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Contribution by South Africa

to the CSTD 2023-2024 priority theme on "Global cooperation in science, technology and innovation for development"

SOUTH AFRICA'S RESPONSE TO THEME 2

PRIORITY THEME 2: Global cooperation in science, technology and innovation for development

1.What STI cooperative mechanism(s) at global or regional levels has your country joined in?

The Department of Science and Innovation of South Africa has wide International Cooperation and Resources STI portfolio ranging from Africa Bilateral and Multilateral Cooperation, Global Multilateral Cooperation, Overseas Bilateral Cooperation (Europe and the Gulf, and Asia and Americas). All these partnerships are in line with South Africa's foreign policy mandate. In addition, the partnership are under pinned by the DSI's Decadal plan or ten year pan of STI.

The Programme aims to strategically develop, promote and manage international relationships, opportunities and S&T agreements that strengthen the national system of innovation (NSI) and enable an transfer of knowledge, capacity and resources between South Africa and its regional and international partners. The Programme also supports South African foreign policy through science diplomacy.

Strategic objectives

- To secure science, technology and innovation (STI) funds to stimulate knowledge production, technology transfer, enhanced innovation and STI human capital development in pursuit of STI-based socio-economic development in South Africa.
- To increase international exposure to regional, continental and global knowledge and STI networks that will result in knowledge production, technology transfer and enhanced innovation in support of the NSI.
- To contribute towards the shaping of the regional, continental and global STI discourse, decision making and policy formulation using science diplomacy to ensure that the interests of South Africa are represented.
- To support STI capacity in Africa to create conditions for the development of a knowledge-based economy in Africa.
- To increase participation by South Africans in international human capital development opportunities to strengthen the South African NSI.

Components

1. **International Resources** works to increase the flow of international resources into the country by creating conditions for access to international STI skills and global projects.
2. **Multilateral Cooperation and Africa** advances and facilitates South Africa's participation in strategic African bilateral agreements and multilateral organisations, so as to strengthen the NSI and to achieve shared economic and social development in the region and on the continent.

3. **Overseas Bilateral Cooperation** promotes and facilitates collaborative activities and leverages resources in support of the NSI from countries outside Africa, with a specific focus on developing a knowledge-driven economy.

Please see page 68 to 72 of the attached decadal plan.

2.To what extent the existing cooperation programmes are aligned with the development priorities of participating developing countries?

Please see page 68 to 72 of the attached decadal plan.

3.What are the main outcomes of such mechanism(s)? And what are the impacts of the resultant cooperation on your country? Pls. include the gender dimension.

Please see page 68 to 72 of the attached decadal plan.

4.What are the main difficulties member countries have encountered or are facing when implementing the cooperation mechanisms?

Please see page 68 to 72 of the attached decadal plan.

5.In respect of achieving the objectives and goals, what are the factors contributing to the success or failure of the cooperation mechanism(s) that your country has joined in?

Please see page 68 to 72 of the attached decadal plan.

6.In your country's view, what role could CSTD play in coordinating and imparting directionality to international STI collaboration and technology sharing?

Please see page 68 to 72 of the attached decadal plan.

DRAFT SCIENCE, TECHNOLOGY AND INNOVATION DECADAL PLAN

July 2022

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

Making sure it's possible.

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

2030 NDP

MINISTER'S FOREWORD

Our globalised world is experiencing seismic shifts brought on by rapid technological change, climate change and geopolitical and economic fallout from military operations and migration. Amid these, over the past two years, the Covid-19 pandemic brought the inequality between and within countries into sharp focus – with human suffering resulting from the pandemic itself and the extensive job losses that went with it. However, despite being relatively small and inadequately resourced, the South African national system of innovation (NSI) rose to the challenge of producing personal protective equipment and ventilators, and building local vaccine manufacturing capability through various government departments, science councils, universities and local and global firms working together. The potential of science, technology and innovation (STI) to help society navigate not only the pandemic, but also to support job creation in general and to enhance socio-economic welfare was once again brought home.

Recent reviews show that the 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 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 remained relatively flat.

South Africa therefore needs updated policy responses to expand the role that STI can play in, for instance, reindustrialisation, service delivery, modernising the agricultural sector, and mitigating environmental degradation. The aim of the 2019 White Paper on Science, Technology and Innovation (STI) is to build on the successes of the past in developing the NSI, and to enhance the impact of STI on South Africa's challenges to increase economic growth, further social development and support environmental sustainability. The White Paper will be implemented through decadal plans. There has been extensive consultation with stakeholders on this first Decadal Plan, in particular with the Interministerial Committee (IMC) on STI, other STI-intensive government departments, business associations, academia, the Parliamentary Portfolio Committee on Higher Education, Science and Innovation, civil society and the National Economic Development and Labour Council (Nedlac).

To give effect to the policy ambitions expressed in the 2019 STI White Paper, the Decadal Plan identifies societal grand challenges (SGCs) where research, development and innovation (RDI) can support the development of solutions, e.g. in the areas of climate change and education for the future. The Decadal Plan also focuses on innovation to address health and energy, as well as exploit new sources of growth such as the digital economy.

To support the implementation of the above thematic priorities, interventions aimed at a new governance and funding regime are contained in the Decadal Plan. Firstly, an Interministerial Committee on STI will coordinate government's STI endeavour and allocate funding across government for STI programmes. Secondly, a Presidential STI Plenary will bring together representatives from all NSI actors to regularly review and make recommendations on expanding the NSI. Thirdly, a public budget coordination process for STI will form part of the annual Medium-Term Expenditure Committee processes to improve the allocation of resources for STI and assist STI-intensive government departments to set aside an appropriate percentage of their budgets for RDI.

The Decadal Plan also aims to address the need to develop South Africa's innovation capacity, build and transform STI human resources, strengthen and transform the research enterprise, and expand partnerships and linkages through science diplomacy.

It is with pleasure that I introduce the 2022 STI Decadal Plan, which was approved by Cabinet on **xxx**. I want to thank all NSI partners, and especially our sister departments, who helped develop the Decadal Plan – as well as the Director-General and Department of Science and Innovation (DSI) officials who worked tirelessly on the finalisation of the plan.

I believe that as government, along with its academic, social and business partners, moves forward in a coordinated manner to fund and implement the initiatives prioritised in this Decadal Plan, the impact of STI on South African society will grow significantly to support inclusive economic growth, social development and environmental sustainability. I look forward to us building on and expanding the progress that has been made in the NSI since 1996.

Dr BE Nzimande
Minister of Higher Education, Science and Innovation

DEPUTY MINISTER'S FOREWORD

Since the release of the first White Paper on Science and Technology in 1996, shortly after the attainment of democracy in South Africa, the government has been committed to supporting the national system of innovation (NSI). Government's investment has resulted in significant development in the NSI over the ensuing years. Most notably, while the transformation of the NSI is an ongoing process, the shape and size of the system has changed to reflect more closely the growth and development ambitions of South Africa, as well as the demographic make-up of her population.

With the 2019 White Paper on Science, Technology and Innovation (STI) the focus shifted from developing the system to enhancing the outputs of the NSI, and in particular, its impact on South Africa's national priorities. As the implementation plan of the 2019 White Paper, the Decadal Plan defines the initiatives that government, working with business, academia, civil society and labour, will fund and drive to give effect to the White Paper policy ambitions. The Decadal Plan is not only thematically focused on the global challenges of our time, such as climate change and the future of society, but also puts in place a more coordinated approach to managing and funding the public STI endeavour.

A significant part of this coordinated approach is the establishment of a close working relationship between the Department of Science and Innovation and the Department of Higher Education and Training. This is in keeping with international good practice, which puts education and training at the centre of national RDI policies. In South Africa, one of the structural constraints to socio-economic growth and development relates to the high levels of unemployment, especially among low-skilled workers. Therefore, the focus on education and training in the Decadal Plan is to be welcomed.

Furthermore, the Decadal Plan addresses one of the main impediments to the NSI's performance, namely, inadequate levels of funding. The Decadal Plan contains measures to attract increased investment from international sources and business, as well as to pool public funding to support large STI programmes at critical mass to maximise their impact.

I am confident that, through the efficient implementation of these and other initiatives in the Decadal Plan by role players in the public and private spheres, the lives of our people and the fortunes of our communities will be transformed through STI.

Mr Buti Manamela
Deputy Minister of Higher Education, Science and Innovation

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 STI in a more prosperous and inclusive society. The Decadal Plan serves as an implementation plan for the White Paper. The Decadal Plan philosophy is to continue building the NSI, while at the same time pivoting the NSI to have a greater impact on addressing South Africa's national priorities. Science, technology and innovation are, however, a global endeavour, and the Decadal Plan therefore also focuses on the role that STI can play in engaging with, and thriving amid, global trends such as geopolitical shifts and climate change. The Decadal Plan, like the 2019 STI White Paper, emphasises the role of STI in developing the African continent to give effect to our joint ambitions and help address our challenges as Africans. In this respect, science diplomacy enjoys a significant focus in the Decadal Plan.

To maximise the considerable potential of STI to help South Africa thrive in a challenging and changing environment, the Decadal Plan introduces new thematic focus areas and re-emphasises the relevance and importance of current research, development and innovation (RDI) plans.

To address global trends, the Decadal Plan identifies three Societal Grand Challenges (SGCs) – climate change and environmental sustainability, education for the future, and the future of society (including a focus on the future of work). In addition, the Decadal Plan identifies focus areas for large innovation programmes to address specific South African challenges, namely, health, energy and a capable state. The Decadal Plan also contains interventions aimed at modernising mining, manufacturing and agriculture. Lastly, the Decadal Plan expands on plans to exploit new sources of economic growth for South Africa, particularly the circular and digital economies.

In continuing to develop the NSI, the Decadal Plan highlights initiatives aimed at expanding and transforming the human resource base of the NSI and strengthening and transforming the research enterprise. In these respects, the Decadal Plan aims to develop greater synergies between the programmes of the Department of Science and Innovation and the Department of Higher Education and Training – placing education and skills development at the centre of STI policy. In most instances, the Decadal Plan initiatives on education and the research system find resonance with the recommendations of the Ministerial Review Panel on the Higher Education, Science, Technology and Innovation Institutional Landscape. The Decadal Plan therefore also deals with these recommendations.

To support the IMC and STI Plenary with analysis and advice on innovation, the Decadal Plan contains initiatives to strengthen the National Advisory Council on Innovation (NACI). Furthermore, to improve the overall innovation performance of South Africa, the Decadal Plan gives effect to an innovation and skills compact that will see government departments and other NSI actors commit to addressing issues such as the leakage of intellectual property, and the public procurement of locally developed technologies. To ensure that all of these initiatives remain on track, the Decadal Plan proposes a new monitoring and evaluation framework for the NSI, through which the socio-economic impact of STI will be monitored and reported on by NSI actors.

