to set up STI units to facilitate coordination with the DST, industry, and other government departments and organisations, and to improve their STI planning competence. STI units will serve as sites of experimentation and help build a stronger innovation culture across government.

3.4 Policy intent: Strengthen the governance of public NSI institutions

While South African STI institutions are generally well governed, the 2012 Report of the Ministerial Review Committee identified problems such as overlapping mandates and duplication of work, which are depleting the resources of the NSI. Moreover, studies by the DST have shown that, while sector-specific science councils necessarily focus on the needs of sector line departments, there have been instances where the science base of these councils has been neglected. These issues were raised in the 2017 report of the Science, Technology and Innovation Institutional Landscape (STIIL) Review Panel, which recommended that an overarching policy framework be developed that sets out the purpose and governance of public research (and innovation) institutions. The policy framework will further define the role of government departments with respect to the sector-specific science councils that report to them.

Consequently, under the guidance of the DST, such a policy framework will be developed to describe the purpose, functions and governance of Public Research Institutions relevant to national development as guided by the NDP, taking into account the roles of all stakeholders. This will involve clarifying the general purpose of such institutions and the strategic mandates of the DST and other line departments in this respect, and taking into consideration the current capacities of these institutions. Interventions to enhance coordination across different Public Research Institutions and funding agencies will also be developed. The work of the STIIL Review Panel will inform the implementation of the policy framework by way of the decadal plan.

As the mandates of Public Research Institutions are refined according to this policy framework, an appropriate evaluation framework will be put in place to enable objective assessment of their efficiency levels. This will be a prelude to interventions to improve productivity across the focus areas of Public Research Institutions.

The evaluation criteria will include requirements for expanding collaboration with civil society, industry and international partners (e.g. to establish international research institutes). In particular, the requirement to maintain and expand the science base will be incorporated. The ambitions underpinning this White Paper – excellence, inclusion, partnerships and pan-African collaboration – will be built into the evaluation framework.

3.5 Policy intent: Expand the NSI

3.5.1 Establishment of new public STI institutions

If the NSI is to optimally support the NDP's ambitions, additional research institutions will need to be established in areas of strategic importance to South Africa's economic competitiveness, such as the 4IR. The report of the STIIL Review Panel will inform the expansion of the NSI to meet these aims. Regular foresight will also be conducted to help direct this expansion.

3.5.2 Expansion of the scientific knowledge base of the NSI

The DST and DHET will collaborate in implementing overarching measures to expand the science base of the NSI, including increased public investment in scientific research.

The DST will specifically target the expansion of selected strategic, emerging and underdeveloped STI areas in order to improve economic competitiveness through long-term and cross-cutting research, with a specific focus on postgraduate research. As discussed above, the DST will work with line departments and business to develop sector STI plans, which will form the basis for the expansion of research and knowledge creation in priority sectors and relatively mature domains where such activities will lead to increased competitiveness. The DST will further coordinate support for foundational aspects of the NSI, such as human capital development and infrastructure provision related to these STI priority areas.

3.6 Policy intent: Upgrade the M&E and policy capacity of the NSI

Agenda-setting and oversight of the NSI require effective M&E. Policy implementation needs to be improved by monitoring the progress of initiatives and assessing their impact to enable early corrective action. An effective M&E system will keep all stakeholders informed about what is and what is not working. Processes need to be established to ensure that M&E information feeds into policy development and planning.

3.6.1 Institutionalising M&E for the NSI

NACI will be reconfigured to act as the national STI M&E institution, charged with analysing STI information and undertaking work to inform government planning on STI.

Good performance information forms the bedrock of any effective M&E system. NACI will therefore implement knowledge management systems to enhance the analysis of NSI performance and support evaluation work that informs strategies. In this, NACI will draw on the work of existing specialist centres that collect STI-related information. Existing institutional arrangements for data collection (e.g. innovation and R&D surveys) will be maintained and strengthened and, where necessary, expanded.

3.6.2 Skills for M&E in the NSI

The DST and the DPME will cooperate with the higher education sector to expand the NSI's STI-related M&E skills base.

3.6.3 New M&E framework for the NSI

South Africa will intensify its work on international STI measurement guidelines. Particular attention will be given to the SDGs, innovation for inclusive development, and the NDP's objectives.

NACI will convene a high-level forum to develop a framework of indicators to monitor South Africa's NSI performance (see box below). The DST will work with NACI, the DPME and National Treasury to ensure that the framework delivers actionable and comparable information that can inform the management and funding of the NSI initiatives.

A monitoring, evaluation and learning framework for the NSI

This framework will include both quantitative and qualitative measures, as well as benchmarks relative to the rest of the world, covering at least the following:

- Investments/inputs into the NSI (funding sources and spending, people, infrastructure, partnerships/linkages) to indicate how the size, shape and strength of the NSI is evolving.
- The performance of the NSI (innovation activities, including R&D and outputs in terms of knowledge, products, technology transfer and applications).
- The behaviour of NSI actors.
- How the STI system is transforming the economy.
- Responsible Research and Innovation indicators.
- The systemic impact of sustained investment in specific programmes/fields.
- A composite South African Innovation Index will be developed that responds to the specific needs of the country, for example, in terms of skills development, inclusive economic growth and transformation.

Furthermore, to ensure that research remains responsive, a system for evaluating research and reflecting on its impact will be developed and institutionalised.

CHAPTER 4

AN ENABLING INNOVATION ENVIRONMENT

CHAPTER 4: AN ENABLING INNOVATION ENVIRONMENT IN SOUTH AFRICA

Science, technology and innovation have significant transformative potential. For developing countries, STI, and specifically innovation, can support economic growth and employment, create livelihoods at grassroots level, and improve government performance and service delivery. While innovation is not the only factor in faster economic growth, industrialisation and inclusive development, it remains a significant and vital catalyst. Innovation can enhance South Africa's development and improve the quality of life of its citizens. It has the potential to:

- Improve public service delivery and decision making for public policy
- Increase the competitiveness of existing firms
- Form new technology-based firms
- Renew and modernise existing industries
- Develop new and emerging industries
- Exploit new sources of economic growth
- Improve the quality of life of South Africans, at local level, particularly in poor communities
- Promote environmental custodianship

"… this 10th South African Economic Update underscores the large untapped potential of innovation that could be mobilised to advance South Africa's economic and social development goals … Despite widespread fears that automation will result in a loss of jobs, our estimates suggest that greater R&D efforts are likely to create more jobs rather than shed jobs in net terms. The resilience of the South African high-tech manufacturing sector, at a time when lower-tech manufacturing sectors are shedding jobs, illustrates this point. Moreover, innovation can improve the lives of millions of people, particularly poor people, by improving goods and services. Introducing disruptive technologies can lower barriers for competition and expand economic opportunities."

The World Bank, South Africa Economic Update, 2017

4.1 Performance, gaps and innovation focus areas

The McKinsey Global Institute[16] identified five priorities to drive South African growth, namely: advanced manufacturing, infrastructure productivity, natural gas, service exports, and raw and processed agricultural exports. Innovation is fundamental to harnessing these opportunities.

In 2016, the Cornell/INSEAD/World Intellectual Property Organization Global Innovation Index[9] noted that South Africa's strengths lie in market sophistication and investment, as well as some aspects of knowledge absorption and knowledge impact. This progression was mostly due to enhanced competition, better use of talent and an increase in primary school enrollment.

Although knowledge generation does not necessarily lead to innovation, South African patent applications granted in the United States between 1996 and 2016 (an indicator historically regarded as relevant, but becoming increasingly less of a focus as foreign markets change and technology types evolve) have not grown significantly. However, Patent Cooperation Treaty (PCT) applications increased 100-fold over the 20-year period[8]. Over the same period, there were significant increases in trademark applications. Although these represent goods and services in the market, they cannot be viewed as a proxy for innovation performance.

The above statistics are not limited to the public sector, but represent a combination of the public and private sectors where South Africa is recorded as the country of origin. A recent survey[17] covering the period 2008 to 2014 shows progress made by South African HEIs and science councils to advance an innovation agenda. All institutions responding to the survey confirmed that they had established an office of technology transfer. In terms of outputs, the number of disclosures received by these offices more than

doubled during the survey period. Significantly, comparative statistics with the United States reveal that a higher percentage of disclosures were converted into provisional patent applications in South Africa. The number of start-up companies linked to the institutions surveyed quadrupled over the period. Although this increase occurred off a low base, this is a positive development, as is the fact that 75 per cent of these companies were based on publicly financed IP. While the sustainability of these technology start-ups has yet to be proven, this positive statistic suggests growth in the sector and potential to improve the South African Technology Balance of Payments.

Despite these encouraging growth trends, an analysis of the average rate of conversion of IP disclosures to commercialisation/use by these institutions is about 7 per cent[b]. International benchmarking shows that the conversion rate from disclosures to licences for a mature system ranges between 15 and 30 per cent. In terms of this benchmark, the South African public innovation system to still appears be developing.

This chapter identifies aspects of innovation performance to be enhanced via proposals addressing the following:

- Ensure an inclusive innovation system
- Integrate innovation strategies into local and regional economic development planning
- Tap into new sources of innovation and growth
- Use the benefits of innovation to revitalise critical sectors of the South African economy
- Foster an innovation culture across South African society
- Improve collaboration across the NSI to drive innovation
- Harmonise policy instruments to support business, with a specific focus on small and medium enterprises (SMEs)
- Stimulate learning and support the conversion of ideas to commercialisation
- Ensure that South Africa's IP system is in line with development objectives
- Support environmental sustainability

c National Intellectual Property Management Office IP7 database

Innovation snapshot 1996–2016

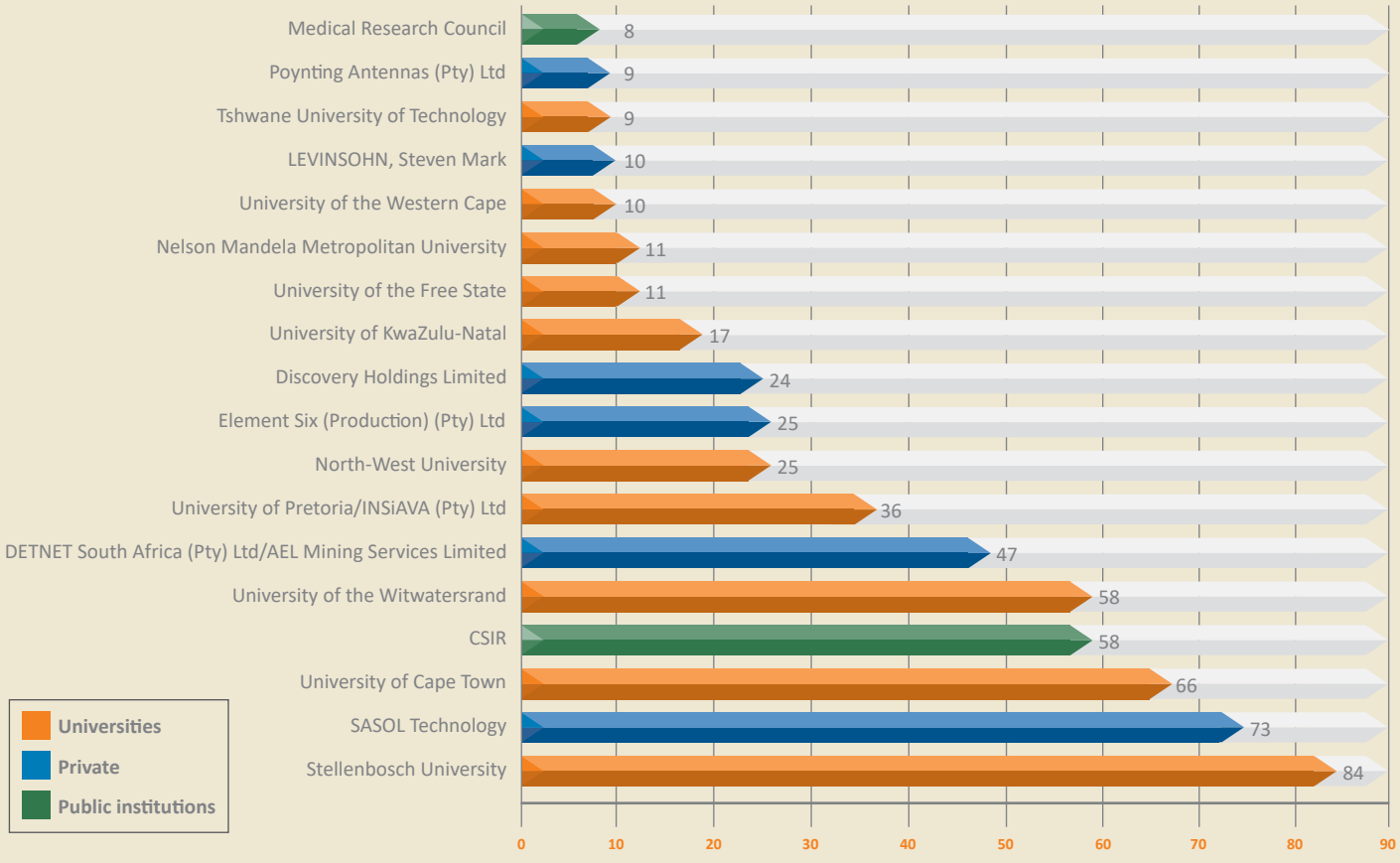
Innovation outputs and outcomes[8]	1996	2016*
US Patent awards (USPTO)	105	144
Patent Cooperation Treaty applications (WIPO)	390	442
Trademark applications (by South African residents)	7 051	19 522
Sales of innovative products (billion)	177	370
High-technology exports as percentage of total exports	5	6

**Official data closest to 1996 and 2016*

75%

Of the technology start-ups created at higher educati on insti tuti ons and science councils between 2008 and 2014, 75% was based on publicly fi nanced R&D[16]

PCT fi lings (2009-2015)[8]*



**Patent Cooperation Treaty*

4.2 Policy intent: Brand South Africa as an innovative country

To brand South Africa as a developer, rather than just a consumer of innovative products and services, the DST will work with relevant role players such as Brand SA and the tourism and communications industries as well as South African embassies.

It is also necessary to strengthen perceptions among citizens that South Africa is an innovative country. Ways of achieving this include international platforms (such as the World Economic Forum, World Intellectual Property Organisation), heralding local innovators, intelligence about South African-made innovative products, processes and services that can be accessed by using a simple application, and exploring the use of a variety of age-appropriate platforms to keep citizens informed.