Since as far back as 2008 when the Organisation for Economic Cooperation and Development reviewed the South African NSI, the significant underfunding of RDI was identified as a factor impeding the performance of the NSI. Therefore, the Decadal Plan looks at initiatives to

ensure that the allocation of public funding for STI is improved, as well as that funding from across government is pooled to fund priority programmes. In particular, the Decadal Plan emphasises a public STI budget coordination process, as well as an STI investment framework developed by a renewed NACI to guide the funding of STI in South Africa.

In the spirit of co-learning, and to garner support for its ambitious agenda, the Decadal Plan has taken into consideration input received from relevant government departments, science entities, business, civil society, Nedlac, academia and STI experts.

With the release of this Decadal Plan, I am confident that South Africa will reap increased benefits from STI to help realise our national priorities. I am excited about the significant progress that lies within our grasp if we work together for the benefit of our country.

Dr Phil Mjwara
Director-General of Science and Innovation

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ABBREVIATIONS

4IR	Fourth Industrial Revolution
AAMP	Agriculture and Agroprocessing Masterplan
AI	artificial intelligence
API	active pharmaceutical ingredients
ARIPO	African Regional Intellectual Property Organisation
ASSAf	Academy of Science of South Africa
AU	African Union
BRICS	Brazil, Russia, India, China and South Africa
CE	circular economy
CET	community education and training
CIPC	Companies and Intellectual Property Commission
CoC	centre of competence
CoE	centre of excellence
CPSI	Centre for Public Service Innovation
DDM	District Development Model
DHET	Department of Higher Education and Training
DIRCO	Department of International Relations and Cooperation
DIRISA	Data-intensive Research Initiative of South Africa
DMRE	Department of Mineral Resources and Energy
DPME	Department of Planning, Monitoring and Evaluation
DSI	Department of Science and Innovation
DCDT	Department of Communications and Digital Technologies
DSBD	Department of Small Business Development
DTIC	Department of Trade, Industry and Competition
EPO	European Patents Office
GDP	gross domestic product
GERD	gross expenditure on research and development
HDI	historically disadvantaged institution
HEI	higher education institution

HESTIIL	higher education, science, technology and innovation institutional landscape
HSRC	Human Sciences Research Council
ICT	information and communications and technology
IDC	Industrial Development Corporation
IKS	indigenous knowledge systems
IMC	Interministerial Committee on STI
IoT	Internet of Things
IP	intellectual property
IPR	intellectual property rights
IPR Act	Intellectual Property Rights from Publicly Financed Research and Development Act
M&E	monitoring and evaluation
MERL	monitoring, evaluation, reflection and learning
NACI	National Advisory Council on Innovation
Nedlac	National Economic Development and Labour Council
NDP	National Development Plan
NIPMO	National Intellectual Property Management Office
NP-PSET	National Plan for Post-School Education and Training
NRF	National Research Foundation
NSDS	National Skills Development Strategy
NSI	national system of innovation
NEET	not in education, employment or training
OECD	Organisation for Economic Cooperation and Development
PSET	post-school education and training
PRI	public research institution
R&D	research and development
RDI	research, development and innovation
SA	South Africa
SADC	Southern African Development Community
SAEON	South African Environmental Observation Network
SANReN	South African National Research Network
SANSA	South African National Space Agency

SARChI	South African Research Chairs Initiative
SDG	Sustainable Development Goals
SETA	sector education and training authorities
SET	science, engineering and technology
SGC	societal grand challenge
SKA	Square Kilometre Array
SMM	strategic management model
SMME	small, medium and micro-enterprise
SOE	state-owned entity
STAs	scientific and technological activities
STEM	science, technology, engineering and mathematics
STI	science, technology and innovation
STIIL	science, technology and innovation institutional landscape
TIA	Technology Innovation Agency
TVET	technical and vocational education and training
TYIP	Ten-Year Innovation Plan
UoTs	universities of technology
USPTO	United States Patent and Trademark Office

DEFINITIONS

Black people: African, coloured, Indian and South African Chinese people who are natural persons and South African citizens.

Centre of competence: A collaborative entity, preferably led by industry, that is resourced by highly qualified researchers associated with public research institutions, and that undertakes market-focused research and technology development to benefit industry and the economy.

Centre of excellence: 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, and will enhance the pursuit of research excellence and capacity development.

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 and system-wide innovation, it aims to redefine products and services to reduce waste and the negative impacts of waste.

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

Established researchers: Active researchers who have established themselves as independent researchers and who have solid research track record. They produce the bulk of the research output and play an important role in training and mentoring.

Fourth Industrial Revolution or 4IR: The era in which technological developments blur the lines between the physical, digital and biological, integrating cyber-physical systems and the Internet of Things, big data and cloud computing, robotics, artificial intelligence 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 society.

Grassroots innovation: Diverse 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 communities have control over the process and outcomes.

Human and social 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 skills required for the NSI.

Innovation: The implementation of a new or significantly improved product (goods or services) or process, or a new marketing method, or a new organisational model in business practice, workplace organisation or external relations.

Megatrend: A social, economic, technological, environmental or geostrategic force that is shaping the world in profound ways, with implications that are broad and varied, and present tremendous opportunities and risks.

National facility: A research institution managed by the National Research Foundation (NRF), centred on substantial instrumentation, equipment or skills bases. The national facilities

constitute indispensable infrastructure platforms that help advance research areas of strategic importance. The national facilities create the foundation for South African researchers to compete globally and train postgraduates.

National system of innovation: There is no single accepted definition for this. What is important is the web of interaction in the system. It is a system of interconnected institutions that create, store and transfer the knowledge, skills and artefacts that define new STI.

Office of technology transfer: Located at a university or science council, an office of technology transfer is focused on facilitating the identification, protection and use of intellectual property (IP) that emanates from publicly funded research and development at the institution for social and/or economic benefit. The office helps researchers to translate their IP into useful and innovative products and services. It gives industry access to this IP to further develop and commercialise it.

Open innovation: The basic premise 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, foster a stronger culture of entrepreneurship and encourage firms to use internal and external ideas, and internal and external paths to market.

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

Policy coherence: The systematic promotion of mutually reinforcing policies across government departments in order to create synergies that will facilitate the achievement of agreed objectives and minimise duplication and negative spillovers in other policy areas.

Policy coordination: The alignment of programmes and activities across various role players to give effect to policy objectives.

Public research institution: One of a heterogeneous group of research organisations with varying degrees of governmental influence on their research activities and funding. Their roles 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: 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: Implemented though section 11D of the Income Tax Act, the incentive is designed 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 taxable income. The incentive is available to businesses of all sizes and in all sectors of the economy.

Research infrastructure: This includes facilities, resources and services used by the science community to conduct research and foster innovation.

Responsible research and innovation: This is the production of ethically acceptable, sustainable and socially desirable research and innovation outcomes.

Sector-specific science councils: A council that is at the forefront of developing technologies that can be applied in a particular sector (e.g. mining, healthcare, social sciences), terminology and culture. They provide trustworthy and impartial scientific and technological support to government. Such councils include the South African Medical Research Council, the Council for Scientific and Industrial Research, the Human Sciences Research Council and Mintek.

Science diplomacy: Scientific cooperation and engagement with the explicit intent of building positive relationships with other governments and societies. This might include providing scientific advice to inform foreign policy objectives, facilitating international science cooperation, and 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: This is a subset of innovation that is cross-sectoral and distinct from business or technological innovation. Social innovation is context-specific, is underpinned by value systems leads to specific outcomes that are a measurable improvement on existing practices, changes social relations for effective governance, and empowers beneficiaries.

South African Research Chairs Initiative: This initiative is designed to attract and retain excellence in research, development and innovation (RDI) at South African public universities through the establishment of research chairs with a long-term investment trajectory. They strengthen the RDI capacity of public universities to produce high-quality postgraduate students and outputs.

Technology balance of payments: According to the OECD1, a country's technology balance of payments registers the commercial transactions related to international technology and know-how transfers. It consists of money paid or received for the use of patents, licences, know-how, trademarks, patterns, designs, technical services (including technical assistance) and for industrial research and development carried out abroad, etc.

Technology Localisation Programme: This provides technological assistance to local firms to increase their competitiveness and help ensure that greater use is made of local production and services, specifically where government or its state-owned entities are procuring capital or operational goods. Its primary aim is to support the local supplier base to participate in government procurement initiatives.

Technology Stations Programme: This enables universities of technology to provide technology development services to SMMEs, providing innovative STI solutions for complex engineering challenges in relevant industrial sectors to support government's socio-economic priorities.

Transdisciplinarity: Research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological and translational

[1] https://stats.oecd.org/glossary/detail.asp?ID=2693

innovations that integrate and move beyond discipline-specific approaches 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.

CHAPTER 1: BASIC PHILOSOPHY OF THE DECADAL PLAN

1.1 Introduction

Science, technology, and innovation (STI) are critical to a competitive and sustainable economy and for addressing societal challenges. The STI Decadal Plan (the Decadal Plan) sets out to (a) pivot the national system of innovation (NSI) towards an increased positive impact on South Africa's socio-economic and environmental priorities, and (b) maintain equilibrium between impact (e.g. inclusive innovation) and continued investment in and development of the NSI. The latter includes systemic enablers such as human resource development, institution building, infrastructure, knowledge production and international collaboration.

This Decadal Plan implements the vision of the 2019 White Paper on Science Technology and Innovation (the White Paper), namely, STI "enabling inclusive and sustainable South African development in a changing world". It emphasises STI priorities aligned with key sectors of the economy (agriculture, manufacturing, mining, health, energy, and the digital and circular economies), as well as three Societal Grand Challenges (SGCs), namely, climate change, future-proofing education and skills, and the future of society. It proposes a new strategic management model, a budget coordination process and an innovation compact as critical components of the NSI governance architecture.

1.2 Context: The National Development Plan and STI White Paper

The National Development Plan (NDP) is a long-term plan for South Africa, developed in 2012 by the National Planning Commission in collaboration with South Africans from all walks of life. It serves as an action plan to secure the future of the country as envisaged in the Constitution. Its broad objective is to eliminate poverty, reduce inequality and ensure a decent standard of living for all South Africans by 2030. It recognises STI as vital enablers of economic growth and employment, and therefore sets targets for PhD production, research activity, the productivity of STI investment, and the efficiency of STI institutions.

Aligned to the NDP, the White Paper sets the long-term policy direction for the South African government to ensure a growing role for STI in a more prosperous and inclusive society – accelerating inclusive and sustainable socio-economic development, and enhancing competitiveness, quality of life and well-being. The White Paper recognises that the world is changing rapidly and fundamentally. The 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. blurring of lines between the physical and digital spheres because of ICTs and the Fourth Industrial Revolution or 4IR), and environmental (noting climate change's severe consequences for the world, particularly it most vulnerable people). These global megatrends and drivers render even the near future uncertain. There are critical implications for how South Africa (SA) interprets and responds to this changing world.

People should not be left behind as society and the economy become more technologically driven. STI has a fundamental role in achieving the sustainable development goals (SDGs). South Africa's future is inextricably linked to that of the African continent, and therefore the potential of STI for African development and continental integration needs to be fully exploited.