The establishment of an agency to coordinate system-wide science engagement will be guided by the DST's science engagement strategy. Such an agency will play a critical role in shaping perceptions among South Africans by profiling South African science and science achievements, and demonstrating their contribution to national development and global science, thereby enhancing its public standing.

4.3 Policy intent: Adopt a broader conceptualisation of innovation beyond R&D

The White Paper adopts a broader conceptualisation of innovation and its sources. Recognition that the sources and nature of innovation go beyond R&D-led and radical innovation, and include for instance imitative, frugal and incremental innovation, is critical for a developmental state and emerging economy. Design and engineering activities, on-the-shop-floor attempts to improve productivity, and investment in organisational learning, learning by doing, using and interacting, and observing what others are doing are important activities that drive innovation. Appropriate access mechanisms to the formal intellectual property rights (IPR) registration system will be introduced to ensure that all innovations, regardless of source and nature, may find protection, where relevant and desirable.

The concept of open innovation will be supported, acknowledging that open innovation and protection of IP assets are not mutually exclusive, but can complement each other in strengthening the NSI.

In developing countries, indigenous knowledge and know-how are particularly relevant. The DST will continue with initiatives to strengthen the recording, protection and utilisation of this knowledge, to the benefit of the knowledge holders and the country.

Previously, focus resided on the supply-side of innovation with less of a market-driven approach. This White Paper has a strong focus on addressing the needs of the business sector and thus has an increasing demand-side focus, all the while noting that innovation may result from a combination of both demand- and supply-side driven activities. Innovation for inclusive development and frugal innovation are essential to meet societal needs at grassroots level. The DST will continue to champion innovation for inclusive development, especially in the context of developing and empowering both urban and rural communities.

The involvement of the business sector, civil society and academia in support of learning and innovation will be incentivised.

4.4 Policy intent: Adopt a whole-of- society approach to innovation

As discussed in Chapter 3, the White Paper aims to enhance policy coherence and programme coordination in the NSI. This will require formal mechanisms such as the proposed Ministerial STI Structure discussed in Chapter 3, as well as infusing the whole of government and society with an innovation culture, and aligning policies (e.g. immigration and competition policies) that impact on innovation – developing a national innovation compact.

In addition to the general innovation compact and the policy nexuses around critical policy areas, there is a need to strengthen the role of STI policy in enhancing the competitiveness of firms, sustaining high growth in the productive and services sectors, and supporting the development of new firms and industries. The NSI currently contributes to the Industrial Policy Action Plan (IPAP), but there is room for the DST, science councils and relevant public entities across the NSI to achieve greater impact. The current contributions of the NSI to IPAP will therefore be deepened to ensure that the programmes of science councils are aligned with priority industrial sectors, as well as with new growth opportunities identified by, among others, the Industrial Development Corporation (IDC). STI will be integrated into future frameworks and legislation to advance national industrial and economic objectives. An important step towards aligning STI and industrial policy will be the establishment of the proposed policy nexus on trade and investment.

4.5 Policy intent: Use public procurement as a vehicle to further innovation

New and complex technology products (e.g. for satellites or civilian aircraft) usually require "launch customers" to help establish customer and market confidence in the product, as well as downstream maintenance and support. In most instances, such programmes rely on a "lead market" in the form of government procurement to help position the product for future sustainability.

Public procurement can also help ensure the sustainability of new and transformed broad-based black economic empowerment firms in or outside the existing supply chains of SOEs, as well as increase the number of SMEs in these supply chains.

Therefore, strategies will be developed to ensure that government is the first customer when it comes to using locally developed technologies. Government's Infrastructure Build Programme is one example where locally developed technologies can be supported and tested.

A supportive legislative environment will be ensured, and where the success of new industry development efforts (e.g. in the fields of medical devices, ICT and environmental technologies) depends on government procurement, a formal strategy will be jointly developed by the DST and the government department responsible for procurement.

The role of the Public Finance Management Act, 1999 in R&D-related activities will be made clear (e.g. to differentiate collaboration and partnerships from procurement-related activities). Technology conditionality will be built into large procurement contracts (e.g. fleet procurement for rail) to ensure that South Africa acquires the latest technologies and that there is technology transfer in the localisation process. The Competitive Supplier Development Programme, championed by SOEs, will also be expanded to include local technologies.

4.6 Policy intent: Increase support for and collaboration with the business sector

4.6.1 Supporting business R&D needs

Public funding of private sector, needs-based R&D will be increased. A 2014 study by National Treasury[18] on the effectiveness of South African science council partnerships with industry found that there was significant room for improving the focus of research on industry needs. Therefore, government will continue to incentivise partnerships among business, HEIs and Public Research Institutions. The incentive regime will be monitored to ensure the appropriate balance between direct and indirect support to business, with the understanding that both are needed. Furthermore, the mining R&D hub and other instruments to support the private sector will be strengthened.

4.6.2 Targeted technology development and deployment to support firms

In line with national priorities, sectors (and potentially sub-sectors) in which South Africa has a competitive advantage will be identified in collaboration with business, with the aim of targeting public support for R&D-led industry development and encouraging high-technology exports. The DST will also work with business to identify opportunities to acquire technologies from abroad when appropriate. This information will inform R&D planning and funding, as well as procurement strategies at national, provincial and local levels.

Efforts to localise and diffuse technologies will be intensified through existing and new technology-based support interventions (including the Technology Stations Programme and the Technology Localisation Programme). Sectors with growth potential will be targeted for funding support, e.g. through expanded sector innovation funds.

4.6.3 Global value chains

The growing importance of complex global value chains provides opportunities to attract foreign direct investment and associated benefits, including technology transfer. The extent to which a country will benefit from these global value chains depends on its absorptive capacity and the level of its R&D stock. Economies with higher levels of R&D capacity are more likely to maximise technology spill-overs and ensure greater technology diffusion. The absorptive capacity of enterprises may be further increased by supporting innovation and technology transfer activities.

The DST will work with relevant NSI partners to intensify support for technology transfer and absorption. This will include supporting early adopters, developing R&D capacity within firms, integrating local companies or sectors into global value chains, supporting clustering and agglomeration in key sectors, and offering incentives to attract foreign direct investment.

4.6.4 Specific support for SMEs

Besides identified challenges such as access to finance and credit, and inadequate infrastructure, SMEs often struggle to innovate, perform R&D, access knowledge and absorb new technology. Therefore, the current model for providing broad-based support to SMEs (e.g. through walk-in support at technology stations) will be scaled up to ensure that even more SMEs can access services, equipment and support in product/technology commercialisation.

SMEs play an important role in the industrial value chain, and initiatives aimed at developing and/or upgrading them as suppliers to government and larger firms will be scaled up. Tailored technological support (e.g. through technology assistance packages) will be intensified to enable SMEs to meet the technical and commercial requirements for becoming qualified suppliers, both locally and globally. Links between SMEs and larger firms will be incentivised to diffuse technology and improve the ability of SMEs to innovate.

A comprehensive support package for SMEs in priority focus areas will be developed collaboratively by the relevant government departments. The existing instruments (e.g. those of the DST, *the dti*, the Department of Small Business Development, the Economic Development Department and the Department of Public Enterprises) will be aligned to support SMEs and emerging industries. As an example, both technological and other innovation support to SMEs will be provided to develop new markets or to support systems innovation. New support instruments (e.g. an R&D voucher scheme for eligible firms to cash in with registered R&D service providers) will be introduced. The maturation and growth of technology-intensive SMEs (e.g. university spin-out companies, or niche SMEs in high-technology sectors) should be facilitated through the establishment of more innovation hubs providing standard support and coaching/mentoring services, focused on market and enterprise development, including intellectual property strategy development and access strategies to markets. In addition, consideration will be given to regulatory hurdles, as well as burdensome administration and legal requirements.

In pursuit of an inclusive innovation system, particular attention will be given to supporting SMEs in informal settlements, rural areas and cooperatives. Futhermore, to support the transformation of the demographic ownership profile of technology-based firms (and in particular SMEs) in South Africa, the DST will develop guidelines, in cooperation with relevant NSI partners, to use intellectual property from publicly funded R&D under appropriate conditions to support women and black entrepreneurs when such intellectual property is commercialised.

4.6.5 Revitalising the role of SOEs in innovation

State-owned enterprises are important actors in the South African economy, given their role in providing infrastructure and services (e.g. energy, water, transport and communications). SOEs serve as clusters of expertise and have important linkages to various parts of the economy – as anchor institutions in their sectors, as channels for international knowledge spill-overs, and as hubs for human capital development. SOEs are users, funders, performers and collaborators in R&D and technological innovation. Ten such enterprises account for about 99 per cent of all SOE R&D. However, recent data show a decline in SOE expenditure on R&D (from a peak in 2008/09)[10].

To turn this trend around, the following strategies will be adopted:

- The implementation of the White Paper and the next iterations of IPAP will require explicit plans on how the R&D programmes of SOEs will advance South Africa's R&D capability, technological innovation performance and industrialisation. A mechanism will be adopted, across all departments responsible for SOEs, for improving the coordination of long-term planning and funding for R&D programmes in SOEs.
- A national flagship programme directed at closing the engineering and design gap should be established, in line with national imperatives for human capital development and transformation. This will require existing programmes to be revised in order to strengthen the links between interventions for high-end skills and those meant to expand technical/vocational competencies required by SOEs relating to design, engineering and small enterprise development.
- Conditions will be created to encourage SOEs to continue R&D partnerships among themselves and with universities, science councils and the local business sector. The aim is to leverage broader knowledge and innovation networks for the benefit of the country. SOEs need a much larger base from which to draw research, engineering and other technical expertise.
- Domestic technological knowledge gaps require the sourcing of knowledge and R&D services from abroad. For such international sourcing arrangements to be beneficial, they should be linked to a particular strategy for technology transfer and/or localisation in cases where domestic capability is inadequate. Along with the "smart buyer" principles, strategic sourcing from abroad should be linked to national imperatives for technology accumulation, so that, in the medium to long term, SOEs in specific technology spaces will buy from local service providers and institutions rather than from foreign firms.

4.7 Policy intent: Support commercialisation of publicly funded intellectual property

Offices of Technology Transfer in higher education and science councils play an important role in identifying and protecting new technologies, sourcing licensing partners, and establishing firms to market new technologies.

Support for Offices of Technology Transfer will be increased through existing instruments, initially to develop capacity, and, over time, on the basis of the quantity and quality of outputs. To support the transformation of higher education, the type of government support to these offices will be differentiated according to the research intensity and technology transfer maturity of the institution in question.

4.8 Policy intent: Ensuring that legislation on intellectual property rights from publicly financed research and development responds to the changing policy context

Based on the current review of the Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act), which came into effect on 2 August 2010, as well as of its implementing office, NIPMO, aspects that will be addressed include the expanded impact of Offices of Technology Transfer, enhanced commercialisation of intellectual property, support for openness, enhanced support for SMEs, and the appropriate structure and positioning of NIPMO in the NSI.

4.9 Policy intent: Increase the spatial footprint of innovation in South Africa

Historically speaking, STI policy has mostly focused on R&D, perpetuating a system that has not optimally contributed to improving local economies. Furthermore, innovation-support institutions remain concentrated in the major metropolitan areas.

Improved spatial inclusivity will receive attention through a stronger role for innovation in rural development, and support for regional and local systems of innovation. These approaches will bring actors such as local government, regional development agencies, local chambers of commerce and community-based entrepreneurs into the regional and local innovation systems.

Local and provincial growth and development strategies will include innovation plans. "Innovation hubs" will be expanded to enhance provincial growth and development strategies, and promote provincial technology competencies.

As part of these, cooperative research centres (involving industry, science councils and HEIs) and local innovation ecosystems will be developed, where appropriate.

Furthermore, a "no wrong door" policy will be adopted across government, particularly at local and provincial government level, which will see innovation-related enquiries routed efficiently to provide the required information or support. This intervention could initially be implemented through an appropriately located hotline or information kiosks.

Local innovation ecosystems

Such ecosystems may consist of the following:

- Walk-in innovation centres (preferably established at accessible facilities such as post offices)
- Reconstructed living labs (core activities of the living lab are skills training, community development, social and disruptive innovation, mobile and internet solutions, social enterprise incubation, impact investing and social franchising)
- Local incubators (preferably attached to an institution with a technology station, and mobile application laboratories)
- Science centres
- Where necessary, product certification facilities

4.10 Policy intent: Support innovation for social and grassroots innovation

Innovation policy should enable all sectors of society to equitably access knowledge infrastructure and participate in creating and actualising innovation opportunities, and ensure that all individuals share in the benefits of innovation.

> *"Actions in support of broad-based and grassroots innovation and entrepreneurship can strongly sustain a process of inclusive growth."*
>
> The Organisation for Economic Cooperation and Development (OECD), 2018

There is growing interest in broadening the concept of innovation to include innovation for inclusive development, i.e. innovation for societal benefit and the public good. Globally, there is greater activity and benefit in bottom-up, grassroots, distributed and local innovation. The public sector needs to become an enabler of innovation for inclusive development. This can be done, for example, by strengthening ICT applications for e-government, e-learning and e-health, and can include co-creation and user-led initiatives using socially innovative methods such as living labs. The approach will involve widening the range of stakeholders and deepening their engagement in deliberative planning.

Over the past decade, grassroots innovation, as a particular priority within the broader innovation for inclusive development agenda, has gained prominence in STI initiatives, both globally and in South Africa. Support for grassroots innovation will be a planning priority in all relevant initiatives. It will be funded accordingly, and monitored in all relevant M&E frameworks. Developers of local economic development plans, as well as provincial growth and development strategies, will be encouraged to include support for grassroots innovation, and innovation scouting in plans.

A multi-tiered package will provide support appropriate to the level of development of grassroots innovators. Mentorship will be incentivised through a government-funded voucher system and awards, and complemented by corporate social responsibility programmes. Grassroots innovators will be capacitated and supported by, for example, supplier development programmes.

Government will further leverage the potential of publicly funded IP to support grassroots innovation. South Africa will develop a country-specific, second-tier patent system, offering a cheap, no-examination protection regime for technical inventions that would not usually fulfil the strict patentability criteria. With the introduction of a substantive patent search and examination system at the Companies and Intellectual Property Commission (CIPC), a preferential accelerated patent examination system will be introduced for SMEs, broad-based black economic empowerment firms, previously disadvantaged individuals, and young innovators, depending on criteria such as the involvement of start-up firms.

Civil society will also be assisted in its many roles, including as a source of innovation, information, mentorship and networks. Efforts will be made to strategically link this sector to NSI actors such as technology stations and science councils. Its function as innovation intermediary between government and grassroots innovators will be strengthened. Training packages will be developed, using social media and digital technologies, to equip civil society with innovation development skills. Collaboration within the civil society sector will be strengthened and incentivised, including partnerships with publicly funded R&D institutions and science councils in piloting and distributing technology for public benefit.

Finally, as part of its drive to increase funding to the NSI, and to target investments to help address national priorities, government will work with NSI partners to develop an appropriate funding instrument for grassroots innovation. The objective will be to target both neglected and marginalised groups of innovators, including the youth, as well as to support innovations with high social returns that are unlikely to gain traction because of market and other failures.

4.11 Policy intent: Exploit new sources of growth

4.11.1 Support for emerging industries

To facilitate sustained and improved competitiveness, particularly in the context of the 4IR, the ability to incubate and support emerging industries is crucial.

Therefore, to maximise the growth of R&D-intensive and non-R&D-intensive emerging industries, joint planning and co-investment will be facilitated through improved partnering between firms, universities, science councils and government. Associated support initiatives with large business enterprises, SOEs and SMEs will be prioritised for government support.

4.11.2 Greening the economy

The current economic crisis and climate change considerations present opportunities to transition to a low-carbon economy by accelerating eco-innovation. Policy makers are also increasingly paying attention to the need for radical and systemic policy innovations as a powerful lever in enabling a long-term transition towards a greener economy. Leading firms and entrepreneurs are looking to create and capture value from new business models that benefit not only the economy, but the environment as well.

South Africa is signatory to the Paris Agreement and the SDGs. To meet these goals will not only require government interventions, but also close cooperation with industry. A transition to a greener economy (of which circular economy is a part) will address the reduction in greenhouse gas emissions, create new markets to assist in the transition to jobs of the future and keep South African industry relevant to our trading partners. As trading partners like China and regions like the European Union have already started implementing circular economy policies, South Africa has to be prepared for this new economic paradigm. Research, development and innovation (RDI) is crucial as it will provide the evidence base on which industrial, environmental and societal decisions will be made to remain relevant in a changing world to meet the Paris Agreement and to keep the global temperature increase below 2 degrees. The DST will therefore work with the relevant NSI partners to develop an STI approach to greening the economy, as well as to fund the required research and capabilities.

In addition, the economic opportunities of greening the economy will be harnessed to provide jobs. It is estimated that green innovation in South Africa can lead to the creation of around 400 000 jobs[5].

4.11.3 A focus on ICT

In collaboration with its NSI partners, government will shape the future of the digital economy and society by cultivating a shared, trusted digital environment that drives inclusion, economic development and social progress.

Cabinet approved the ICT Research Development and Innovation Roadmap, entitled “Our digital future”, in 2013. The Roadmap identifies several strategic domains, including broadband services and infrastructure, ICT for development, sustainability and the environment, grand science, industry applications and the services economy. It is underpinned by up-to-date research on South Africa’s capabilities and development potential in the ICT sector, and aims to enable South Africa to exploit market opportunities in areas such as future wireless technologies, e-inclusion, green ICT, geospatial applications, biomedical sciences, smart infrastructure, mining, manufacturing, asset management, m-health, e-services, education, outsourcing and payment solutions.

The development of the domestic high-technology ICT sector will be prioritised within these domains. The overarching objectives are collaborative planning on ICT (involving government, business and civil society), a focus on universal access to ICT (with broadband as an urgent priority), the development of e-government and pro-poor ICT policies, and the positioning of South Africa to benefit from the 4IR.

The big data revolution is set to accelerate and a period of significant disruption is anticipated in the upcoming decades in which the impact of digital technologies will radically transform the global economy, the research landscape, and policy and decision making. This will affect the quality of life and lifestyle of people and enable the addressing of global challenges such as energy, health and climate change in novel ways.

In today's connected world, everyone benefits from advanced cyber-defence programmes. At an individual level, a cybersecurity attack can result in anything from identity theft to extortion attempts. Everyone relies on critical infrastructure like power plants, hospitals and financial service companies. Securing these and other organisations is essential to keeping our society functioning. Therefore, new policies and frameworks are necessary to protect individual privacy and clarify the roles and responsibilities of various actors (owner, custodian, host, etc.) involved in the creation and use of big data. A coherent approach incorporating related initiatives (such as the development of an Open Science Policy), as well as regulatory entities (e.g. NIPMO and other government departments) would be needed to develop frameworks and policies that harmonise openness (of data and science) with privacy and security.

There are a number of South African developments and competitiveness requirements (e.g. SKA, mining modernisation and geological exploration) that require world-leading ICT systems and capabilities (e.g. big data, AI, fast connectivity and positioning, advanced signal processing, embedded systems, large numbers of sensors and software layers). Coordination and collaborative planning between government and the private sector is therefore essential to help ensure that South Africa participates in the broad development of these technologies (tailored for our requirements) rather than merely adopting these technologies or solutions.

To enable collaborative planning, a policy nexus that encompasses the DST and relevant departments such as the Department of Telecommunications and Postal Services (DTPS) will, among other things:

- Drive the digital society in South Africa
- Use big data at local government level to create jobs
- Use open data to transform local government services
- Create localised ICT hubs as Centres of Excellence
- Modernise local government services
- Use e-government services to transform local government services
- Prioritise cybersecurity resilience
- Support emerging start-up digital enterprises
- Address the high cost of broadband in South Africa

4.11.4 The Fourth Industrial Revolution

As discussed in Chapter 2, the 4IR involves a convergence of different technologies. This global trend has profound implications for South Africa and Africa. For instance, there are opportunities for increased economic growth through the modernisation of existing industries, but also a need to upskill and re-skill the workforce for new technological job opportunities, as technological changes will have a significant effect on the world of work. Various initiatives are under way at policy, industry and technology level, and there has been engagement with international stakeholders such as the World Economic Forum. However, a coordinated national policy response is required, including considerable support and actions from policy makers.

If the full potential of the 4IR is to be realised, new institutional arrangements will be needed to manage convergence, as will expanded R&D aimed at the enabling technologies. These arrangements must support research at universities in disciplines relating to current base technologies, while developing knowledge in new areas.

A high-level national collaborative platform will be established to position South Africa to respond to the opportunities and risks flowing from the 4IR. The platform will help identify and support priority STI programmes linked to the 4IR. This platform will contribute to the development of a South African strategy on AI. South Africa's contribution and participation in developing AI knowledge, technologies and applications, in the context of strengthening the NSI and to help mitigate potential negative impacts from AI, will be captured in a South African strategy for AI.

The existing national initiatives on AI (e.g. the Centre for AI Research) will be expanded and ways of upskilling and re-training existing professionals will be explored. Leveraging AI in a number of sectors (e.g. geological exploration) has the ability to materially change the way research is performed. The concept of applying AI concepts (e.g. reskilling mining engineers in AI to improve exploration, mining and processing)

per industrial sector will be investigated. A regulatory framework addressing issues such as the impact of the fast-changing ICT/telecommunication and AI environment needs to be implemented in a flexible manner to address challenges as they arise.

The collaborative platform will be managed by a steering committee that includes relevant departments such as the DST, *the dti* and the DTPS, among others. Business and labour will also be included in the steering committee, as will the Department of Labour, to focus on strategies to address potential job losses in affected industries.

4.12 Policy intent: Innovation to revitalise existing sectors

South Africa is one of the richest countries in the world in terms of mineral deposits. Mining has been one of the primary contributions to South Africa's GDP. Despite the long history of mining, it is once again viewed as a sunrise industry. However, in order to address the challenges of mining deeper, and narrower ore bodies, with increased safety, a comprehensive mining research, extraction research, development and innovation (SAMERDI) strategy has been launched. In addition to developing technologies for increased safety and mine life (sustainability), there is a strong focus on developing the next generation of mining equipment (strengthening manufacturing in South Africa).

In addition to the focus on substantially enhanced mining and equipment technologies, there is also an increased focus on community development and environmental protection. As an example, diesel underground (linked to excessive noise and exhaust pollution) will be replaced by cleaner technologies.

Modern mining in South Africa will be substantially more automated, enabled by sensors on humans, equipment and the mining environment. This will improve safety, but will also allow more real-time monitoring of the physical environment, production rate and overall process statistics.

Despite the continued emphasis on ICT and the growing GDP contribution of the services sector, manufacturing remains a key sector due to the associated high employment and value multipliers. In addition, manufacturing is a natural market demand lever for minerals beneficiation and locally produced metals. The DST will continue to fund incremental and radical technology development (in coordination with *the dti*) aimed at enhancing the short- and medium-term competitiveness of the local manufacturing sector. The continued capacity building and technology development in additive manufacturing will be expanded, resulting in the establishment of new industry segments.

Agriculture is important for food security, exports and absorbing labour. Agriculture will be modernised to increase global competitiveness (for instance with precision agriculture approaches). The government, as part of its broad response to the 4IR, will design instruments to re-skill workers, where appropriate.

4.13 Policy intent: Strengthen government's role as an enabler for innovation

Governments often act to address market failures, taking the lead in making high-risk investments[19] in, for instance, information technology (United States), biotechnology (United Kingdom), nanotechnology (Russia) and green technology (Spain). The private sector only invests after government has made the initial high-risk investment. However, for government to play this role, it will need to develop a more innovation-enabling mindset and culture.

To help entrench a culture of innovation in government, the DST will work with the Centre for Public Service Innovation (CPSI) and other relevant national, provincial and local agencies on strengthening the innovation mindset of public servants, using awards to motivate them and celebrating role models. More specifically, the DST will work with the CPSI to increase service delivery through initiatives such as e-government.

Furthermore, as experimentation is vital for improving service delivery, government will invest in demonstration projects and support risk procurement where appropriate. A critical dimension of initiatives to encourage experimentation will be to stimulate co-learning and co-creation among researchers, officials and users/buyers of technology. Civil society will also be empowered to play a stronger role in planning and implementing projects that lend themselves to experimentation.

No ambitious STI policy agenda, such as that set out in this White Paper, can be sustained without an enabling culture across society. An innovation culture thrives on inspiration, creativity, collaboration, problem-solving and risk-taking. It enables us to pursue ideas and learn from taking risks and making mistakes. Adopting this culture will require a shift to encourage South Africans in business, government and civil society to take risks on smart ideas. Establishing such a culture will take time. It will need to be nurtured and reinforced by a range of initiatives.

An innovation mindset needs to be fostered from the early stages of childhood. Therefore, curiosity, creativity, critical thinking, the ability to learn from failure, and entrepreneurial skills will feature strongly in programmes and curricula at various stages: in early childhood development, at school, and during post-school education and training. For example, the role of the arts in stimulating children's creativity will be strengthened.

The DST will therefore work with relevant government departments, such as the DHET, the Department of Basic Education and the Department of Social Development, to develop programmes to build an innovation mindset from early childhood. Successful innovators, mentors and entrepreneurs will be celebrated as role models. Initiatives to achieve this will include advocacy and awareness, awards across society at all levels of government, and exchange and incubation programmes. Particular attention will be paid to equity considerations, ensuring that people who seldom have the opportunity to become innovators – such as rural youth and women, people with disabilities and those with low levels of formal education – are coached, mentored and celebrated. These initiatives will be implemented as a partnership between government, the private sector, higher education and civil society.

CHAPTER 5

INCREASED HUMAN CAPABILITIES AND AN EXPANDED KNOWLEDGE ENTERPRISE

CHAPTER 5: INCREASED HUMAN CAPABILITIES AND AN EXPANDED KNOWLEDGE ENTERPRISE

The South African research system is diverse, with pockets of excellence, for instance in the biomedical field. This chapter outlines how outputs can be reoriented and increased by expanding and transforming the research system in response to a rapidly changing and increasingly technologically advanced world. The application of research to help address health challenges and to grow understanding of how social groups interact with each other are but two examples of how knowledge from different fields (in this case in the natural and social sciences) interacts to increase understanding of and help address South Africa's long-standing and grave challenges. However, research and the creation of knowledge have far more than just instrumental value. Research also contributes to the development of an empowered and thinking citizenry that functions effectively, creatively and ethically as part of a democratic society.

To achieve these aims will require attention to the supply of high-level skills, the openness of the system, the diffusion of knowledge, and access to scientific infrastructure. Linkages between science and society, including public engagement, science diplomacy and internationalisation, are central to these ambitions.

5.1 Progress, gaps and approaches to expanding capabilities and knowledge

5.1.1 Research and the next generation of researchers[8]

South Africa has a strong and growing science and technology system, including world-class universities. In 2014, total university enrollments (two-thirds contact and one-third distance) approached 1 million, with postgraduate students constituting about 16 per cent of total enrollments (the NDP target is 25 per cent). Foreign students accounted for some 60 000 enrollments, mostly at postgraduate level. Undergraduate science, engineering and technology (SET) enrollment remains close to 30 per cent of the total. Several flagship programmes to address the shortage of researchers have been introduced, including SARChI and the Centres of Excellence. However, more programmes are needed. The DST has been working to increase the number of researchers by providing comprehensive bursary funding that compares favourably with entry-level salaries at each qualification level. The introduction of the Comprehensive Bursary Programme to target honours students improved the retention of postgraduate students.

Doctoral awards have more than doubled in the period 2002–2014. While the number of PhDs has increased to 41.8 per million of the population in 2015, it is still lower than the NDP target of 100 per million by 2030. An important driver in the production of doctoral graduates is the number of PhD-qualified staff at universities. By 2014, 43 per cent of research and teaching staff at universities had a PhD, which, although a substantial increase, is still far off the 75 per cent target set in the NDP. While the number of PhD-qualified staff increased by 65 per cent, the number of enrolled students increased by 350 per cent, leading to a supervisory bottleneck. This has been partly addressed through the increased number of postdoctoral students. For the NDP targets for PhD productivity and PhD-qualified lecturers to be reached, more high-quality matric passes in science and mathematics are needed.

In 2013, the Minister of Science and Technology approved a set of equity-based guidelines for bursaries and scholarships. These guidelines have contributed to transforming the postgraduate cohort. Although there is significant room for improvement, especially at the higher levels in the research system (discussed below), South Africa's gender-equity performance is better than many more advanced countries. Recent survey data reveals that women researchers made up 44.3 per cent of total researchers in 2014/15, which is a higher participation rate than that of many developed countries. Research outputs by historically disadvantaged groups are also growing; the share of scientific papers published by black authors increased from 10 per cent to 32 per cent between 1998 and 2014, while that of women authors increased from 20 per cent to 32 per cent over the same period. However, racial and gender inequalities do persist. Furthermore, the number of full-time equivalent researchers in the system has not increased significantly from 2005/06, the date of the earliest available data.