Since 1996, the NSI has made notable progress in using STI to address societal challenges.

NSI successes: The establishment of new institutions such as the Technology Innovation Agency (TIA), South African National Space Agency (SANSA) and National Intellectual Property Office (NIPMO); deepened linkages between the Department of Science and Innovation (DSI) and other government departments such as the Department of Trade, Industry and Competition (DTIC); and increased business support and public funding, grassroots innovation and technology start-ups.

Remaining challenges: STI policy remains fragmented across government and between business, academia and civil society, there is continued and significant underfunding of the NSI, and the participation of black people and women at senior level (e.g. professors) remains low.

As noted in the OECD Science, Technology and Innovation Outlook 2021, the Covid-19 pandemic has stretched the STI systems across the world to their limits, revealing areas that need strengthening to improve resilience and preparedness for future crises. Leaving such limitations unattended could impact the power of STI to promote and deliver transitions.

Looking ahead, the Decadal Plan builds on the foundation of the NSI (Figure 1.1) and pivots the system to address societal challenges and contribute towards accelerated knowledge and innovation-driven, inclusive, sustainable socio-economic development.

The NSI initially focused on establishing institutions and developing policies to serve the interests of all. Then it ramped up its response to the demands of a democratic South Africa, and from 2019 onwards it has seen an increased focus on contributing to socio-economic development, environmental sustainability and a capable state.

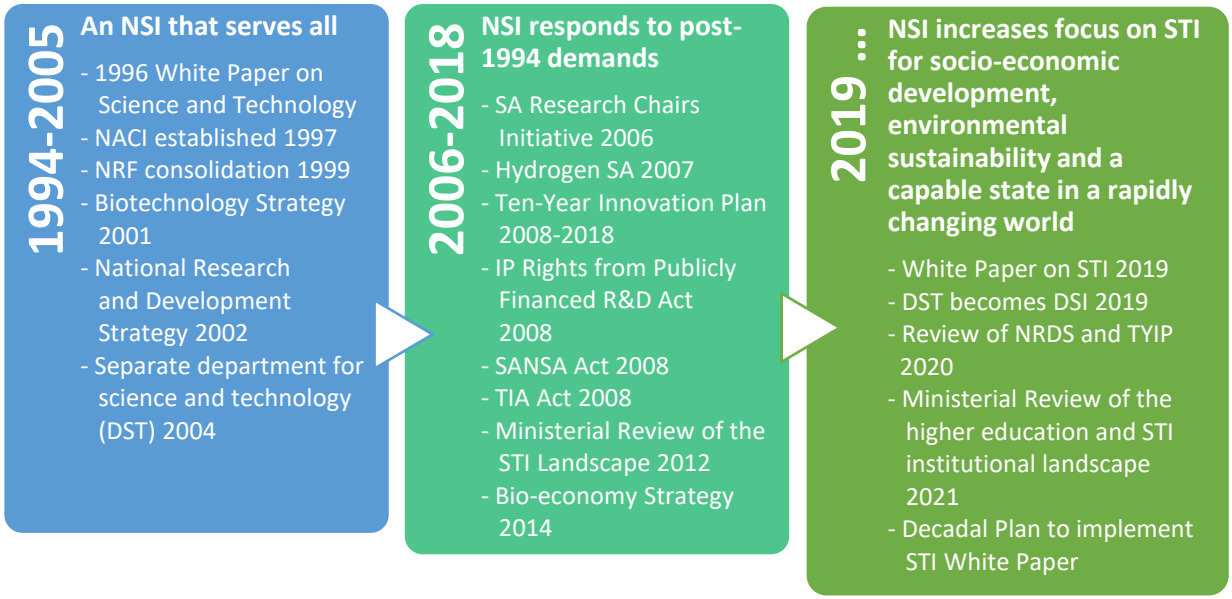

Figure 1.1: Overview of NSI policy and institutional development, 1994 to the present

1.3 Redirecting the NSI

The structure of the South African economy continues to be shaped by colonial and apartheid legacies. The stubbornly low economic growth rate continues to compound the challenges of poverty, unemployment and inequality. Developmental progress to date has been uneven across the various dimensions of the socio-economic landscape. South Africa faces a growing

demand by multiple population segments for a more inclusive and equitable economy. Tackling the country's numerous socio-economic challenges requires novel strategies with multipronged approaches.

Strategic planning, resource mobilisation and intensive human resource development investment are essential preconditions for building the required capabilities — as exemplified by countries such as Japan, Korea, Taiwan and China.

Export growth and international competitiveness require sustained investment in innovation. The total value of goods and services exported by South Africa has been growing steadily, to about 30% of gross domestic product (GDP) in 2022. However, exports still rely heavily on ores and metals, which account for nearly 30% of total export value. High-tech manufactured exports, which represent the degree of technological competitiveness in global markets, account for less than 5% of the value of all manufactured exports, a rate well below China's 33%.

The global Covid-19 pandemic has been devastating, and exacerbated existing economic, ecological and social crises. In response, the government introduced an Economic Reconstruction and Recovery Plan for SA in October 2020, in which the potential of STI, and specifically innovation, to support the country's turnaround is evident.

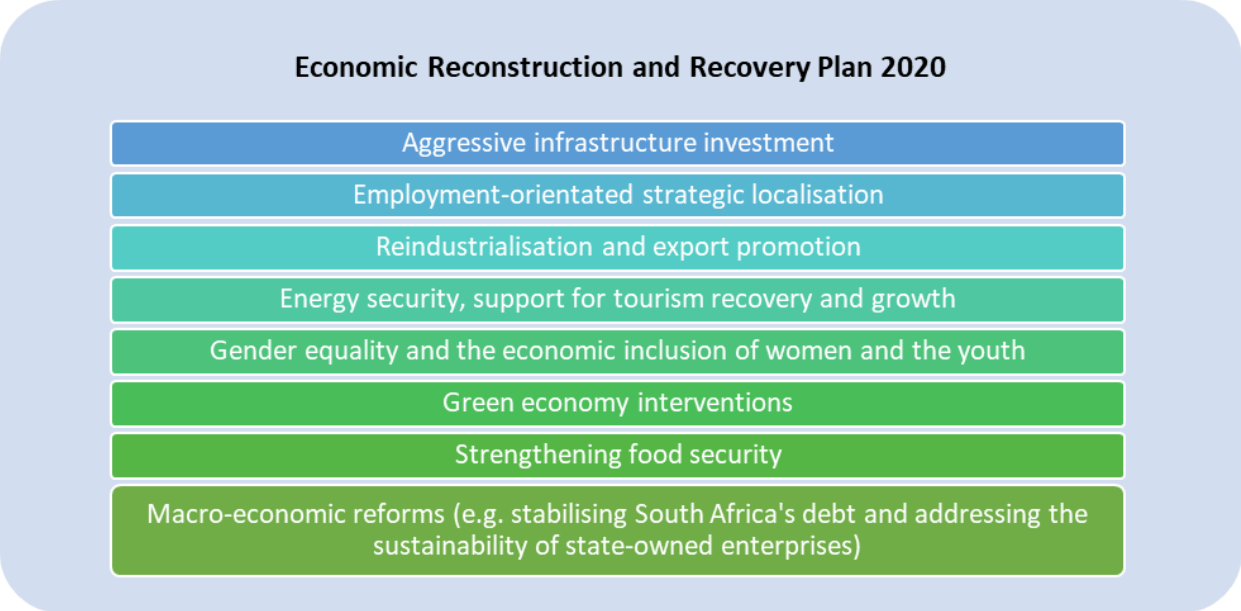

Figure 1.2: South Africa's Economic Reconstruction and Recovery Plan

The White Paper advocates a purposeful approach to increasing STI's impact on addressing the challenges, while considering environmental sustainability. This approach is anchored in the NDP ambitions for South Africa and the SDGs.

Inclusive innovation or innovation for inclusive development, in which all citizens share in the benefits, is central to the White Paper. This encapsulates a broader view of actors, forms of innovation and the spatial footprint of innovation. It means supporting communities and civil society to innovate, embracing a more diverse knowledge system (including indigenous knowledge systems (IKS) and addressing the "decolonisation of knowledge"), and using innovation to improve service delivery, government decision making, educational outcomes and broadband access. Inclusive innovation improves science literacy and awareness, as well

as demographic representation across the NSI. For example, using intellectual property from publicly funded R&D to establish new firms and support small, medium and micro-enterprises (SMMEs) has the potential to change the ownership profile of the economy.

1.4 Potential impacts

The Decadal Plan proposes a transdisciplinary process to analyse, quantify and develop a set of impact measures that can be used to recalibrate, refocus and scale up the contribution of innovation to socio-economic development.

Box 4: Potential impacts of innovation for socio-economic development

- **Job creation:** According to the World Bank, innovation in any sector potentially creates jobs and raises the consumption of the poorest 40% of households at the aggregate level. In 2011, the Green Jobs Report estimated that SA could create 462 000 additional jobs in the long term by investing in clean energy generation, improvements in energy efficiency, pollution control, and sustainable natural resource management[1].
- **Skills development:** The South African government has implemented a sophisticated system to support entrepreneurship, technology absorption and innovation in the private sector, including measures across the education sector to drive training and skills development for the future.
- **Export growth and competitiveness:** Disruptive technologies can strengthen competition (e.g. e-hailing service Uber disrupted the taxi industry's vested interests). Reducing mark-ups realised in dominant market positions by 50% could recognise 300 000 additional jobs and lift 600 000 people out of poverty.[2] The DTIC's National Exporter Development Programme focuses on increasing exports, particularly products and services that add value and contribute to employment and the green economy.[3]
- **Access to healthcare:** Vula (a mobile app for healthcare) connects healthcare workers in remote areas and provides a secure, safe platform to receive advice on patient treatment plans and refer patients to specialist services and departments.
- **Poverty reduction:** Poorer households gain most from innovation in public transport, electricity, food, footwear, beverages and agriculture. Owing to the number of unskilled and semi-skilled people employed in the mining sector and dependent on social housing, innovations in these sectors can alleviate poverty. [4]
- **Innovation and 4IR:** coordinates SA's efforts to position the country as a leader in this area, supporting socio-economic development and innovation.

Source: Department of Trade, Industry and Competition (2013). The National Exporter Development Programme. http://www.thedtic.gov.za/wp-content/uploads/NEDP_Booklet.pdf

1.5 Transformative change, sustainability transitions, inclusivity

The Decadal Plan seeks to use STI to meet social needs and contribute to sustainable and inclusive societies at a more fundamental level[5]. Challenges in this regard have been described as "intractable" impediments to transformation and socio-economic growth. A strong approach, with an emphasis on the system-wide transformation of socio-technical systems, is needed to deal with these challenges decisively. If the White Paper is not implemented optimally to improve institutions and practices in energy, mobility, healthcare, agriculture, and water management, South Africa is unlikely to respond adequately to societal challenges.

[1] Giordano et al (2011) Green Jobs: An Estimate of the Direct Employment Potential of a Greening South African Economy. Industrial Development Corporation, Development Bank of Southern Africa, Trade and Industrial Policy Strategies

[2] World Bank. 2017. South Africa Economic Update: Innovation for productivity and inclusiveness. Washington DC: The World Bank.

[3] Department of Trade, Industry and Competition (2013), January 2013.The National Exporter Development Programme (NEDP) http://www.thedtic.gov.za/wp-content/uploads/NEDP_Booklet.pdf

[4] World Bank. 2017. South Africa Economic Update: Innovation for productivity and inclusiveness. Washington DC: The World Bank.

5 Schot and Steinmueller (2016). Framing innovation Policy for Transformative Change: Innovation Policy 3.0

By embracing transformative change, the Decadal Plan promotes the broadest concept of innovation beyond its traditional focus on invention, to include innovation and the impacts arising from embedding innovation in society, far beyond support for R&D and the prioritisation of specific research avenues. It encourages the involvement of a wide range of actors from the private sector and knowledge producing institutions, to users, NGOs and governments.[1]

Transformative change seeks to support the transition processes of socio-technical ecosystems towards continuously opening windows of opportunity and sustainable growth. Multi-level perspectives are required to explain the interactions and continuous learning and knowledge sharing between regimes, niches and landscapes, as shown in Figure 1.3. These three levels can be understood as the three levels of operation. The landscape, at a macro-level, consists of "influencers" at national or international level, pressing socio-economic and environmental issues such as the Paris Agreement, or goals and frameworks such as the SDGs. These influencers can define the transformation required and strongly direct policies transnationally, giving rise to a distinct type of transformative policy that seeks to respond to demands at the landscape level (Figure 1.3).

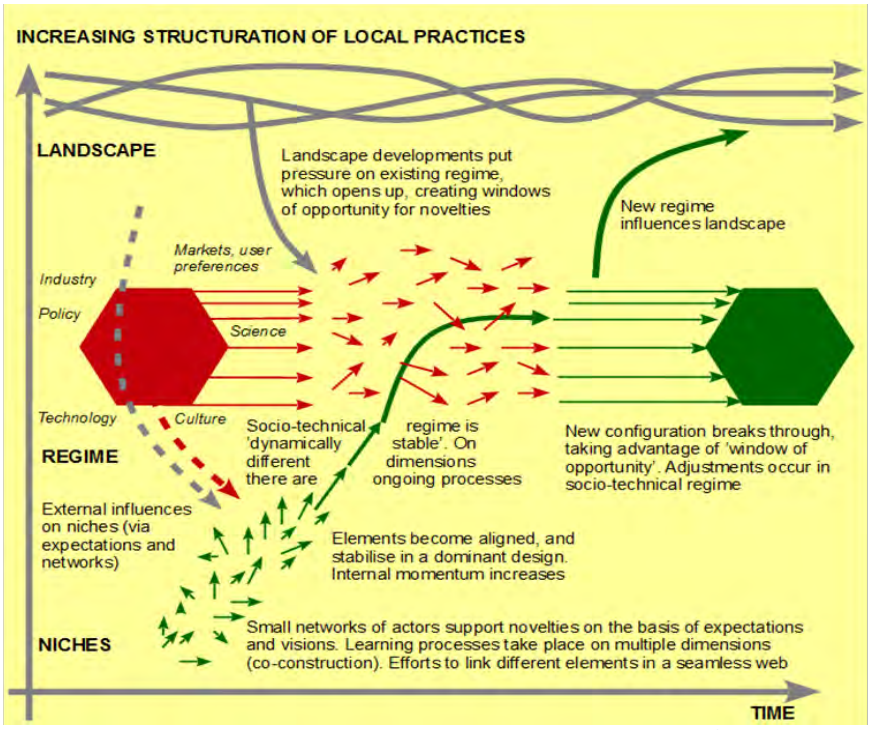

Figure 1.3: Multi-level perspectives on socio-technical transition[2]

Governments often follow a set of policies that may be outdated and not transformative. For instance, there might be policies that support the use of coal (which contributes to greenhouse gases) and prevent the transformation of the energy sector to address climate change. Likewise, over time, people become used to unsustainable socio-technical systems, believing the materials and technical elements for these are easily accessible and affordable.

1 Daniels, Schot, Chataway, Ramirez & Steinmueller (2020) Mapping New Approaches to Innovation Policy for Stronger Transformative Outcomes in Africa

2 Geels and Schot (2017). The Socio-Technical Dynamics of Low-Carbon Transitions, Schot and Kanger (2016). The roles of users in shaping transitions to new energy systems; Geels (2002) Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study.

The transformative change embedded in the Decadal Plan can facilitate the transition of established socio-technical systems in areas such as agriculture, mining, manufacturing, energy and water, to more sustainable systems.

1.6 Systemic enablers, values and principles, efficiency and sustainability

The implementation of the SGCs and STI priorities requires a "whole-of-government" approach, stronger policy coordination and alignment, and increased investments. In this regard, the Decadal Plan proposes a new strategic management model, a budget coordination process, and an innovation compact (including research, development and innovation or RDI plans). It proposes various initiatives to expand and transform human resources and research systems and deepen international collaboration. The values guiding the development and implementation of the Decadal Plan are shown in Figure 1.4. The significance of these values is ultimately manifested in the outsider's view of South Africa's shared perceptions of accountability and of desirable, responsible practices.

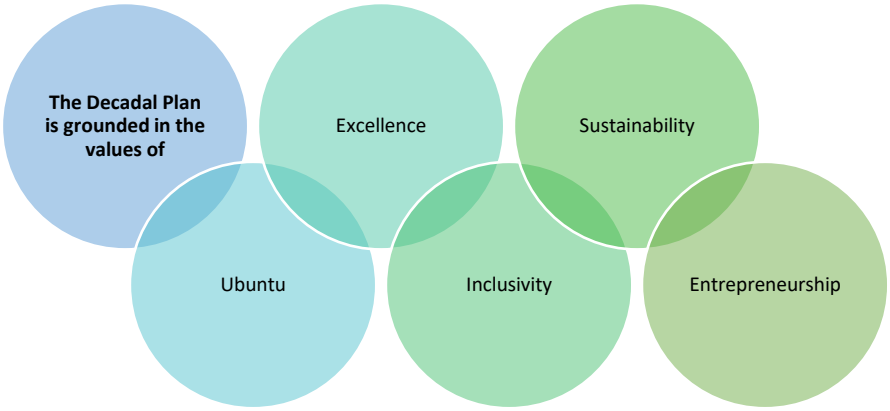

Figure 1.4: Values guiding the implementation of the Decadal Plan

These values find expression in a commitment to transformation (demographic, institutional, geographical) and inclusivity; a balance between innovation-driven socio-economic impact and basic science; and a recognition of the contribution of all scientific fields to innovation; as well as in agility, responsiveness and entrepreneurship, and in efficient and sustained implementation.

To ensure that the potential of innovation to contribute to SA's socio-economic ambitions is realised, the Decadal Plan prioritises a suite of systemic enablers, such as increased funding, joint programmes and coordination, high-level and technical skills for the economy, transdisciplinary knowledge creation, increased links between government and business, and improved monitoring and evaluation (Chapter 10).

While the Decadal Plan aims to increase SA's innovative capabilities, the basic sciences and curiosity-driven research will continue to receive support.

1.7 Implementation of the Decadal Plan: Risk mitigation

The implementation of any (national) plan depends on several critical success factors. These include –

- clear implementation strategies with realistic and achievable outputs and targets;
- appropriate resourcing of core activities;

- sustained commitment and support by key actors ("champions") in the NSI;
- sufficient adaptability to respond to unforeseen exogenous developments.

Arguably the greatest threat to the successful implementation of the Decadal Plan is the fiscal crisis and related cuts to the budgets of STI-intensive departments, exacerbated by the weak global demand for South Africa's products and low business confidence in the aftermath of the Covid-19 pandemic. To mitigate this risk, it will be necessary to intensify advocacy for STI at the highest levels of government through the Interministerial Committee on STI (Chapter 8), to develop stronger partnerships with industry through the STI Presidential Plenary and the Sector RDI Plans (Chapter 8) and to illustrate the impact of the NSI by moving rapidly on a small number of focused, high-profile and high-impact initiatives (Chapter 3).

Strategies to secure financial resources for the implementation of the Decadal Plan are discussed in Chapter 9. It is expected that the policy certainty that will result from a more coherent and better coordinated NSI (Chapter 8) will attract private sector and international funding. Using the NDP vision as an analogy, it is further envisaged that STI investment will lead to "a virtuous cycle of growth and development" over the medium to longer term.

1.8 The structure of the Decadal Plan

Although some time has passed since the adoption of the White Paper — with the accompanying drastic developments of the Covid-19 pandemic and increasing understanding of the enormous challenges related to climate action — the 2019 White Paper on STI remains the main reference for the Decadal Plan. The links between the key challenges facing the South African NSI and the eight goal statements that were formulated to address them are illustrated in Figure 1.5.

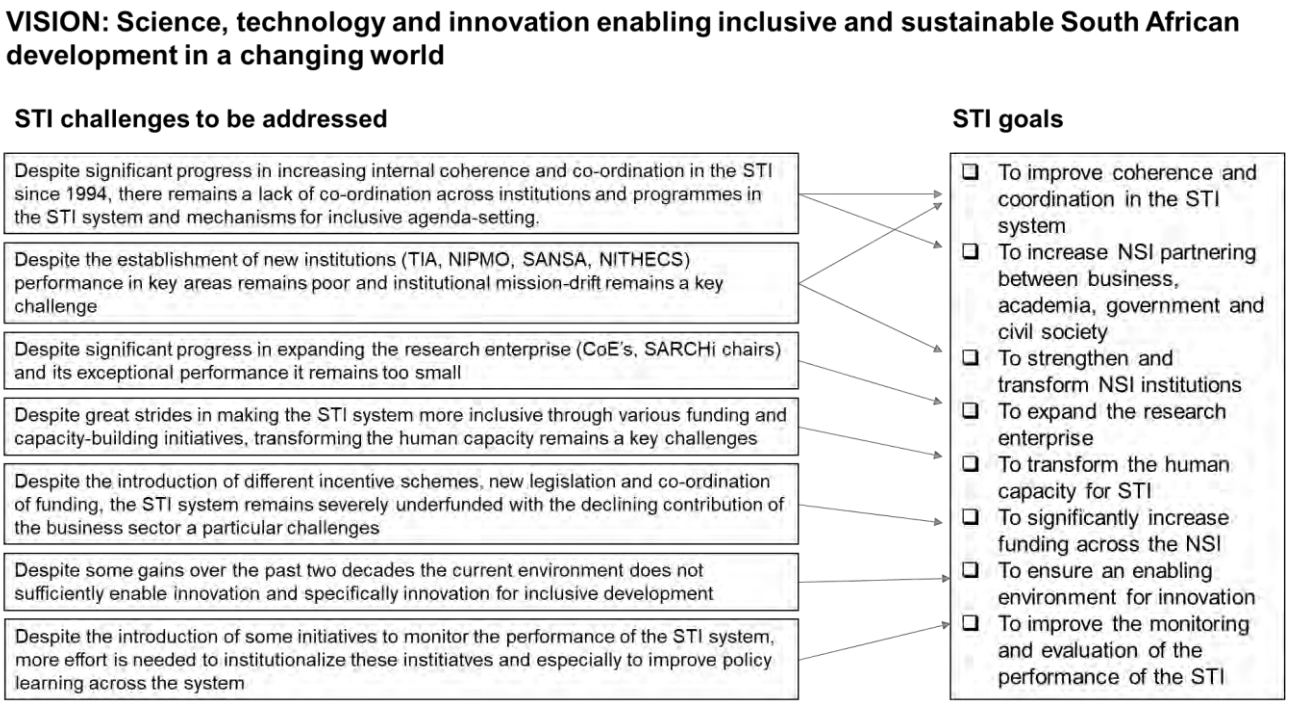

Figure 1.5: Links between STI challenges and STI goals in the 2019 White Paper

Given the logic and structure of the White Paper, the *Decadal Plan* follows the same framework.