Whole-count research publications increased from 5 540 in 1994 to 15 542 in 2014, while the per-capita research output doubled between 2001 (0.39) and 2014 (0.84). The revised university funding formula of 2003 has had a positive effect on research outputs.

Despite the progress discussed above, South Africa's research system is restricted by inherited structural inequities, as reflected in the differing capacities of our institutions. Research performance varies greatly across different sectors (universities, industry and science councils), and within different institutions in the same sector. The higher education sector is responsible for nearly 90 per cent of all research publications, compared to about 8 per cent for all the science councils and national research facilities combined. Within the university sector, five universities produce more than 60 per cent of research outputs from the sector.

The aim of the National Plan for Higher Education[20] was to transform the higher education system, bringing about institutional mergers to eliminate historical disparities, and the differentiation of universities according to mission. Despite the plan, there are performance gaps between universities and universities of technology, and between historically advantaged and disadvantaged institutions. For example, three-quarters of the country's PhD graduates are produced by only six of its universities.

South Africa has active global knowledge partnerships and long-standing collaborations with leading science nations, resulting in the increasing international mobility (inward and outward) of researchers. South African researchers, through the work of the DST, have formalised access to global research infrastructure (e.g. the particle physics laboratory operated by the European Organisation for Nuclear Research). A recent bibliometric assessment of South African papers shows that more than 50 per cent was co-authored with international partners[21, 22].

There are international concerns about the diminishing role of the humanities and social sciences in academia and the wider knowledge sphere. While, in South Africa, the evidence does not support concerns about the prioritisation of the natural, physical and engineering sciences over the humanities and social sciences, it is necessary for the latter to play a stronger role in the science system, and not only in a narrow utilitarian sense or as mere supporting disciplines. The challenge is to incorporate the knowledge and insight of the humanities and social sciences into research and innovation in the natural, physical and engineering sciences.

5.1.2 Infrastructure

Through the South African Research Infrastructure Roadmap and the Innovation Infrastructure Roadmap, there has been notable progress in all categories of research and innovation infrastructure. Five National Facilities and one major project – the MeerKAT/SKA Radio Telescope – have been established, as have national preclinical facilities at HEIs. In terms of high-end infrastructure, a multipurpose fluorochemicals pilot plant, a titanium pilot plant and several technology demonstrators are in operation.

Cyber infrastructure has also advanced through the Centre for High Performance Computing, the South African National Research Network (SANReN), the Data-intensive Research Initiative of South Africa (DIRISA), and the National Integrated Cyber infrastructure System. The ICT RDI Roadmap is being implemented.

There are also international collaborations involving, for example, the European Organisation for Nuclear Research, the Planck Telescope, large health science projects, the MeerKAT/SKA, the Southern African Large Telescope, and the iThemba Laboratory for Accelerator-based Sciences.

5.1.3 Focus areas for expanding the knowledge enterprise

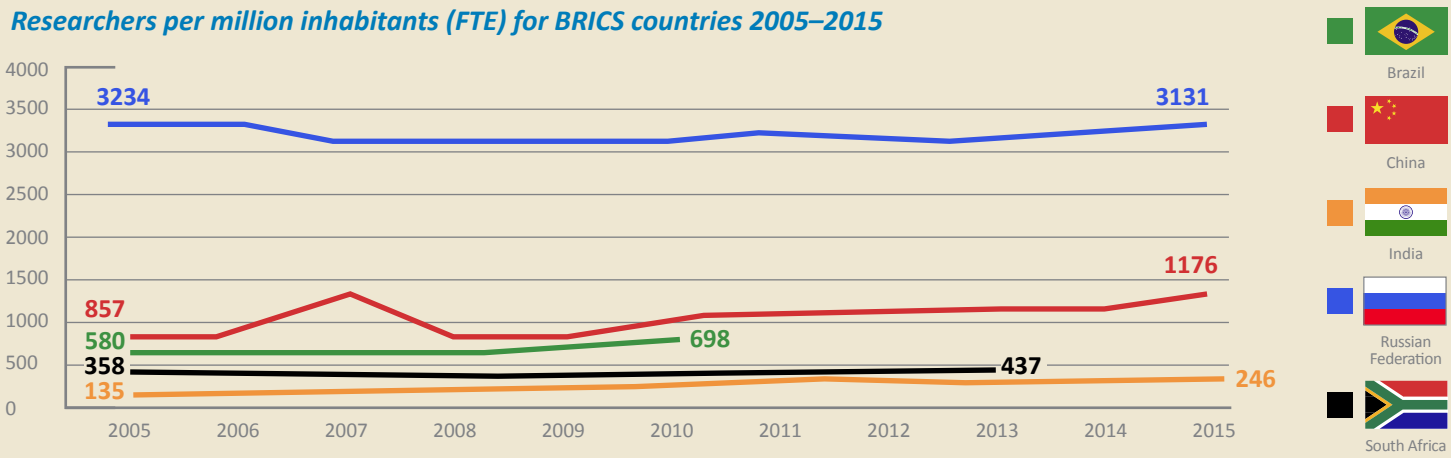
It is clear from the above that, despite good progress, the full potential of South Africa's research system and its human resources has yet to be realised. In order to achieve this, it is necessary to do the following:

- Increase research outputs
- Expand and transform the research system and facilitate knowledge diffusion
- Ensure an open, responsive and diverse knowledge system
- Upgrade knowledge and innovation infrastructure
- Develop skills for the economy
- Strengthen international cooperation and science diplomacy
- Create a culture of innovation and science literacy

Expanding knowledge and human capabilities

South Africa has a strong and growing research system, including world-class universities. Significant progress was made with for instance total university enrollments, doctoral graduations, and research and teaching staff with PhDs. The number of black enrolled students increased by 350%. Per capita research output doubled between 2001 (0.39) and 2014 (0.84), and research output tripled between 1994 (5 540) and 2014 (15 542).

Researchers per million inhabitants (FTE) for BRICS countries 2005–2015



42%

In 2018[21] only *42%* of senior lecturers and *25%* of lecturers could be categorised as actively publishing.

41.8/m

Against an NDP target of 100 PhDs per million by 2030, by 2014 the number of PhDs per million people had grown to *41.8* – a significant increase, but still far off the target.

100%

Between 1994 and 2014 the per-capita research output doubled. Within the university sector, only 5 universities produce more than *60%* of the research outputs from that sector.

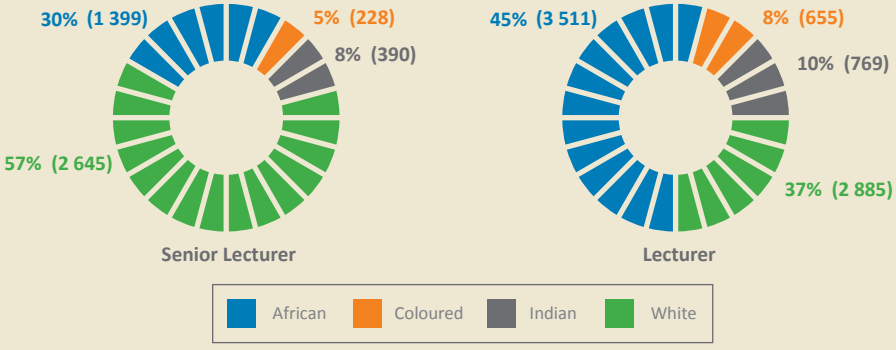
32%

The share of publications by women authors increased from *20%* to *32%* from 1998 to 2014.

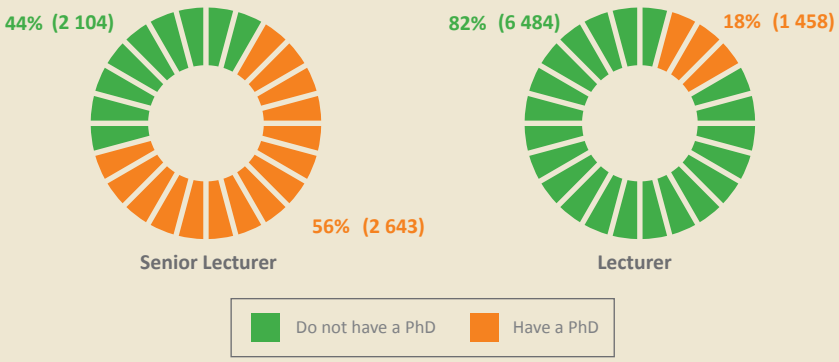
Composition of senior lecturers and lecturers according to gender, race and qualification, 2017[23]

Breakdown according to gender

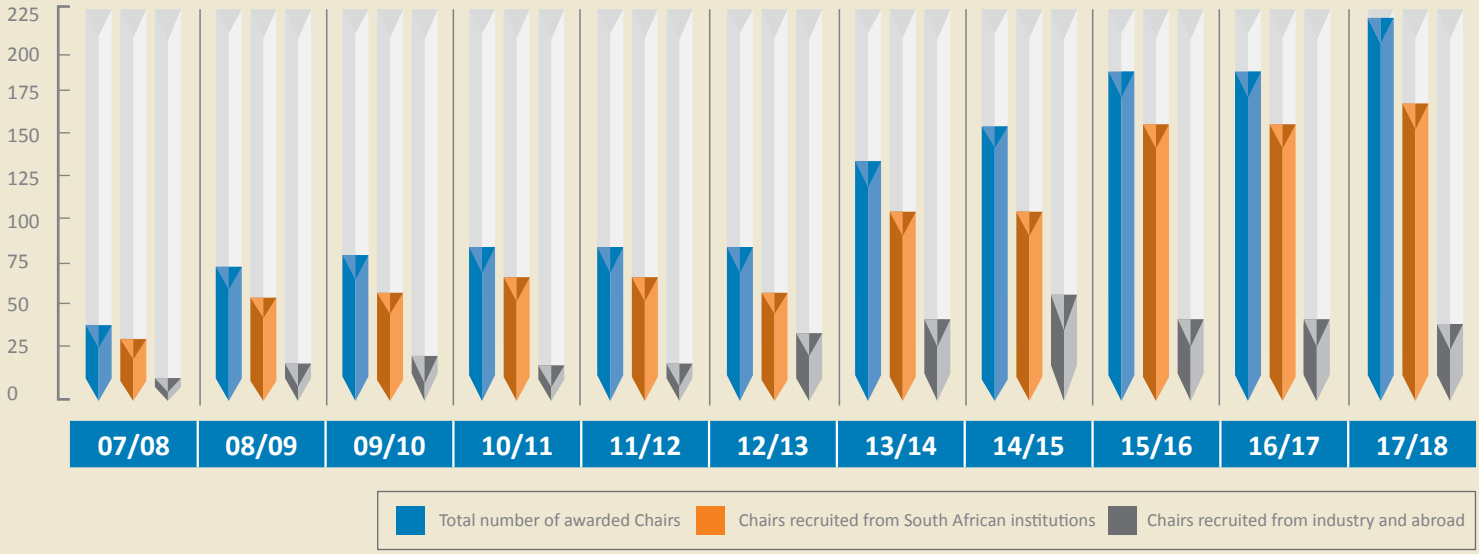
Breakdown according to race



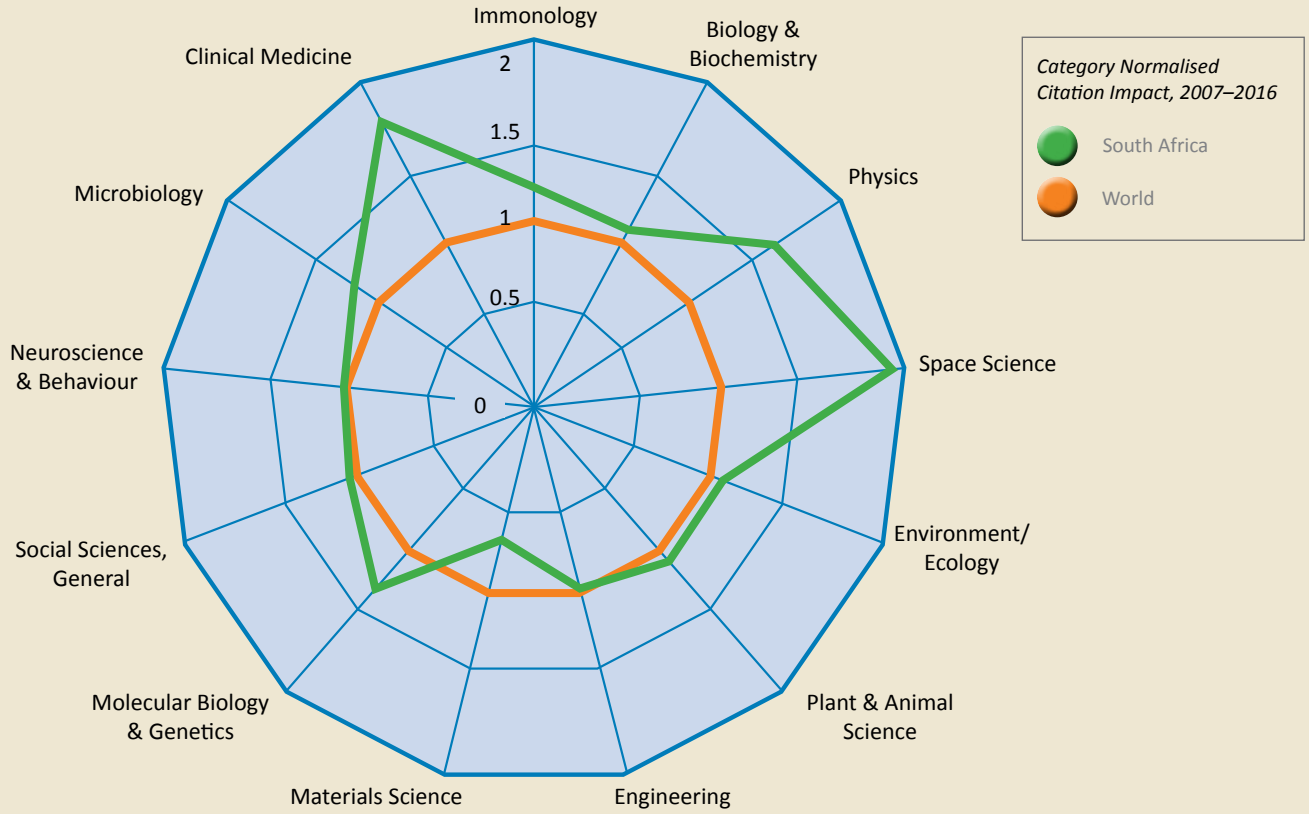
Breakdown according to qualification



Research chairs have grown, giving a boost to human capabilities development and research outputs



South Africa has world-class researchers in a number of fields[3, 8]



Growth in South African scientific publications[8]

1996	4 696
2013	14 890
2015	17 246

Number of scientific publications

1996	0.39%
2013	0.61%
2015	0.69%

World share of publications

1996	0.31%
2013	0.76%
2015	0.89%

World share of citations

1996	19.72%
2013	45.68%
2015	50.18%

International collaboration publications

1996	0.54%
2013	1.69%
2015	1.39%

Publications in top 1%

1996	6.88%
2013	9.99%
2015	9.32%

Publications in top 10%

5.2 Policy intent: Expanding research outputs and transforming the research institutional landscape

To expand the research system, once the relevant studies have been conducted, the institutional landscape will be grown and diversified by establishing new research institutions and consolidating existing programmes. Lessons will be drawn from the Science, Technology and Innovation Institutional Landscape Review.