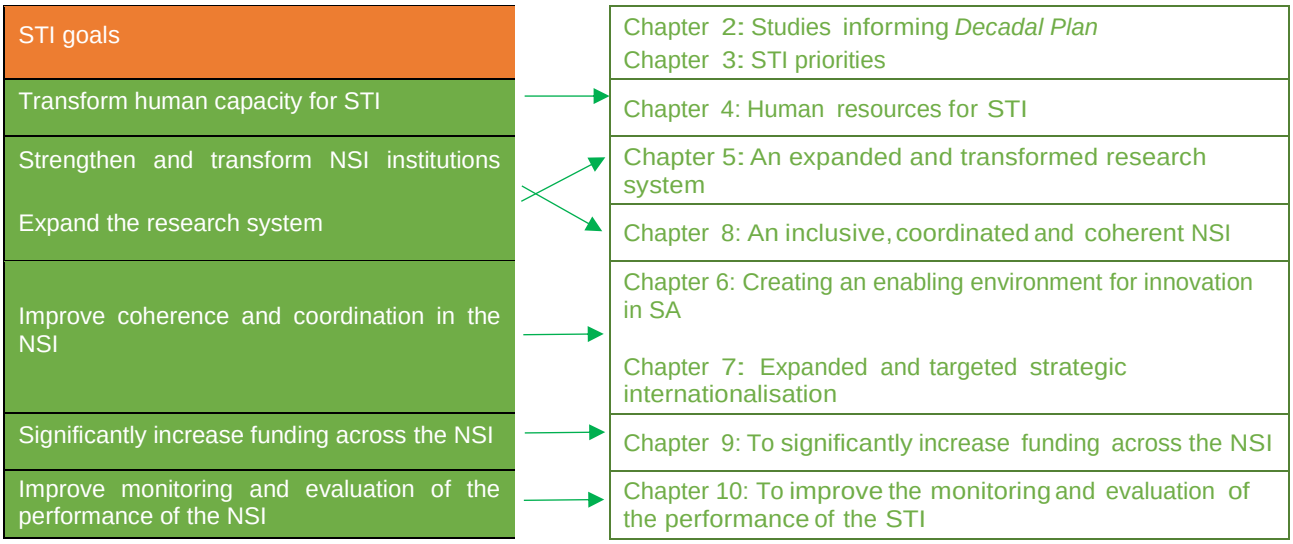

Figure 1.6: How the STI goals map to the Decadal Plan chapters

CHAPTER 2: STUDIES INFORMING THE DECADAL PLAN

2.1 Approach of the Decadal Plan

The Decadal Plan is built on the vision of the 2019 White Paper on STI, which is science, technology and innovation enabling sustainable and inclusive development in a changing world. The White Paper builds on previous successes and embraces technological change for socio-economic and environmental impact.

The Decadal Plan has three mutually reinforcing aims, namely, pivoting the NSI so that it can have a greater effect on SA's socio-economic and environmental priorities; maintaining equilibrium between a focus on impact and continued investment to develop the system; and the transformative role of innovation. Achievement of these aims is reflected in the structured focus illustrated in Figure 2.1 below.

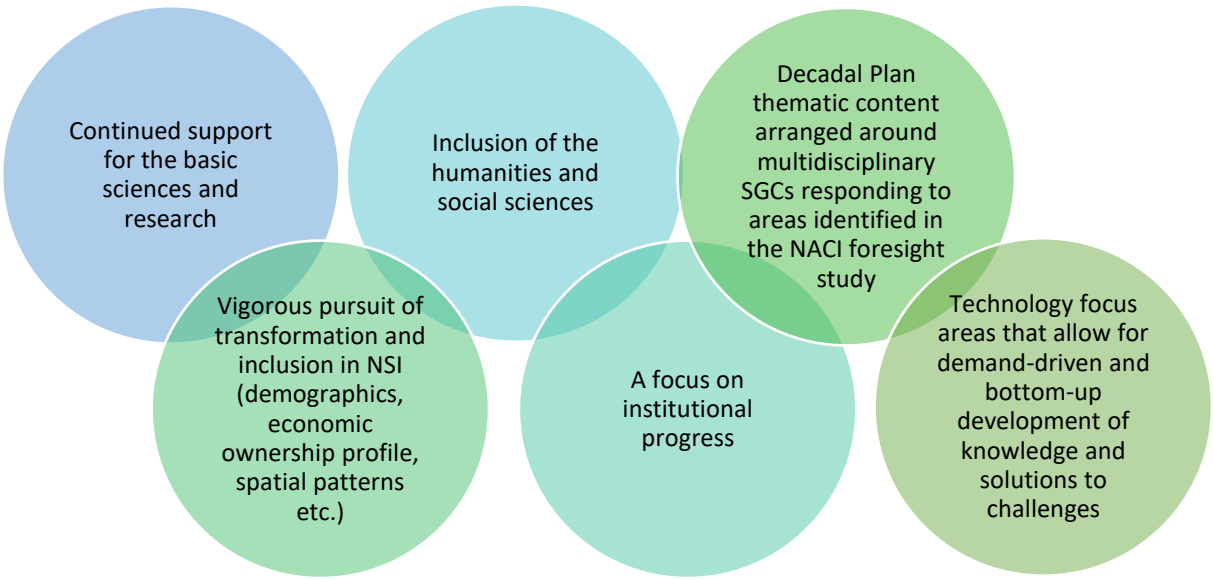

Figure 2.1 Some outcomes of this approach

Like the White Paper, the Decadal Plan aims to retain what is working in the NSI and stop what is not. However, as reflected in Figure 2.1, if a discipline is not mentioned in the Decadal Plan, this does not mean funding is to stop. The National Advisory Council on Innovation (NACI) Review of the National Research and Development Strategy and the Ten-Year Innovation Plan, published in May 2020, looked at institutional progress and identified the successes and weaknesses in the implementation of these policy documents.

Further studies, in particular, the NACI-led South African Foresight Exercise for Science, Technology and Innovation 2030, identified a set of priority areas that include the circular economy, education for the future, sustainable energy, the future of society, health innovation, high-tech industrialisation, ICTs and smart systems, nutrition security, and water security. This chapter focuses on identified priorities that will enable the NSI to assist South Africa to achieve the objectives of the NDP.

2.2 Rationale for priorities

The government funds RDI in the NSI, supporting initiatives in areas ranging from basic and fundamental research to enhanced technology transfer and diffusion from the science sector.

This requires (and produces) skilled human resources, infrastructure, effective hard technology transfer mechanisms, and the more effective and efficient use of technology in the business and government sectors.

The government needs to prioritise areas that will stimulate higher and inclusive economic growth, speed up socio-economic development, improve service delivery, improve government decision making, enhance the efficiency of institutions, and promote environmental sustainability.

The Decadal Plan seeks to respond to the NDP STI targets that propose that innovation be earmarked to improve the productivity and competitiveness of key sectors of the economy and to contribute to higher GDP growth overall. The NDP, White Paper and SDGs all call for transformative change to socio-economic systems, including through policy.

2.3 International approaches

The seven societal challenges included in the EU's RDI programme, Horizon 2020, all refer to problems and deficiencies that affect society — in healthcare, food security, safe and clean energy, the problems of pollution and high carbon-emissions, problems related to refugees and migration, poverty, inequality, and so on. These are not scientific or technological problems, they are human problems. South Africa's current White Paper on STI has its origin in society and key societal challenges.

2.4 Priorities informed by the review of the NRDS and TYIP

The NRDS and TYIP review suggests that the DSI pursue the notion of "grand societal challenges" as a framing principle for high-level interventions in the Decadal Plan. The review recommends that the DSI retain the science missions in the palaeosciences, astronomy, marine and Antarctic research, and IKS (including biodiversity). The continued support of science missions comes with the proviso that mission-related outcomes be incorporated and measured over time. The review also recommends that South Africa continue to pursue technology missions, refining and implementing the high-technology platforms (biotechnology, ICT and advanced manufacturing) and grand challenges (the bioeconomy, space science and technology, energy security, climate change, and human and social dynamics).

2.5 The South African Foresight Study for STI

The South African Foresight Study for STI sought to investigate the future use of STI to address societal, sustainability and economic challenges, create inclusive and sustainable growth, and improve quality of life and well-being in South Africa. The exercise identified seven broad, STI domains related to STI (as well as to societal needs and issues), and 25 related thrusts. Thrusts are STI-related priority areas that indicate what South Africa wishes to achieve by 2030.

Table 1.1: STI domains and thrusts

STI domain	STI thrust	
Circular economy	CE1	Reduce, reuse and recycle waste
	CE2	Ensuring sustainable water, energy and food (agriculture) security
	CE3	Low-carbon and climate-resilient economy
	CE4	Smart connectivity (human-machine interface) and mobility in communities

STI domain		STI thrust
Education	ED1	Skills for 4IR
	ED2	Inclusive innovation and development
	ED3	Curriculum development 2030
Energy	EN1	Clean, affordable and sustainable energy for all
	EN2	Renewable energy sources and technologies
	EN3	Energy efficiency solutions for industry and household use
	EN4	Distributed energy generation and storage
Future of society	FS1	Policies and indicators for STI in a changing South African society
	FS2	STI for inclusive, people-led development
Health	HE1	Optimisation of health systems
	HE2	Improving the quality of healthcare
	HE3	Digitisation of health systems
High-tech industry	HT1	Enabling small business to adopt high tech
	HT3	New thinking for new industries
	HT4	New thinking for old industries
ICTs	IT1	Checks and balances for a digital future
	IT2	ICT Infrastructure and Internet access
	IT3	Big data, data analytics and decision support
	IT4	Smart and sustainable municipal service delivery
Nutrition	NU1	Zero-impact agriculture
	NU2	Use and acceptance of modern biotechnology
	NU3	Personalised information for healthy nutrition for all
	NU4	Precision and big data in agri-businesses
Water	WA1	Future-oriented water and sanitation solutions
	WA2	Embedding the water sector in the 4IR
	WA3	Off-grid and decentralised water, wastewater and sanitation solutions

2.6 Other sources of evidence

The Decadal Plan considers a wide range of previous studies and STI-relevant data (scientometric and bibliometric). The former includes studies that the DSI (and other national agencies) have commissioned, including the following:

- Study on Building a Cadre of Emerging Scholars for Higher Education in SA (2018).
- The State of the South African Research Enterprise (2018).
- The Quality of SA's Research Publications (2019).
- Monitoring and Evaluation Framework for the South African Science, Technology and Innovation System (2019).
- Scientometric studies of 16 scientific fields (2017-2020).