The DST and DHET, in collaboration with international partners and industry, will continue to support research-intensive universities, while actively supporting universities of technology and historically disadvantaged institutions. However, it is important to recognise existing areas of excellence in these institutions, as the type of institution is not the only factor to affect research performance. Programmes will be established to improve research capacity at these institutions. The twinning of research-intensive universities with historically disadvantaged institutions will be encouraged.

The university funding formula that was introduced in 2003 had a positive effect on research outputs. Incentives of this nature will be investigated to also support research that informs society, for instance research that improves quality of life.

The DST will deepen partnerships with R&D and STI-intensive government departments like the DHET and the Departments of Energy and Environmental Affairs in order to strengthen support for the research enterprise. Furthermore, the DST and other relevant government departments will intensify their focus and collaboration around the incentive programme for science councils to improve their research performance.

5.3 Policy intent: Transform the profile of the researcher base

The DST and DHET will emphasise the development of black and women researchers at emerging researcher level (with a specific focus on black women), and mentor them beyond qualification to take up senior management positions in research management and science institutions.

Over the short term, an increase in the number of researchers will be achieved through focused, fast-tracking interventions that will tap into the PhD-qualified, research-inactive "silent majority" of existing permanent academic staff, especially black and women staff.

The DST will continue its support for the DHET's Staffing South Africa's Universities Framework, which aims to change the number and composition of university staff.

5.4 Policy intent: Improve the research system's output of human capabilities

The White Paper adopts a broad view of human capabilities development in higher education, recognising the need to:

- Take cognisance of the multidimensional nature of black students' lived realities (relating to university fees, accommodation, nutrition and transport)
- Change the demographics of academic staff
- Transform curricula and research agendas where appropriate
- Cultivate greater awareness of African STI
- Eliminate racism, sexism and all other forms of unjust discrimination
- Improve academic success rates and expand student support, in particular for black students

5.4.1 Supervisory capacity

Given the country's supervisory capacity constraints and the global research projects that it hosts, the need exists to attract world-class research talent by easing immigration rules.

Government will expand instruments that have proven successful in research and postgraduate outputs, such as SARChI, and put in place programmes to establish full-time equivalent research positions at universities. Given the sustained increases in the number of PhD graduates, government aims to support and retain an appropriate percentage of each annual graduating PhD cohort in the postdoctoral programme for eventual absorption into the academic and research system.

The experience and expertise of ageing researchers will be harnessed, while putting in place research and supervision skills transfer programmes to benefit younger and emerging researchers.

In order to increase the proportion of university staff with PhDs, direct support for attaining a PhD will be prioritised, particularly for staff at universities where the proportion of PhD-qualified staff is below the norm. Twinning programmes with research-intensive universities and international institutions will assist in addressing the shortfall.

Postdoctoral fellows make an invaluable contribution to the research system by mentoring postgraduate students. The number of postdoctoral fellows hosted at universities and science councils has generally increased, but their contribution has not been optimised because their status has not been defined. The DST and DHET will formalise a set of guidelines on how to optimise the contribution of postdoctoral fellows.

To improve demographic representation among established researchers, the DST and DHET will target and retain a significant number of black and women doctoral graduates, particularly South Africans, in the Postdoctoral Fellowship Programme. Foreign postdoctoral fellows will be targeted in strategic priority areas to alleviate supervisory bottlenecks. At the same time, the DST and DHET will establish a programme for South Africans to pursue postdoctoral fellowships abroad, targeting black people and women.

5.4.2 The human resource development pipeline

The DST and DHET are the key government departments responsible for strengthening the postgraduate human resource development pipeline, supported by the Department of Basic Education and the Department of Labour.

Addressing the problems relating to the teaching and learning of English, Mathematics and Physical Science in schools must be at the heart of any STI strategy and is a prerequisite for an advanced STI system in South Africa. However, the South African schooling system is not yet delivering outputs at the required level.

A number of departments will therefore collaborate with the aim of building the science, technology, engineering and mathematics (STEM) pipeline. The DST, in collaboration with the Department of Basic Education, will scale up existing initiatives to improve English, Mathematics and Physical Science at school. Developing a scientist or engineer begins early in life with the nurturing of children's health, curiosity and creativity. Early childhood development programmes will be expanded by the Departments of Basic Education, Social Development, and Health. The government aims to use the potential of STI to increase the reach and impact of such programmes.

Government will put in place specific interventions to enable all children (and, where appropriate, adults) to become digitally literate. Examples could include making greater use of mobile phone technology and existing public infrastructure in rural areas such as post offices, schools or libraries to introduce children to gaming and coding, and to teach adults digital skills. The private sector will be encouraged to partner with the government in these endeavours.

Structured mechanisms will be created by government to strengthen the links between researchers and scientists, on the one hand, and school teachers on the other, to encourage the introduction of scientific

concepts from primary and pre-primary level (in particular in ICT-related skills training linked to the 4IR), as well as to enhance the development of appropriate educational technologies. The "adoption" of schools by universities and science councils could reinforce this approach. Furthermore, SET-based industries will be incentivised to "adopt" schools for support – although government will not abdicate its responsibility in this regard. Another, longer-term option might be to link postgraduate funding to a quota of community service to assist with the teaching of SET in schools. Such a programme should, however, not compromise the time in which degrees are completed, or the graduation rates.

Currently, too few students are supported at too low a financial level, and public support for postgraduate studies needs to be increased, especially given that the gradual implementation of free higher education might result in increased postgraduate enrollments. Increased public support for postgraduate studies will also require government, industry and international funders to coordinate their efforts. A framework will be developed for cooperation across government, particularly involving departments that have SET postgraduate bursary programmes.

In addition to research masters and PhDs, the NSI and the economy require technical and other skills that support innovation. Government will therefore expand its student support programmes to include the development of technical, entrepreneurship and innovation-related skills, such as IP management.

5.4.3 Reversing the “brain drain”

South Africa supports the vision of an Africa where its citizens can move freely across national borders, where intra-Africa trade is encouraged and where there is a greater integration and development of the African continent. Our future lies, together with others, in being part of the African continent that has a knowledge-driven base, thriving trade and free flow of people, goods information and capital. However, South Africa, as an emerging market, is herself in need of skills and expertise to grow her economy. The international mobility of talent will play a role in meeting our emerging economy's skills needs. South Africa’s White Paper on Migration is centred around the principle of the strategic management of international migration to achieve national development goals.

For the longest time, Africa has been at the receiving end of what was called the “brain drain” as African scientists left the continent in pursuit of more lucrative research careers in advanced laboratories abroad. On the other hand, Africa has increasingly tapped into its diaspora network for developmental purposes. Globalisation, ICT, convenient modes of transport and the collaborative nature of research (knowledge networks) have all conspired to enable the Africa diaspora to work with home-country researchers who can also embark on short-term visits abroad. Strategies will be put in place to optimise this flow of skills and attract investment as South Africa increasingly becomes a host to global research programmes, drawing international researchers and expertise into the country.

5.5 Policy intent: Strengthen skills in the economy

5.5.1 Diversity of post-secondary education

In South Africa, it is necessary to improve the responsiveness of the post-school education and training system to the skills needs of the 21st century, in particular innovation and technology-driven change that affects organisations and individuals alike. Currently, the education level and skills base is lower than that of many other productive economies. The pool of students who can potentially access university and science-based technical and vocational education and training (TVET) programmes is small in comparison to the country’s demand for skills.

The main constraint is the inadequate quality of basic education (particularly in languages, Mathematics and Physical Science). This impedes progression to and success in post-school education and training and the workplace. A coordinated, system-wide effort is needed to improve the quality of teaching and learning from the Foundation Phase of schooling, and to ensure stronger integration of government departments’ strategies targeting skills development and education.

The availability of high-quality STEM graduates and teachers, especially secondary school Mathematics and Science teachers and early childhood development practitioners, is essential. At technician level, there is an undersupply of engineering technicians and associate professionals. The sector must develop enrollment targets in line with the skills needed for the labour market. This, in turn, requires assurance that TVET staff have the necessary competence and recent relevant experience.

Increased absorption of doctoral graduates into the economy is only possible if the acquired PhD-level skills and training are appropriate to the needs of industry, government and science councils, among others. Government and industry must be co-creators of human resources and must nurture an increased appetite for PhD-level skills. Government will consider incentives, e.g. tax breaks for industries investing in funding PhDs (and technical skills development) from their own workforce.

Increased cooperation between universities, industry and government will increase the relevance of PhD training. Therefore, the diversification of knowledge workers through doctoral programmes facilitated jointly with industries, such as industrial doctorates, will be pursued. Government will also invest in tracer studies to understand the career paths and mobility of people with PhDs across different sectors (such as universities, science councils and industry).

Finally, open platforms could have an amplifying effect by dramatically increasing the pool of individuals available to address a given question and decreasing the time to develop solutions, ultimately decreasing the time to market. The DST will therefore continue to explore opportunities and barriers (e.g. IP and mission conflicts) for universities, science councils, government and the private sector to participate in open collaboration platforms.

5.5.2 Education and training for a future of digital jobs

The government will plan the future human resource needs of the country (according to the NDP and beyond) in a coordinated manner to ensure that scarce educational resources are optimised. More specifically, the DST will work with the DHET (and the Department of Basic Education) to integrate the need for STI skills in the South African National Skills Plan. The DTPS, among others, will be involved in reshaping the country's skills development agenda in line with the jobs landscape of the future, prioritising digital skills. The STI policy nexus on education and training will serve as coordinating mechanism to avoid fragmentation of this effort across government and business.

Government needs to equip South Africa's youth with skills for the future, expose more students to coding and computational thinking, and train students in problem-solving and critical reasoning skills. South Africa, which is already facing skills backlogs, needs to capacitate its citizens to thrive in the changing world, and to ensure inclusive economic progress for the country. Our education system must equip students to be successful entrepreneurs, hold diverse jobs and work across a number of industries.

To thrive, ICT skills will not be enough. South Africa's educators will design future-ready curricula that encourage critical thinking, creativity and emotional intelligence, and accelerate the acquisition of digital, STEM skills to match the way people will work and collaborate in the future, particularly in the context of the 4IR.

Successive industrial revolutions have brought about changes in the nature of work, job markets and training activities for the workforce. Many of the roles, skills and job titles of tomorrow are unknown to us today, and universities have an agile role to play in not only equipping students with approaches to learning and relevant content, but also in understanding and mapping the consequences of the 4IR. Every researcher, whether in the natural or engineering sciences, social sciences or humanities, has a role to play in responding to the impact of the 4IR. Government, universities and relevant research councils will undertake surveys as a form of a reflection-in-action activity on how the country is responding to the 4IR.

5.6 Policy intent: Ensure an open, responsive and diverse knowledge system

As discussed in Chapter 2, the world is facing challenges that require not only intensified knowledge development and research, but also new forms of knowledge production through open science and by combining inputs from different disciplines.

5.6.1 Open Science and Open Innovation

The OECD estimates that 30 per cent of innovation in Europe is open in the sense of being shared. For example, the Philips Research Campus in Eindhoven invites industry participation with a view to facilitating collaboration between publicly funded and privately funded research. The Bill & Melinda Gates Foundation's malaria project is also using data from a number of resources, because open innovation means that the disease can be addressed more quickly. It must be remembered, however, that open innovation does not mean “free”. Patents and IPR still apply, but only at the end of the innovation process.

The DST is actively examining the transition to open science and open innovation. This will call for appropriate regulatory frameworks and data skills development, as discussed below.

Incentives for open science will be fostered through education programmes and career development programmes for researchers. A focus on citizen science will also be introduced. Barriers to open science will be evaluated and where necessary removed, ensuring that legislation and practice support, rather than thwart, the principles of open and collaborative science. Government will therefore review these, taking into account certain aspects of IPR from publicly funded research and accepting that open science, open innovation and IP, and the associated rights, are not mutually exclusive. Government will also review the policies and institutions governing access to research data and research publications.

The DST, in consultation with DTPS and DHET, will produce a national open science (and data) framework consisting of principles and guidelines for the adoption of open science in South Africa. The framework will be used as a vehicle for awareness raising and training on good practice.

As a general principle, publicly funded research and research data may, after a careful analysis, be made available (with some exceptions including data that can compromise sovereign security and which is of a confidential nature). Government will encourage researchers to deposit data arising from research in publicly accessible repositories, and to support open journal publishing and data sharing, providing access to data and other research outputs arising from publicly funded research. In this manner, research will be made more transparent, rigorous and efficient in stimulating innovation and promoting public engagement.

South Africa does not have formal protection for databases. Government will identify a licence system for depositing data and for the use of open data. What is in the public domain, what is not, or when it becomes available are pressing issues that need to be dealt with. Ensuring that the needs and wants of the data provider are respected, and determining who can use the data, and under what conditions (research use, teaching and commercial use) are also important considerations. In this regard, the free and open access to public-good data, for instance to monitor environmental impact, also needs to be ensured. The Creative Commons licence is a good example for starting to draft specific licence types for different types of open data.