The scientometric studies include the more recent available statistics on human resources for science and technology in South Africa (R&D survey and Higher Education Management Information System data), trends in the funding of R&D (the national surveys on scientific and technological research carried out by the Centre for STI Indicators), and bibliometric studies on trends in scientific publications (the Centre of Excellence in Scientometrics and STI Policy). Other information on key STI indicators were sourced from NACI's annual STI indicators reports.

CHAPTER 3: SCIENCE, TECHNOLOGY AND INNOVATION PRIORITIES

3.1 Introduction

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. Planned interventions should upscale the impact of innovation to address poverty, inequality and unemployment (PIU), thereby improving its citizens' quality of life.

The priorities of the Decadal Plan take into account the nine high-level thematic focus areas identified in the foresight exercise and the review of the NRDS and the TYIP (as discussed in Chapter 2), integrating existing, relevant and ongoing work linked to previous policy instruments. It is envisaged that, over time, the NSI will pivot towards the Decadal Plan's STI priorities and, consequently, all NSI actors will need to plan for this transition.

The following are some of the activities are required for the transition:

- Using STI to modernise key sectors of the economy, driving competitiveness and productivity improvements and, ultimately, higher GDP contributions.
- Exploring opportunities presented the emerging circular and digital economies as new sources of growth.
- Harnessing the capabilities built by the NSI to drive innovation across several sectors (e.g. health and energy) to support the development of a capable and entrepreneurial state.
- Using STI to contribute to an STI-enabled, capable state, enabling improved service delivery and decision making.
- Using STI to support social progress, including economic inclusivity and sustainable livelihoods.
- Using STI to address the SGCs in the areas of climate change and environmental sustainability (SGC 1), future-proof education and skills (SGC 2) and the future of society (SGC 3).

The Decadal Plan articulates its core projections for the next decade as STI priorities and SGCs. It retains a focus on enablers while, at the same time, aiming to pivot the system towards the achievement of key STI and SGC priorities. The enablers in Chapters 7 to 9 seek to expand and strengthen a flourishing of human endeavour across all priority fields targeted in previous and current science, technology, engineering and innovation policies. This requires investment in and international collaboration on the development of human resources and infrastructure.

3.2 The manufacturing, agriculture and mining sectors

South Africa's GDP has contracted over the past decade. This is in part due to the decreasing growth in total factor productivity of three key sectors of the economy, namely, manufacturing, agriculture and mining.[1] Developing innovation capabilities is one way to drive productivity improvements in these sectors, and ultimately the economic growth of the country. An innovation-led response to the modernisation and industrialisation of these sectors presents a possible long-term competitive advantage for the country. Consequently, the Decadal Plan aims to harness innovation to boost productivity in these three sectors.

3.2.1 Modernising manufacturing

STI capabilities are the backbone of most modernised industrial sectors and play an increasingly important role in enhancing the competitiveness of many economic sectors, including manufacturing.[2]

Production trends in manufacturing are evolving from labour-intensive mechanical processes to more sophisticated high-tech applications[3] and processing. The increased use of technological innovation in manufacturing is considered instrumental in industrialisation, driving higher production performance, and improving manufacturing value-addition and productivity.[4]

Low innovation levels in manufacturing are one of the factors preventing South Africa from moving to the higher-value-added activities needed to boost economic growth.[5] Other high-level problems include an over-reliance on low tech solutions,[6] processing inefficiencies in some industries, limited local market attractiveness,[7] inability to seize new market opportunities, and low levels of locally developed high-tech manufacturing SMMEs.[8]

As a result of the global move towards a low carbon economy and greener practices, conventional manufacturing industries are expected to meet environmental requirements and lower their carbon footprint. An acceptable strategy to modernise would be through greener production practices. In manufacturing, high-tech firms create opportunities for low-skilled workers due to the manufacturing sector's multiplier effect.[9] Thus, new products and markets from high-tech innovations have potential socio-economic impact through indirect job creation. In some sectors, a multiplier equivalent of one high-tech job to almost five new

1 The World Bank Report (2017) Innovation for Productivity and Inclusiveness. South Africa Economic Update 10.
2 Lécuyer C & Brock D (2009) High tech manufacturing, History and Technology, 25:3; Krammer MS (2017) Science, technology, and innovation for economic competitiveness: The role of smart specialization in less-developed countries. Technological Forecasting and Social Change, 123, 95-107
3 Advanced manufacturing is a collection of high value-adding manufacturing processes, management techniques, technologies and knowledge capital that occupy the top tier of manufacturing industries and drive competitiveness in local and global economies; Shipp et al. 2012 Emerging Global Trends in Advanced Manufacturing. Institute for Defense Analyses (https://www.nist.gov/system/files/documents/2017/05/09/IDA-STPI-report-on-Global-Emerging-Trends-in-Adv-Mfr-P-4603_Final2-1.pdf) Williams et al. 2014 Advanced Manufacturing and Jobs in South Africa: An Examination of Perceptions and Trends
4 Vurm et al. 2009 R&D, Structural Change and Productivity: The Role of High and Medium-High Technology Industries, Economia Aplicada
5 HSRC (2012) Innovation in the South African Manufacturing Sector, 2010-2012; The World Bank Report (2017) Innovation for Productivity and Inclusiveness. South Africa Economic Update 10.
6 HSRC (2012) Innovation in the South African Manufacturing Sector, 2010-2012
7 Manufacturing Circle (2017) Map-to-a-Million: Map to a million new jobs in a decade, Stats SA (2013). Economic growth (http://beta2.statssa.gov.za/?page_id=735&id=1); Stats SA 2014 Quarterly Labour Force Survey, Q3. Statistical Release P0203
8 World Bank Report 2018 Creating Markets in South Africa
9 Moretti (2010) Local Multiplier American Economic Review: Papers & Proceedings: 1–7 (Multiplier effects measure the impact of higher growth in a given sector on the demand for goods and services from other sectors)

indirect jobs has been reported.[1] Empirical evidence suggests that knowledge spillovers from high-tech innovation in a particular sector can drive entrepreneurship in other sectors of the economy.[2]

1 Echeverri-Carroll, E and Lowe N (2008) Wage differentials and spatial concertation of high-tech industries. Papers in Regional Science 88:3; Moretti and Thuli (2013) Local multipliers and human capital in the United States. Industrial and Corporate Change 22:1; Sachs J (2003) The Global Innovation Divide in Jaffe A, Lerner J and Stern S (eds) Innovation Policy and the Economy Boson: MIT Press

2 Moretti (2010) Local Multiplier American Economic Review: Papers & Proceedings: 1–7; Lee and Pose (2016) Is there trickle-down from tech? Poverty, employment and the high technology multiplier in US cities.

STI in support of manufacturing

Foresight reports[1] have identified key emerging technologies expected to drive future production and competitiveness in manufacturing globally. All are relevant to South Africa, but biomanufacturing, space science, additive manufacturing and numerous ICT-based technologies are a priority. Prioritisation is informed by the sustained investment support and progress in the NSI over the years in building critical mass, world-class competencies, RDI funding instruments and pilot facilities in these technology focal areas.[2]

Through systematic technology exposure, upgrading the technological intensity of SMMEs, and exploiting some key enabling technologies, the sector can develop new industry segments and renew the competitiveness of mature industries. The Decadal Plan intends to leverage existing capabilities to ensure that STI solutions are available to boost the technological intensity of manufacturing firms, increasing competitiveness and foreign revenue. The following approaches can support the effort:

- Enabling small manufacturing businesses to adopt high tech: Over the years, the NSI has developed solid technical capabilities in additive manufacturing, biotechnology manufacturing, space technologies and digital technologies. These capabilities would be harnessed to assist small manufacturing enterprises to enter high-tech markets.
- New thinking for new industries: The creation of new high-tech industries in support of manufacturing remains a key priority for the South African economy owing to manufacturing's multiplier effect. In this regard, the multiplier effect of high-tech industries is expected to accrue from the activation of new manufacturing value chains, the expansion of supply chains, and the employment absorption of a highly skilled workforce.
- New thinking for mature industries: Several industries that are contributors to the country's manufacturing GDP have reached a mature stage of business development and some are in decline. Strategies that integrate incremental and radical technology development to boost the short and medium-term competitiveness of the local manufacturing sector are required. It is envisaged that the adoption of advanced, novel manufacturing technologies that are greener and incorporate digital technologies will enable both the survival and growth of mature industries in the future.

In addition to relying on individual technology-specific domains, manufacturing, as well as other sectors of the economy, can benefit enormously from the technology convergence approach. The entrenchment of the technology convergence approaches to manufacturing can lead to improved productivity, product development agility, and sustainable production processes, among other benefits.

3.2.2 Modernising agriculture

Agriculture is a key driver of food security and rural economic development in South Africa. The country is food secure and a net food exporter for certain agricultural goods. Despite this, inequality leaves many poorer households food insecure and malnourished. Agriculture

1 The World Economic Forum Readiness for the Future of Production, the World Bank Creating Markets, the Boston Consulting Group Nine Technologies Transforming Industrial Production Report and the NACI foresight Report

2 Biomanufacturing Industry Development Centre, Biorefinery Industry Development Facility, National Biocatalysis Platform (Now Industrial Biocatalysis Hub, TIA Umbogintwini Bioprocessing Platform, Supercritical Carbon Dioxide Encapsulation Facility, Aeroswift platform, Collaborative programme in additive manufacturing, Nanotechnology Innovation Centres, satellite manufacturing

delivers more jobs per rand invested than any other sector[1], and the NDP estimates the potential to create one million jobs by 2030 (600 000 jobs in communal areas and 300 000 jobs through commercial agriculture)[2] in agricultural production, processing and related activities. Traditionally, agriculture has been a positive contributor to the country's GDP growth, but the sector has shed 30% to 40% of jobs in recent years. This is due in part to global competition, where the average farm size is increasing to allow economies of scale to be realised, but also because technologies and mechanisation reduce certain labour-intensive activities.