Contemporary open science and open innovation requires data to be findable, accessible, interoperable and reusable (FAIR) in the long term, and these objectives are rapidly becoming expectations of funding agencies and publishers. The current IPR Act will be reconsidered to ensure that it supports the FAIR guiding principles for scientific data management and storage.

National data storage is a further matter that needs to be addressed. The DST will develop a long-term sustainable business model for a South African research data cloud. Institutional data repositories will be encouraged. More support is also needed for the harmonisation of repositories, which can take place through the Data-intensive Research Initiative of South Africa.

The DST will work with the higher education sector and the relevant government departments to ensure data-related skills development for making efficient use of new scientific datasets, tools and methods.

Digital technologies are making the conduct of science and innovation more collaborative, international and open to citizens. In the next decade, as connectivity becomes ubiquitous, the shift to more distributed, networked and open organisational models will become commonplace. Those who are unable to make the change will be left behind. Therefore, government will prioritise funding for the provision of digital resources to the communities and institutions that need them the most.

As part of its commitment to African STI cooperation, South Africa will also work to advance the open science agenda elsewhere on the continent and within regional frameworks. The strategic role of the African Open Science Platform, hosted by ASSAf, which promotes the African-wide development and coordination of data policies, data training and data infrastructure, will be leveraged with the support of the DST and the NRF. In addition, South Africa is one of the founding members of the global Open Government Partnership, and took over the chair in 2015. As one of the signatories of this partnership, South Africa is committed to developing an open data policy framework and action plan.

5.6.2 Diversity of knowledge fields

Public investment in science and research (both fundamental and applied) is an investment in the nation's future, ensuring that South Africa has a productive economy and a healthy society, and contributes to a sustainable world. To this end, a general shift in focus towards innovation is required in the South African STI landscape. However, this does not imply an NSI that is overly focused on investment in experimental and/or applied research. Instead, a dynamic balance is needed, determined on the basis of, among other considerations, the status of the field of knowledge in question, perceived innovation opportunities, and the research intensity and structure of the industries involved.

Studies on the state of health of the different knowledge fields in South Africa will be intensified to allow the DST and other funding institutions to deploy research funding strategically and sustainably. However, support to all academic disciplines, that is, the arts (performing arts and visual arts), humanities (such as languages, literature and philosophy), social sciences (including economics, law, psychology and sociology), natural sciences (physics, chemistry and biology) and applied sciences (engineering and technology, medicine, health sciences, agricultural sciences and computer science) must continue and expand. Government policies need to recognise the importance of language, particularly the home language of children, as the carrier of scientific meaning and information.

Many of the challenges facing humans in the near future, particularly in developing countries, will be solved by the engineering sciences (e.g. infrastructure for rapidly growing cities and improved transport and logistics, water and energy infrastructure, and satellites to ensure information security for the state). Given the present shortage of skilled engineers in the country, government will need to increase support for engineering science and research.

Regardless of the type of research being conducted, two requirements will remain important: whether the research is aligned to the country's needs and delivering the required impact, and whether the research is of a consistently high standard (which to some extent overlaps with the first requirement). Government will therefore implement a framework for research evaluation and impact assessment, supported by an Responsible Research and Innovation framework for the South African context.

5.6.3 Role of the humanities and social sciences

The DST recognises the growing interconnectedness and complementarity between the natural sciences, and the humanities and social sciences, the potential for creativity and innovation that these connections can generate, and the limits of using isolated scientific approaches to tackle societal challenges.

The purposeful inclusion of the humanities and social sciences in the NSI will be prioritised, not only in the role of observer and commentator, but also in conceptualising, planning and executing innovation initiatives.

The DST and DHET will further ensure that the equipment and infrastructure required for the humanities and social sciences, e.g. survey equipment and ICT infrastructure, is given prominence in the various equipment and infrastructure funding instruments in the NSI.

Relevant government departments will commit stable funding for a programme of social surveys and will institutionalise several critical longitudinal socio-economic surveys, e.g. on education outcomes (international comparison), South Africans' health behaviours, and aspects related to social cohesion and entrepreneurship.

5.6.4 Complex societal problems and inter- and transdisciplinarity

"Interdisciplinarity" is usually characterised by collaboration and the integration of concepts and methods (and in turn may lead to the creation of new concepts and knowledge). "Transdisciplinarity" takes this a step further and may represent a different kind of knowledge production, embracing both scientific and other types of knowledge and the involvement of a broader range of expertise, including, potentially, the end users of such research.

A transdisciplinary research process links societal problem solving with scientific knowledge production in a process of co-producing knowledge. Close interaction with societal actors that can make decisions or take action, or may be affected in the respective field is key. To overcome the knowledge-action gap, the approach includes stakeholders from the beginning (co-design), deliberates on normative target questions (e.g. "What are more desirable futures?") and co-produces knowledge on how to reach these targets.

Support for transdisciplinary research faces many obstacles. These include institutional and administrative rigidity, established specialisations among journals and professional societies, funder preferences and policies, and the incentives and constraints embedded in academic and research career tracks. It is important to address these, but there should not be a top-down forcing of inter- or transdisciplinary approaches. The idea is to build a more balanced research ecosystem that will stimulate creativity and advance our understanding of the world.

Universities and science councils will find creative ways, including incentives (e.g. funding for publications) for experienced and established cross-disciplinary researchers to mentor and guide cross-disciplinary research projects, as well as to play a role in strategic advice at the institutional level in promoting such activity.

The DST and DHET will encourage universities and science councils to intentionally promote transdisciplinary research by reducing institutional barriers to transdisciplinary research and interdisciplinary research teams. They will also develop structures to encourage input and participation from outside ongoing projects in such a way as to bring researchers from several institutions, representing multiple approaches, together in a transdisciplinary research environment. Funding agencies such as the NRF will support transdisciplinary research and create stepping stones for transdisciplinary careers.

Transdisciplinary research brings insights and ideas to people, but it is necessary to work on the skills involved. It is necessary to embed a transdisciplinary approach in academic institutions. The institutional culture is still predicated on publications rather than other outputs. Incentives such as increased funding for large multidisciplinary projects (that include the humanities and social sciences) and awards to increase awareness will be put in place to stimulate this behaviour, at both national and institutional level. This dimension of knowledge generation will be included in the research evaluation and impact assessment framework to ensure that it is implemented.

5.6.5 Selection of key research areas, sectors and technologies

According to the OECD, it is important for countries such as South Africa (middle income, with small innovation systems) to focus their STI efforts. However, NACI points out that an incorrect choice of focus area or focus strategy can be more damaging than a strategy of diversification[8]. Furthermore, analysts have noted that the resources of the South African NSI are too thinly spread to make a significant impact in priority areas. Some of the areas in which there has been good knowledge production may not necessarily be aligned to the areas in which innovation for socio-economic impact is most needed. The issue of selection is therefore both important and complex. The DST will develop a process for the selection of focus areas as illustrated in the box that follows.

Selecting and supporting focus areas

- Identify the national STI priorities based on the SDGs and the objectives of the NDP. Examples of such priorities would include the need for a more inclusive economy, areas of social need, e.g. housing, health and education, opportunities for firm growth, exports and job creation, environmental sustainability, preparing for a more digitally advanced world and the disruption of the 4IR, building smart cities as centres of growth, and improving network infrastructure.
- Within these priorities, select focus areas, based on factors such as the capacity of South Africa to succeed in a field, for example, where a competitive or comparative advantage exists, and where the required critical mass of investment is feasible.
- Institutionalise the selection process and select the focus areas for the whole of government. The focus areas will be supported at the level of the Deputy President via the annual STI plenary meeting and the Ministerial STI Structure to coordinate action on the focus areas.
- Concentrate resources at critical mass on the focus areas through an annual STI investment framework that will guide the allocation of research funding to national priorities, and that will ensure that funding flows to both the currently research-intensive institutions and historically disadvantaged institutions to make it possible to tap into the potential of the entire research system.

5.6.6 Knowledge diffusion

Government will enhance the spread of knowledge and encourage the sharing of ideas and research results by adopting an open science paradigm. Knowledge diffusion will also be improved through the enhanced coordination of STI activities across the NSI, which will facilitate the movement of researchers and knowledge between enterprises, universities, science councils and government. The increased absorption of people with PhDs and other highly skilled people into research-performing institutions will also enhance knowledge diffusion. Some of the mechanisms that could be used to achieve this are joint appointments and public-private partnerships.

Research cooperation will be improved. Investment in research programmes at the interface of various public research institutions (e.g. universities and science councils), SOEs and industry will help build bridges for sustainable research cooperation, and ensure that skills produced by universities match those required by industry and science councils. Programmes at the interface will require easy movement of researchers between universities, science councils and industry. This will be achieved through joint appointments, and staff and student mobility programmes, for instance.

The contribution of Public Research Institutions and their ouputs in supporting government policy and national priorities needs to be enhanced. Research grant schemes to incentivise collaboration between universities and other Public Research Institutions in inter- and transdisciplinary research will be developed.

Government will support increased networking and the diffusion of knowledge by leveraging existing global partnerships and knowledge networks better, introducing specific programmes for the secondment of South African researchers to institutions in other countries, providing increased support for training abroad, and providing enhanced support for conferences and workshops. An appropriate quota of international research cooperation engagements and resources will be channelled to historically disadvantaged institutions and universities of technology. Similarly, the role of Offices of Technology Transfer needs to be enhanced to support in-bound technology transfers.

South Africa's profile as a destination of choice for researchers and students from other African countries wishing to gain international experience and expertise needs to be promoted. Already, other African nationals are making significant contributions to strengthening the human capabilities available to the NSI. At the same time,

programmes designed to create international mobility, exchange and training opportunities for South African researchers and students should include a concerted pan-African focus, promoting the outward mobility of South Africans to Centres of Excellence and institutions elsewhere in Africa.

5.7 Policy intent: Support a science-literate and science-aware society

One of the prerequisites for an effectively functioning NSI is a society that is aware of the value and potential dangers of science, is able to evaluate the products of science, uses the processes of science in their daily lives (e.g. asking questions, collecting and analysing evidence, and evaluating possible results), and engages in debate on science-related matters of public interest. Greater public awareness of scientific issues will also stimulate the interest of young South Africans in pursuing careers in science – thereby increasing the number of secondary students choosing subjects to prepare them for university studies in STEM fields.

In the current global "post-factual" society, raising science awareness is of increasing importance in efforts to provide credible alternatives to dubious sources of information. However, with growing access to the internet and the proliferation of unverified information across digital media, these efforts are all the more difficult. In South Africa, the problem is compounded by problems in the education system and the fact that the spatial development patterns of apartheid have to a large degree persisted, particularly in rural areas, which means that many people live beyond the reach of science awareness campaigns.

Since 1996, the South African government, led by the DST, has made good progress in stimulating public awareness of science. Some gaps remain to be addressed, as detailed below.

5.7.1 The institutional environment

A national coordinator of science engagement in South Africa will be entrenched through legislation. A system-wide science engagement coordination model will be instituted, going beyond the DST and its entities, enabling the higher education sector, industry, research councils, science centres and other relevant stakeholders to collaborate in science engagement.

Government will introduce an approach whereby a fixed percentage of the transfers by STI-intensive departments to their entities is to be spent on raising science awareness.

Support for existing science centres will be sustained, and support packages will be developed to establish more strategically positioned science centres, including world-class national flagship science centres or museums. This will require private sector co-funding.

5.7.2 Incentives for researchers

Scientists who participate in science engagement activities will be awarded continuing professional development points by the South African Council for Natural Scientific Professions.

Conditions for research training grants and research development programmes to science councils and public universities (e.g. research chairs and Centres of Excellence) will make it mandatory for recipient individuals and institutions to communicate their research to the public. Initiatives such as digital literacy programmes can only produce the required results if society is science literate. It is therefore necessary to train scientists and researchers in science communication and science engagement skills. These trained researchers and scientists would then help to introduce developmentally appropriate engagement activities and projects for both adults and school learners. Government will aim to have these skills taken up in the curricula of SET students in the higher education sector.

5.7.3 The reach and effectiveness of science engagement activities

To increase the reach of awareness initiatives and promote access to information, science engagement activities will increasingly target the local government level, using appropriate communication technologies and techniques, including mainstream media and social media.

The development of science engagement and communication skills will be prioritised. Such skills development initiatives will target journalists, scientists, students, learners, educators and science interpreters.

Indicators to measure the success of system-wide science engagement performance will be adopted to inform an institutionalised survey on public perceptions of science and country comparison studies.

5.8 Policy intent: Upgrade and expand research infrastructure

Research and innovation infrastructure is recognised as a key element for boosting scientific knowledge generation, accelerating technology development, enhancing both technological and social innovation, and providing advanced scientific training for new generations of scientists and science managers. Furthermore, research and innovation infrastructure provides an enabling environment for established researchers to improve their performance and knowledge and innovation outputs.

The factors that underlie current challenges in the provision of research and innovation infrastructure (including scientific collections) include the following:

- A lack of long-term planning by institutions to meet the high demand for research and laboratory equipment.
- Inadequate funding to upgrade and replace old research infrastructure, lack of national accredited health (preclinical) research facilities, and the need to improve the overarching governance of distributed research infrastructure.
- Inadequate specialised skills related to research infrastructure, e.g. for maintenance.
- Inadequate coordination across institutions in providing data-intensive research infrastructure, and lack of digitisation facilities.
- The challenges and gaps arising from the emerging imperatives for a competitive NSI, including a lack of capability to exploit the convergence of ICT fully.
- Insufficient access to research infrastructure for grassroots innovators.
- Inadequate provision of research infrastructure to support social research.
- The significant costs associated with innovation infrastructure and the lack of fully developed financial decision-making systems, and partnership and financing models related to such infrastructure.

To renew and maintain the current infrastructure base adequately, a long-term coordinated planning approach for research and innovation infrastructure investment (across different departments, particularly the relevant SET departments) will be developed. The investment planning will make provision for renewal and replacement, as well as maintenance and technical support.

Lack of coordination and integration among departments in providing and accessing research infrastructure leads to bottlenecks and the duplication of effort. Government will establish an intergovernmental coordination and steering platform with a clear mandate and scope, strategy and policy guidelines, co-funding, shared procurement agreements, and joint planning principles to address the lack of coordination.

To help address the challenge of insufficient funding for research and innovation infrastructure across the entire innovation value chain, a national Research Infrastructure Fund at National Treasury will be established with long-term planning horizons. The level of investment in knowledge infrastructure will be increased to ensure that South Africa remains competitive in terms of knowledge and innovation outputs, as well as to train the next generation of researchers.