Challenges in the agricultural sector include the loss of arable land, high input costs (seeds, machinery and pesticides), low technological innovation, and inadequate advisory services. From a productivity perspective, the challenges of sustainable rural economic growth are exacerbated by the divide between the first and second economies. Global agricultural competition is also fierce and often subsidised. Food safety requirements for exports continue to increase.

STI in support of agriculture

The draft Agriculture and Agroprocessing Masterplan (AAMP) proposes addressing the challenges in the sector through partnerships, transformation and spatial planning, strengthened value chains, coordination, building on lessons learnt, and co-funding.

The Decadal Plan will support the AAMP and the agricultural sector through the deployment of bioinnovation products, processes and technological services. The approach (Figure 3.1) involves several transdisciplinary and multi-institutional STI interventions aimed at agricultural intensification and new knowledge products, technology transfer and adoption, nutrition security and livelihoods, and enabling mechanisms such as skills development and training.

Outputs include new bioinnovations, more farmers becoming commercialised, increased nutrition security, skills development and new production value chains, as well as precision agriculture and digital capabilities to modernise the sector. These STI interventions will form the basis for the agricultural RDI plan between government and industry in support of the AAMP.

1 https://agrisa.co.za/wp-content/uploads/2014/10/011-APAP-AgriSA.pdf
2 Chapter 6 of the NDP.

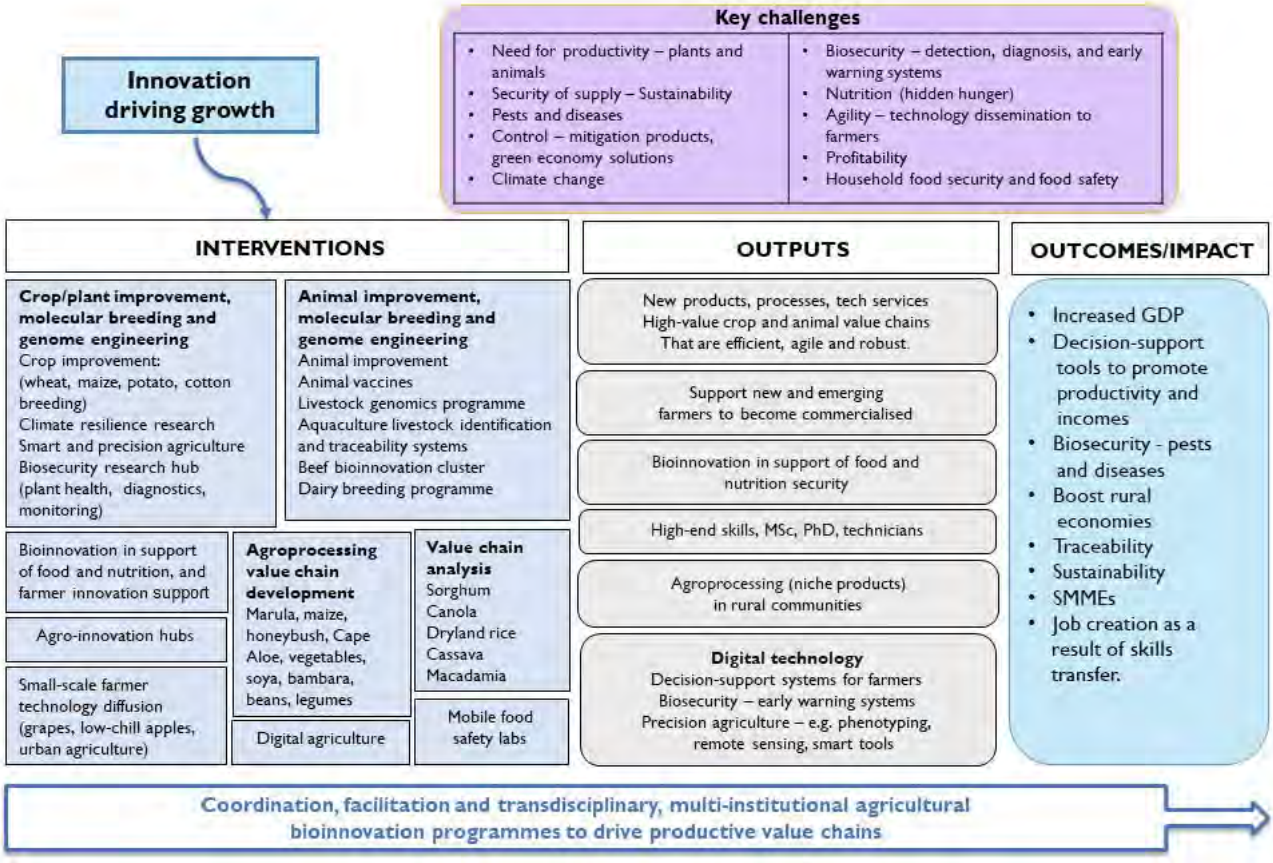

Figure 3.1: Innovation driving the revitalisation of agriculture

3.2.3 Modernising mining

South Africa has one of the largest mineral resource endowments in the world. Mining has made a significant contribution to the South African economy for more than a century. The sector remains extremely important to the economy in terms of employment, GDP, exports and total fixed investment.

Many of the challenges facing the domestic minerals sector over the medium to long term are common worldwide. As mining commodity prices continue to slump, smaller mines face closure and the post-mining rehabilitation and regeneration of mine land therefore becomes critical.

STI in support of mining

STI approaches are required to discover, access and process low-grade, complex and deeper ore bodies, in increasingly remote locations, while maximising the socio-economic returns and securing energy and water. STI is needed to help manage escalating costs, shrinking product lifecycles, time-to-market, and technical skills shortages.

The modernisation of the mining sector through STI interventions is envisaged in two focus areas, namely, mining and mining equipment manufacturing. This is intended to enhance –

- rock cutting, rock-breaking and rock-handling at the stope face;
- the digitalisation of mines;

- extending the life of mines.

The Decadal Plan envisages supporting, leveraging and improving the coordination of existing STI programmes such as the South African Mining Extraction Research, Development and Innovation Strategy and the industry-funded RDI programmes detailed below, to increase the competitiveness of the sector and, with the Mining Equipment Manufacturers of South Africa, to create innovation and product opportunities for locally developed mining equipment. In terms of metals and mineral beneficiation, the minerals to beneficiate are being selected in consultation with the Department of Mineral Resources and Energy (DMRE) and the DTIC. There are beneficiation programmes under way for titanium, aluminium, various steels and other materials such as fluorspar. The Advanced Materials Initiative contributes towards the beneficiation of light metals (including aluminium), precious metals, ferrous metals and nuclear metals. In addition, the beneficiation programmes under way for titanium and fluorspar will be considered in the context of the respective masterplans and market opportunities.

3.3 New sources of growth: The digital and circular economy

3.3.1 The digital economy

Digital solutions have become a major part of everyday life, presenting enormous opportunities for SA to chart a new digital-driven development path. Other developing countries have shown that digital economy development is an essential national growth strategy, and that the rewards are great. As many of the traditional employment pathways start to close due to automation and the restoration of global value chains, the digital economy offers a promising pathway to collective prosperity.[1]

Information and communication technologies (ICTs) are a key enabler of development in all domains, from agriculture and health to industry, service delivery and governance. The Internet of Things (IoT) promises a hyperconnected and digitally responsive society that supports human, societal and environmental developments. Artificial intelligence (AI) offers unique opportunities to improve human lives and address major societal challenges. Blockchain technology is expected to disrupt markets by ensuring trustworthy transactions without the necessity of a third party. These technologies bring opportunities as well as threats for socio-economic systems. Their development therefore needs to be regulated by addressing concerns regarding security, privacy, equity and integrity.

STI in support of the digital economy

ICTs have the potential to affect many aspects of the economy, including GDP growth, productivity and poverty alleviation, i.e. sustainable livelihoods (employment and entrepreneurship). They impact societal activities such as education, healthcare and sustainable human settlements. Through the contribution of ICT innovation and entrepreneurship (start-ups and SMMEs), STI can be used to empower young people, women and marginalised groups, creating employment opportunities. Social media can be used to bring about social change.

The Decadal Plan's ICT-based interventions are focused on applications in sector modernisation and building foundational capabilities. It seeks to respond to the imperatives

1 ICT and Digital Economy Masterplan: Draft for discussion, by Genesys Analytics and Knowledge Executive, 31 July 2020.

of the draft Digital Economy Masterplan and recognises that the development of the digital economy development is essential for any country's national growth strategy. The draft Digital Economy Masterplan sets out mechanisms to enable the creation of sustainable livelihoods in sustainable human settlements.

ICT-based applications in sector modernisation

In line with the sector modernisation framing, ICT interventions are expected to play a significant role in driving productivity improvements in manufacturing, agriculture and mining.

- With STI interventions aimed at enabling small businesses to adopt high tech, new thinking for new industries and new thinking for mature industries, advances in ICT-based applications are of critical importance in driving productivity improvements in manufacturing. ICT-based innovations are envisaged to play a crucial role in addressing the issues of growth, competitiveness, sustainability and the current low number of successful and viable high-tech manufacturing SMMEs
- In the agricultural sector, the application of digital and precision technologies is expected to drive modernisation, sustainability and competitiveness by addressing several productivity related challenges such as high and volatile input costs (fertilizer, water, energy etc.), the delayed detection of crop and animal diseases outbreaks, and farmers' inability to access market trading information in good time (especially small-scale farmers). Advances in ICT-based applications offer precision-driven solutions for the agricultural sector. For example, the use of the Internet of Things, integrating satellite, drone and sensor technologies is driving crop monitoring improvements and diseases diagnosis, and surveillance – saving the sector millions of rands from lost production and boosting competitiveness.
- The mining sector contributes significantly to South Africa's internal energy requirements, trade balance, internal investment, domestic savings, foreign capital, and direct and indirect employment creation. Increasing costs, declining grades and the increasing average depth of precious metal mining are some of the factors weighing heavily on the sector. As the sector moves forward, there is a greater need to streamline existing processes, improve recoveries and find innovative new cost-efficient ways of extracting these commodities. The adoption of digital, technology and data analytics offer significant benefits for the mining sector, in particular relating to the optimisation of operations and reduction of mining risks. The mining RDI implementation plans, which are to be centred around the application of the ICT-based innovation, are expected to drive the sector's improved global competitiveness.

ICT-based foundational capabilities

The other ICT-based focal area is the development of foundational capabilities in several domain areas (Figure 3.2) to bridge the country's increasing digital divide. The infrastructure requirements are an efficient and effective Internet backbone, fixed broadband, mobile telecommunications and communications satellites; other network infrastructure such as Wi-Fi; cloud platforms, automation systems, integration and application programme interfaces and services. This will require RDI programmes to develop systems for hands-free engagement with links to optics, neuroscience, neurology and cognitive sciences. Core technologies include advances in photonics, acoustics and sensing, leading to the

fundamental development of freeform optics, computational imaging, audio rendering and mixed technology integration.