There is a specific need for increased investment in high-end infrastructure to support innovation, produce new products and develop new industries, among other things. Examples of this type of facility are those focused on resource beneficiation, such as pilot plants for the platinum powder industry and hydrogen fuel cells. The exact level of funding that is required would depend on the type of high-end infrastructure, but an agreed percentage of total knowledge infrastructure funding will be used to support such infrastructure.

Government will retain the six national research facilities currently managed by the NRF as research infrastructure platforms. However, the implementation of the South African Research Infrastructure Roadmap will require many

more such facilities. The management model will therefore be changed to facilitate scale-up, sustainability and improvements in the performance and establishment of these facilities. Training and developing key human resources is critical to ensure the optimal and sustainable use of research infrastructure. Government will therefore introduce a mandatory requirement that infrastructure provision policies include human resource development support (scientific and technical) for infrastructure development and maintenance through internships, curriculum changes in HEIs, and absorption into the workplace.

Not sharing or integrating research infrastructure leads to isolated and/or duplicated research infrastructure deployment and use. To address this challenge, government will develop programmes and interventions that build a continuum of research infrastructure capabilities at institutional, regional and national level. It will also establish distributed national research infrastructure to optimise and share resources, including for the humanities and social sciences.

Grassroots and other categories of neglected innovators who are not part of formal systems of innovation need access to research infrastructure. Government will therefore establish open access (and mobility) research infrastructure support platforms (excellence/evidence-based) for grassroots and other neglected innovators, as well as to support innovation for inclusive development.

South Africa's national policies and strategies, including on investment planning for research infrastructures, must embrace a regional and continental focus. African regional e-infrastructures, such as dedicated high-speed research networks, will be essential for enabling intensified intra-African research collaboration, which South Africa needs and seeks to promote. Investment planning for large-scale facilities with expensive construction and operational costs should consider the possibility of jointly developing the facilities with other African partners as regional or continental facilities. Programmes and networks should also be developed to facilitate reciprocal access and collaboration between different African countries' National Facilities. South Africa will work within the frameworks of the AU and SADC to support the formulation of African continental and regional research infrastructure policies and strategies.

Through partnerships with international research facilities such as the European Organisation for Nuclear Research, the European Molecular Biology Laboratory, the European Synchrotron Radiation Facility, and Russia's Joint Institute for Nuclear Research, South Africa has gained access to cutting-edge research infrastructure that cannot be duplicated in South Africa because of its complexity and the massive financial investment needed. These partnerships have provided South African scientists with an opportunity to conduct research at the frontier of knowledge, attracted prominent visiting scientists to South Africa, extended the PhD and masters supervisory capacity of South African HEIs, provided opportunities for training, and skills and technology transfer, contributed significantly to the internationalisation of South African world-class research, enhanced South Africa's visibility and footprint in the international scientific community, and leveraged international research funding from new partnerships. These partnerships will be intensified.

There are weak links and partnerships between the private and public sectors on investment in research infrastructure. Open-access research infrastructure support platforms will be established to encourage private sector investment in research infrastructure.

To attract multinational corporations to locate their technological infrastructure in South Africa, incentives and the appropriate skills will be required. For South Africa to use public funding to support such facilities, it will be necessary to ensure that the new technological infrastructure is backed by a group of companies or by entire industrial sectors on the basis of their potential competitive gains, as well as by scientific organisations.

It has become critical for South Africa to formulate the risks of adoption or non-adoption of an integrated digital strategy. To mitigate the risks, government will develop a South African integrated digital strategy setting out the key enabling role that the use of ICT will have to play. It will also develop national legislation/policy on digital data to regulate data sharing and access, ethics, privacy and IP at national level.

5.9 Policy intent: Expand internationalisation and science diplomacy

> *"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."*
>
> Louis Pasteur

One of the strengths of South Africa's NSI, and a critical one given that it is comparatively small, is its extensive and active set of international partnerships. Over the past 20 years, global cooperation and support have contributed significantly to the growth and development of the NSI. However, well-resourced South African institutions find it much easier to take part in these programmes than historically disadvantaged institutions, and a more inclusive approach is needed.

South Africa will continue to prioritise support for the development of STI capacities in Africa, including through the implementation of the AU's Science, Technology, and Innovation Strategy for Africa and initiatives bolstering regional integration within SADC. Informed by the priority focus on pan-African partnership and solidarity of South Africa's foreign policy, South Africa is determined to meet its responsibility to contribute to STI capacity building as an instrument for growth and development in Africa. Partnership initiatives will focus on enhancing policy frameworks and institutional capacities, including research infrastructures, as well as human capabilities development with a special focus on the intra-African mobility of young African researchers.

It is important to emphasise the importance of international engagement, not as an objective in its own right, but as an integral part of the overall further evolution of the NSI. The focus for South Africa to contribute to building African STI capacities is, thus, not an altruistic endeavour, but very much one informed by national interest, as the South African NSI will only flourish as part of vibrant Southern African regional and broader continental innovation ecosystems. The government's initiatives below relate to the strategic policy context, implementation modalities, and planning and coordination of international cooperation.

5.9.1 Enhanced strategic focusing

Rather than following an ad-hoc approach, science diplomacy will be strategically harnessed as an instrument to advance South Africa's foreign policy agenda and optimise the role of international STI cooperation in the implementation of Chapter 7 of the NDP, "Positioning South Africa in the world".

South Africa's engagements with African STI partners will be more strategically coordinated to ensure the implementation of the AU and SADC's STI agenda to better leverage synergies between the two agendas and avoid duplication. The government will facilitate support for a pan-African STI funding programmes, which should notably increase joint publication by South African researchers with partners from the rest of the continent.

The SDGs will be the guiding multilateral policy framework for South Africa's international STI cooperation. It is anticipated that developments in the African and regional context will increasingly affect the NSI as South Africa's political and economic integration deepens in the AU and SADC.

As competition for international cooperation opportunities intensifies, efforts to promote South Africa's profile as a global STI partner of choice will be stepped up. This will include initiatives such as institutionalising the management of Science Forum South Africa.

5.9.2 Efficiencies in international cooperation

To improve the NSI's innovation performance, a systematised framework for South Africa's engagement with international innovation partnerships (as opposed to the traditional academic and basic research-orientated focus of international cooperation) will be developed, with particular attention given to funding instruments.

Interventions will be developed to increase South African researchers' access to training opportunities abroad, responding to capacity needs in the NSI and ensuring that the NSI reabsorbs South Africans studying abroad, while also attracting skills to South Africa and fostering cooperation with the South African diaspora.

The interventions will include a focus on attracting postdoctoral researchers to South Africa, with the specific aim of boosting South Africa's PhD productivity through increased supervisory capacity. The overall role of international cooperation in enhancing South Africa's research capacity, e.g. through co-authorship, will be strengthened.

There will be an intensified focus on attracting STI-related investment to the country, and these efforts will be better aligned with government's general efforts to attract foreign investment into South Africa. The intent is to secure at least 15 per cent of South Africa's GERD from international sources, and to grow this ratio over time.

A strategy will be developed to increase the participation of historically disadvantaged institutions in international collaborations, and to ensure that international collaboration does not perpetuate exclusion.

5.9.3 Planning and coordination for international cooperation

Coordinating mechanisms will be developed to ensure greater strategic focus and efficiency in international STI cooperation, avoiding fragmentation and duplication. These will include intelligence and information sharing, joint priority setting, and encouraging the exploitation of synergies.

Indicators and an M&E framework will be developed to better gauge the impact and outcomes of international STI partnerships. This will include systems for enhanced knowledge management of all South Africa's international STI cooperation initiatives (government and business).

CHAPTER 6

FINANCING SCIENCE, TECHNOLOGY AND INNOVATION

CHAPTER 6: FINANCING SCIENCE, TECHNOLOGY AND INNOVATION

Very few of the ambitions of this White Paper will be realised without adequate funding. Financial resources directly influence the size, shape and strength of the NSI and its ability to support the NDP. The White Paper concludes with this chapter on financing South African STI.

6.1 Progress in financing STI, gaps and focus areas to increase NSI financial resources

"R&D has played an important role in helping middle-income countries such as South Korea advance to high-income status. While South Africa needs to spend more on R&D in general, the institutional set-up also needs to improve the link between innovation and the productive needs of business. Government should partner with the private sector to raise the level of R&D in firms. Public resources should be targeted to build the research infrastructure required by a modern economy in line with the country's development strategy."

South Africa's National Development Plan, 2011

Recent reviews all point to the fact that the South African NSI is underfunded, both at the aggregate level and at the level of STI in critical sectors of the economy, such as agriculture and mining. Furthermore, the reviews note that funding is not appropriately spread across the entire innovation value chain, and that foundational STI functions such as human resource development and infrastructure provision are underfunded. To enhance South Africa's innovation performance, increased funding is also needed to leverage international funding and resources, technology transfer activities, and public incentives to encourage private sector RDI.

GERD in constant 2010 rand terms and as a percentage of GDP has increased slowly over the past two decades[24]. However, South Africa's global share of R&D declined by 25 per cent over the period 2007 to 2013, while India and China grew their shares by 18 per cent and 92 per cent respectively. GERD, as a percentage of GDP, was 0.8 per cent in 2016/17 – a small improvement from the 0.7 per cent reported in the four periods between 2010/11 and 2013/14, and 0.73 per cent reported in the previous four R&D surveys. This improvement is significant, however, since it took place in the context of slowing GDP growth, which stood at 2.5 per cent in 2013, slowing to 0.6 per cent in 2016.

The relatively low level of GERD and the near stagnation of GERD as a percentage of GDP, particularly in comparison with other emerging economies, is a concern, and it is important to understand the figures in more detail. The business sector, which includes local private enterprises (large businesses, SMEs and start-up firms), SOEs and multinational enterprises, has a significant influence on the overall trend of GERD. Between 2004 and 2016, in real terms, business funding of R&D increased by 25 per cent, whereas government funding for R&D increased by 101 per cent. Government was therefore responsible for the bulk of the increase.

However, there are signs that this trend is changing. For instance, the business sector contributed to the bulk of GERD recovery in 2013 and 2014, although the increases were off a low base. In fact, this sector remains the largest performer in the history of the South African R&D survey. Furthermore, foreign funding for R&D oscilated between 10 and 15 per cent for the 13 years from 2001/05 to 2016/17, with relatively small changes over a period straddling the 2008/09 global financial crisis, pointing to resilience in South Africa's ability to attract foreign funding for R&D.

Over the past two decades, public resources for innovation have increased significantly. The budgets of all departments active within the NSI have increased in real terms, led by the DST, whose expenditure has increased ninefold since 2005/06. Government funding of R&D has continued to grow steadily and sustainably over the past five years, amid slow growth conditions. In addition, sectoral public investment in R&D is taking place via sector-specific science councils such as Mintek, the Agricultural Research Council and the South African Medical Research Council.

Despite these signs, increased funding by all sectors, not only for R&D, but for STI in general, remains critical. Government funding is necessary to catalyse investments in areas where other actors have limited incentives to fund. For a developing country like South Africa, the rationale for government investment in STI is even greater, given that the country not only needs to catch up in several dimensions of economic growth and development, but also needs to establish new SET capabilities for its long-term competitiveness.

However, government funding on its own is insufficient for growing the NSI to its full potential. Increased private sector involvement in resourcing the NSI is vital, both to advance private sector objectives and to support the government in RDI initiatives for the public good. Furthermore, a modern, open economy must attract higher rates of international funding and resources for RDI. With South Africa now more integrated globally than it was in 1996, it faces a new test, namely, to match its peers in attracting the shifting global RDI investments that continue to favour emerging economies. It will therefore need to provide equitable co-investment to attract funding from international partnerships.

Finally, in addition to the problem of general underfunding of the NSI, the 2012 Report of the Ministerial Review Committee on the STI Landscape[11] highlighted the need to improve the allocation of public funding to STI priorities, as resources are often too thinly spread to achieve an impact in areas critical to South Africa's development. There is also room to increase the productivity of funding.

To address the reasons for the situation described above, this chapter contains policy proposals to:

- Increase funding to the NSI, with a focus on increasing business and foreign investment in STI, as well as to encourage provincial and local governments to invest more in STI as part of their development strategies.
- Improve the allocation of public funding for STI, and the coordination of public investment, to ensure that government's STI priorities are appropriately funded.
- Enhance the efficiency of funding in the NSI.

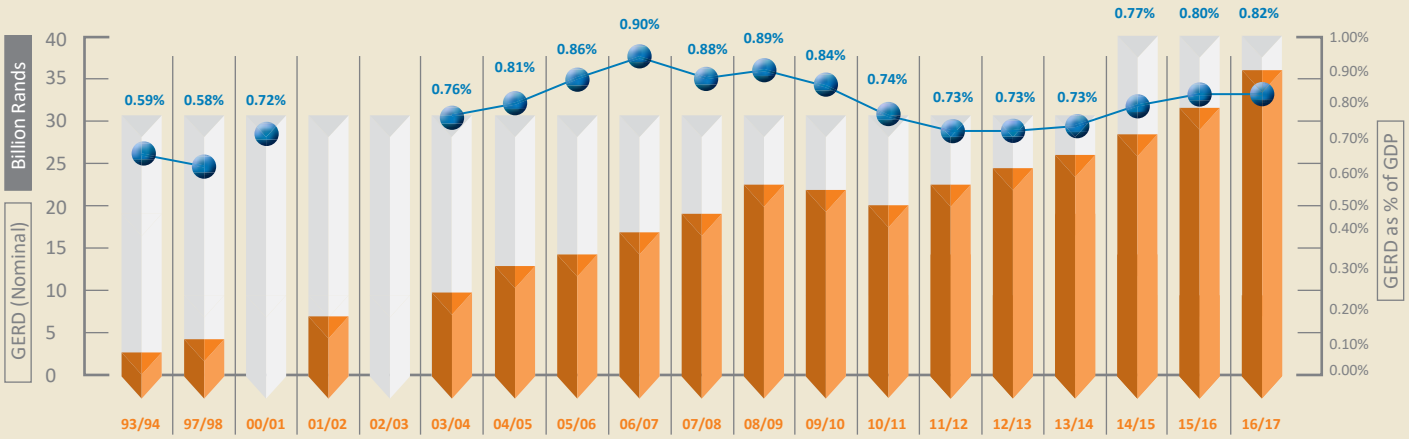
Financing the NSI

The South African NSI is seriously underfunded.[11] South Africa has a long-standing target of GERD at 1.5% of GDP. While the target has proven elusive, it is encouraging that the GERD/GDP indicator (at 0.82% for 2016/17) increased for the fourth consecuti ve period, under conditi ons of slowing economic growth.

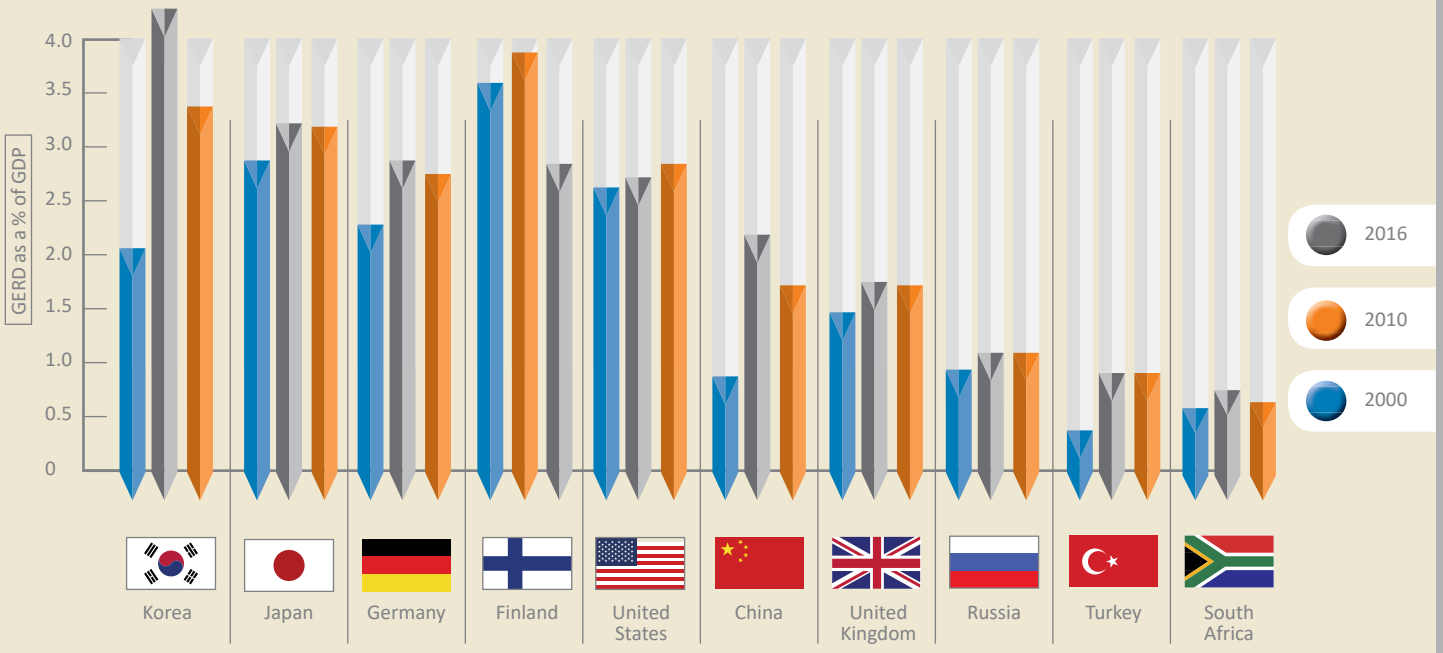
1.5%

SA GERD/GDP target

GERD AS A PERCENTAGE OF GDP SINCE 1993/194



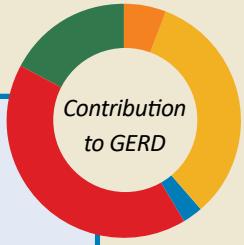
OECD statistics show that, in terms of GERD/GDP, South Africa is lagging global innovation leaders.



*Total science and technology activities expenditure as a percentage of the total annual government budget has been declining over recent years, from **1.87%** in 2014/15 to **1.71%** in 2017/18.*

41.4%

*In 2016/17, business made the largest contribution to GERD, at **41.4%**. Between 2006/07 and 2016/17, business's contribution to GERD reduced from **55.9%** to **41.4%**, and the contribution by higher education increased from **20%** to **33%**, while the contribution by science councils and government's contribution remained largely stable.*



Business: **41.40%**
Higher education: **33%**
Science councils: **17.20%**
Government: **5.90%**
Non-profit: **2.90%**

6.2 Policy intent: Increase levels of funding

Government recommits to the target of increasing the intensity of R&D investment in the economy so that GERD reaches 1.5 per cent of GDP in the next decade, and an aspirational 2 per cent a decade later. However, funding increases are needed for the STI ecosystem, not only for R&D. A number of specific interventions aimed at realising this objective are discussed below. The efforts of all funding partners complement one another in improving the STI performance of the NSI. Therefore, collaboration and co-funding between the business and higher education sectors, as well as business and science councils, will be strengthened to help address the constraints to business R&D. While the bulk of the increase in STI investment should come from the private sector, government has an important role to play – firstly, through creating an investment-enabling environment, and secondly through increasing its own levels of STI investment. Furthermore, as discussed in Section 6.5, systems will be put in place to ensure funding efficiencies.

Government supports the integration of STI in national development, and is of the strong view that STI are key drivers of economic and social development. This is especially so when STI policies are well integrated into national development strategies and combined with institutional and organisational changes to help raise productivity, improve firm competitiveness, support faster growth and create jobs. Government will therefore commit, at the highest level of budget planning, to sustained increases in public STI investment that will grow over the long term, as the fiscal position of government allows. These STI investment increases will not only lead to long-term improvements in the competitiveness of the economy, but will also start adding value through, for instance, improved service delivery and rural development within a short period of time.

National STI-intensive government departments will set appropriate targets for STI in their budgets. In particular, line departments will commit a percentage of their budgets for sectoral RDI plans, and will invest in the science councils that report to them accordingly. Provincial and local governments will actively contribute more to STI funding and, over time, will set appropriate targets for investment in STI as part of their growth and development strategies. Examples of investment opportunities are incubation and testing facilities.

Development finance institutions – the IDC and the Development Bank of Southern Africa – will scale up funding for industrial innovation activities. This approach will help to establish a closer interface with TIA and to scale up the overall level of government support for RDI. This will serve to close a critical gap in funding for large-scale projects that require government funding commitments to catalyse large-scale private sector action. The approach will also accelerate South Africa's investments in other parts of Africa, in the context of the AU's Agenda 2063. In this regard, possible partnerships with the Brazil, Russia, India, China and South Africa (BRICS) Development Bank will be explored. International investments in STI will be included and appropriately positioned in the Trade and Investment South Africa initiative based at *the dti* in order to attract STI-linked foreign direct investment. The focus will be on promoting foreign direct investment, including targeted engagements with multinational companies. In terms of scope, international investment is taken to include direct investment by multinational corporations that fund and perform R&D, as well as mutually beneficial partnerships in human resource development, scientific infrastructure, knowledge networks and collaborative R&D.

New funding models across the innovation value chain will be used. Examples include corporate social investment, crowd funding, and partnerships/collaborations between actors across different sectors and borders. The growing sector of corporate social investment funds and non-profit organisations presents opportunities to advance grassroots and social innovation, for example, through venture capital funding. Government will introduce instruments such as matching funding and awareness raising to make greater use of these opportunities.

There is a specific need for increased commercialisation funding. A Sovereign Innovation Fund will be formed to leverage co-investment by the public and private sectors to address gaps in technology commercialisation. The fund will be designed to complement and enhance existing funding instruments, and to provide large-scale funding for the development and maturation of radical innovations and emerging industries. Within the public sector, agencies such as TIA, the IDC and the Development Bank of Southern Africa, in cooperation with National Treasury, can contribute to this fund.

6.3 Policy intent: Develop funding priorities

To guide long-range planning and budgeting for the STI sector, decadal plans identifying priorities for STI will be developed by the DST in collaboration with relevant role players across the public and private sectors. The STI decadal plans will identify funding requirements per priority sector across the entire innovation value chain – both supply-side (research and human resource development funding needs) and demand-side (co-funding incentives, public procurement commitments to assist with commercialisation, and Sector Innovation Funds). The decadal plans will further assist the DPME in drafting its annual Budget Mandate Paper on funding priorities for government.

In the short term, new industries that add value to South Africa's mineral and agricultural resources, and move the country higher up the value chain, as well as initiatives linked to the 4IR, will be prioritised in the decadal plans. Long-term priorities will be determined according to the assessment of market drivers, the strategic use of techno-economic studies (including analyses of competitive advantage), the identification of lead users and industrialisation partners, governance arrangements and funding requirements (see Chapter 5 for more detail on the selection of focus areas).

6.4 Policy intent: Institutionalise a framework for guiding public STI investment

The DST, working with NACI, will develop a public STI investment framework. NACI's role will be to undertake foresight studies and provide an independent STI M&E function (including regular analysis of public STI spending). The framework will be based on an analysis of STI funding requirements in line with strategic and sovereign priorities, as well as consultation across government through an interdepartmental STI Budget Committee at the level of Director-General, including national and provincial governments with significant STI mandates.

The STI investment framework, under the auspices of the Ministerial STI Structure, will guide funding allocations by National Treasury, based on the Budget Mandate Paper. To achieve this, government will institutionalise an appropriate process, as part of its Budget Mandate Paper development process and Medium-term Expenditure Committee process, to enable the interdepartmental STI Budget Committee to provide advice on funding needs for STI priorities and related programmes identified by the STI investment framework. Each department will, however, remain responsible for overseeing transfers to its public entities, and monitoring and reporting on key deliverables.

6.5 Policy intent: Improve funding efficiencies

Although the case for increased funding is clear, it will also be necessary to optimise existing funding through improved coordination (across government, as well as between the public and private sectors), reduce duplication of effort, and improve synergies. Furthermore, to ensure optimum results from investments, the efficiency of public NSI institutions, to which most of this funding is allocated, will need to be enhanced where necessary.

The South African funding regime currently consists of many different institutions with varying mandates and levels of funding, creating a landscape that is difficult for any innovator or institution to navigate. To simplify the application processes and reduce duplication, the functions and funding instruments of the following institutions, among others, will be harmonised: TIA, NIPMO, relevant sections of the Small Enterprise Development Agency, the Technology and Human Resources for Industry Programme, the Support Programme for Industrial Innovation, elements of the IDC, and parts of the NRF. The intention is to ensure a seamless transition between functions and instruments.

The administrative capabilities of the relevant institutions will improve efficiency through, for example, simplified application processes, uniform application forms, "one-stop shop" approaches (including an information/application portal) for addressing questions and assisting applicants, standardised approaches to evaluation, and more information sharing, especially among SMEs. In line with recommendations of the Review of Government Business Incentives led by the DPME, a possibility to consolidate the number of incentives currently available, under a few well-functioning lead agencies, will be investigated. Government's information on public support for business R&D and innovation will be improved appropriately, taking cognisance of the need for sharing restrictions.

CHAPTER 7
CONCLUDING REMARKS

CHAPTER 7: CONCLUDING REMARKS

For South Africa to become a winning nation in the field of STI, and for STI to realise its potential as a driver of economic growth and development, this White Paper proposed various policy shifts. These include the following:

- Increasing the focus on inclusivity, transformation and linkages in the NSI
- Enhancing the innovation culture in society and government (adopting a whole-of-society approach to innovation)
- Institutionalising approaches to improve policy coherence, and programme and budget coordination within the NSI.
- Instituting M&E systems
- Developing an enabling environment for innovation
- Including and supporting civil society and business, with a focus on SMEs, in government planning and funding.
- Developing local innovation ecosystems
- Supporting social and grassroots innovation
- Improving the human capabilities development pipeline and instilling an innovation mindset from basic through tertiary education
- Developing the next generation of researchers and ensuring that PhD graduates fit the needs of the economy
- Endorsing open data, open science and open innovation approaches
- Supporting inter- and transdisciplinary approaches to knowledge development
- Prioritising a pan-African STI agenda
- Increasing investment in the NSI and optimising the productivity of this investment

"This White Paper on Science, Technology and Innovation is principally about impact."

Remark during consultation with Universities South Africa, 2017

The indicators to measure the achievement of these, and the other objectives of the White Paper will be developed as part of the implementation plan for the White Paper (the decadal plan). However, the truest test of this White Paper will be the impact that it has in realising the potential of STI to support the achievement of the NDP's objectives as well as the SDGs and the AU's Agenda 2063.

POLICY EMPHASIS

of the 2019 White Paper on Science, Technology and Innovation

GOVERNANCE

- Increasing the focus on inclusivity, transformation and linkages in the NSI.
- Institutionalising approaches to improve policy coherence and programme and budget coordination.
- Instituting NSI monitoring and evaluation systems.

FINANCING OF THE NSI

- Developing financing instruments to incentivise business investment in STI.
- Increasing investment in the NSI through commitments from government departments.
- Instituting an STI funding allocation framework to coordinate public budgets for STI.
- Optimising the productivity of public STI investment.

INNOVATION

- Enhancing the innovation culture in society and government (adopting a whole-of-society approach to innovation).
- Involving business and other NSI partners in government STI planning.
- Using local procurement to support South African innovators, especially SMEs.
- Developing local and provincial innovation ecosystems.
- Supporting social and grassroots innovation.
- Encouraging entrepreneurship.
- Using STI to modernise existing industries and to respond to the Fourth Industrial Revolution.
- Supporting the greening of the economy via STI.

PARTNERSHIPS & NETWORKS

- Supporting a pan-African STI agenda.
- Including scientists in the diaspora in knowledge networks.
- Developing critical STI policy nexuses.
- Incentivising partnerships across all aspects of STI in priority sectors for South Africa.

KNOWLEDGE DEVELOPMENT

- Strengthening support for all research, and retaining researchers in the HEI system.
- Increasing research outputs, especially in priority areas for South Africa.
- Endorsing open data, open science and open innovation approaches.
- Supporting inter- and transdisciplinary approaches to knowledge development.
- Increasing investment in knowledge infrastructure, including cyber infrastructure.

HUMAN CAPABILITIES

- Improving educational outcomes, from early childhood through to tertiary education, with a focus on STEM skills.
- Developing the next generation of researchers and PhD graduates that can support the economy.
- Developing the skills needed for the Fourth Industrial Revolution, and expanding broadband access.
- Developing an NSI Gender Framework.
- Increasing science awareness and -literacy across society.

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ISBN: 978-0-621-47209-7