There is a need for greater uptake and infusion of high-performance computing in industry, especially SMMEs, for improved efficiency, e.g. ICT application development, prototyping, simulations, and operating in hazardous environments. The following could contribute:

- The connectivity model for the South African National Research Network (SANReN) and the Tertiary Education and Research Network of South Africa could be used to build affordable networks that are accessible to SMMEs.
- The tools and algorithms for big data analytics such as machine learning and AI could be used to assist SMMEs and corporates to define new markets and products.
- Government, through the Department of Small Business Development (DSBD), should come on board to support grants or incentives to SMMEs and/or the National Integrated Cyberinfrastructure System to drive these initiatives.

Figure 3.2: ICT-based focus areas for developing foundational capabilities

The National Institute for Theoretical and Computational Science, formed in 2021 to replace the National Institute for Theoretical Physics, should take a leading role in RDI in "big" computational science and the theoretical modelling of complex systems. A structure able to mobilise a transdisciplinary team of scientists and researchers to address urgent societal problems is crucial. Maintaining world-class expertise in theoretical physics and computational science offers a high return on a modest investment. Most of the advances of the 4IR rest on theoretical and computational skills. Machine learning, AI, risk management, climate modelling, bioinformatics and complex systems dynamics are just a few of the skills required. Without training, RDI in theoretical and computational sciences, many avenues of economic recovery will be precluded.

To be consistent with the framework for quantum-technology-driven RDI in South Africa that the DSI is currently developing, three promising main areas have been identified, namely, quantum computing, quantum communication, and quantum sensors and metrology.

While it is not yet possible to quantify the potential economic impact of the emerging quantum technologies — the consensus is that new industries will emerge in the post-Covid economy and replace some of those made redundant by 4IR. With technology and digitisation increasingly powering the global economy, the emergence of quantum computing could prove to be a significant catalyst for innovation and growth.

3.3.2 Circularity approach to sector modernisation

The circular economy (CE) approach offers numerous opportunities for socio-economic growth and environmental protection. Several scientific, foresight and policy reports[1] have indicated that the CE can contribute to GDP, provide a new source of employment, increase profit margins at firm level and maximise resource utilisation efficiency. For developing countries, the CE can reduce reliance on increasingly scarce raw materials, increase disposable income for individuals, enhance utility and convenience, and improve living conditions and health.[2] Consequently, intensifying the circularity of the economy provides a new model for sustained and resilient economic growth and job creation.[3]

The South African economy is currently estimated to be around 7% circular.[4] With the right policy interventions, it can reach 9% circularity, the global average, and the projected global target of 17% by 2030.[5] The Decadal Plan envisages STI interventions making an accelerated contribution to the circularity of key sectors. The framing of the CE as an opportunity for socio-economic development and environmental preservation is a new development in SA's STI policy evolution. Consequently, no baseline monitoring indicators are yet available to track the contribution of the CE to the environmental and socio-economic imperatives of the country. The implementation of the CE's STI priorities will, thus, correspond with the development of the relevant monitoring indicators to track progress.

STI in support of the circular economy

To ensure a successful transition to circularity, STI interventions in support of manufacturing, agriculture and mining will be developed taking into account the principles of the circular economy, namely, waste and pollution reduction, regenerative systems, and sustainable materials management. The Decadal Plan frames the STI for CE priorities from a broader sustainable materials management perspective, aimed at an overarching resource productivity improvement in the targeted resource-intensive sectors.

- In manufacturing, STI interventions are expected to reduce resource input dependence by integrating 4IR-based manufacturing technologies and innovations. Embedding circularity in manufacturing can be realised by embracing design thinking and reinforcing the principle of a remanufacturing regenerative approach across the sector's value chain.

1 Mining and metals and the circular economy (2016) International Council on Mining and Metal; Ellen MacArthur Foundation: EMF (2017). Circular Economy in Detail; Council for Scientific and Industrial Research (2021) Driving economic growth in South Africa through a low carbon, sustainable and inclusive circular economy, Policy Briefing Note 2021/001; Godfrey, L, Sithole, B et al. (in press). Transitioning to a more circular economy in South Africa: The role of innovation in driving greater waste valorisation. In: Circular Economy and Waste Valorisation: Theory and Practice from an International Perspective

2 Godfrey, L (2021). The circular economy as development opportunity. CSIR: Pretoria.

3 Circle Economy (2021). The Circularity Gap Report 2021, EMF (Ellen MacArthur Foundation) (2020). Financing the Circular Economy: Capturing the Opportunity

4 Von Blottnitz, H, Virag, D, Wiedenhofer, D and Haas, W. (2021). An Economy-Wide Material Flow Analysis to Develop Circular Economy Indicators for South Africa. CSIR: Pretoria.

5 The Circularity Gap Report (2020) When circularity goes from bad to worse: The power of countries to change the game. https://www.circularity-gap.world/2022

- For agriculture, STI contributions can drive the circularity of the sector by adopting reformative agricultural practices and improving resource utilisation through the implementation of precision and digital tools that are central to the regenerative model of the circular economy. STI interventions offer opportunities for waste elimination and chemical pollution reduction by embracing biorefining innovation opportunities for processing agricultural by products.
- In the mining sector, STI interventions can improve the sector's resource (energy and water) utilisation efficiency. The opportunities for embedding circular economy principles lie in optimising recycling efforts and fostering sustainable automated mining methods.

Given the direct link between the energy and water sectors and the three targeted economic sectors, the Decadal Plan circularity STI interventions extend to the energy and water sectors. In terms of the energy sector, STI contributions can support the circular economy transition by developing renewable energy sources to decouple economic growth from non-renewable fossil fuels dependence. The circularity of the water sector can be realised through the deployment of STI interventions targeted at novel water treatment solutions and sustainable water management practices that divert pollution from entering water bodies.

3.4 Health innovation

Healthcare is a basic human right guaranteed by the Constitution. Section 27 of the Constitution provides that everyone has the right to access healthcare services and no one may be refused emergency medical treatment. Yet, South Africa stands at a crossroads concerning tremendous societal health challenges. With less than 1% of the world's population, SA has a disproportionately high HIV and tuberculosis burden. Healthcare services are further burdened by a rise in cardio-vascular and other non-communicable diseases. In addition, the homicide rate in SA is five times the global average, indicating a need for stronger mental health services. The challenge has been described as a lethal cocktail of four colliding epidemics: maternal, newborn and child health; HIV/Aids and tuberculosis; non-communicable diseases; and violence and injury. Innovative tools and services are needed to tackle the quadruple burden of disease that dominates the health landscape and the socio-economic disparity between urban and rural areas.

The NDP envisages that, by 2030, the burden of disease will have been radically reduced, that South Africans' life expectancy will have increased to at least 70 years, and that the generation under 20 is free of HIV. It also envisages a significant shift in the equity, efficiency, effectiveness and quality of healthcare provision. In population coverage terms, SA's health system is dominated by the public health sector, while the private health sector caters mainly for the more affluent members of society. The NDP's health priorities informed the National Health Strategic Plan 2020-2025, which is aimed at achieving a long and healthy life for all.

Given the scale of SA's health challenges, and the complexity of the health value chain, no single institution, intervention or approach will be adequate to address them effectively. Thus, the achievement of the envisaged health outcomes of the country will require both technological and non-technological innovations.

- In respect of non-technological interventions, a balanced body of social sciences knowledge will need to underpin complex transdisciplinary approaches to healthcare challenges. A human-centred approach will be particularly important in addressing the mental health challenges facing South Africans.

- In respect of technology-based interventions, various advances in genetics, precision medicine, data science, nanotechnology and synthetic biology, for example, coupled with the convergence of biological, physical and digital spaces, will give rise to new diagnostic and therapeutic modalities that offer the possibility of curing disease, reducing suffering, lengthening lives and enhancing patient experience. These new and disruptive technologies can be harnessed to optimise health systems, improve the quality of healthcare and increase the digitisation of healthcare systems.

STI in support of health innovation

Covid-19 demonstrated that South Africa (like the rest of the world) can no longer depend on a single health system intervention, especially where pandemic preparedness is central. Endowed with unique megadiversity and rich indigenous knowledge (IK) related to medicinal plants, SA is well positioned to develop a sustainable and complementary IK-based health system. In line with its inclusivity principle, the Decadal Plan embraces two STI health systems, prioritising both a contemporary 4IR precision and digital approach, and IK-rooted health innovation responses.

Contemporary 4IR precision and digital health innovation approach

Innovative approaches brought about by the convergence of various technological disciplines (such as nano and biotechnologies, information technology, and cognitive and social sciences) are changing the face of health sectors (Figure 3.3). The associated benefits include cost-effective healthcare systems, new delivery systems, improved diagnostics and disease management, enhanced remote disease monitoring and improved patient experience.

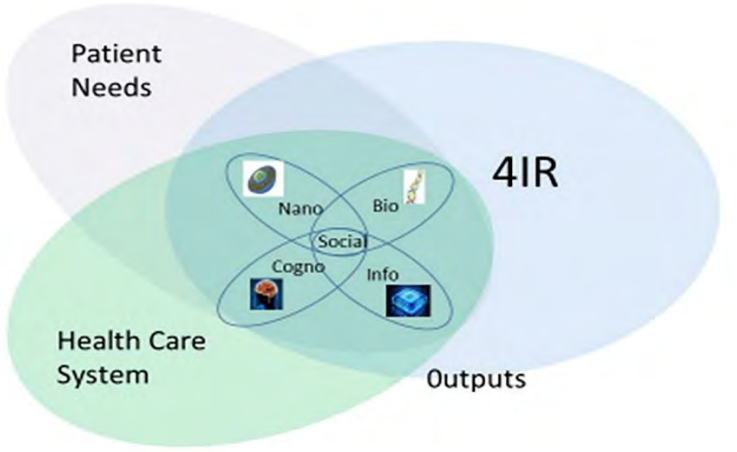

Figure 3.3: Convergence of technologies and needs driving healthcare[1]

In the production of health-related products and services, innovations that are underscored by technology convergence could be harnessed in various technical disciplines to improve manufacturing and related services. Over the years, the NSI has developed strong STI capabilities across the health value chain, including –

- the Strategic Health Innovation Partnerships, which support different research, development and innovation health priorities;
- technology platforms that underpin health systems applications, technologies or processes developed for the end-user;

1 Adapted from: United Nations Industrial Development Organization, 2019. Nature-like and Convergent Technologies Driving the Fourth Industrial Revolution. Vienna

- technology innovation clusters that bring together players from research, government and industry across the value chain to drive and support health innovation.

Thus, in the next decade, the approach is to maintain existing innovation support instruments and programmes while strengthening capabilities and interventions in converging technologies[1], building new capabilities in the emerging health 4IR priorities to accelerate scientific discovery for new treatment and diagnostics, strengthening precision medicine outputs, and digitalising health and healthcare systems.[2]

IK-based health innovation approach

The IK-based health innovation approach seeks to mainstream African natural medicines for the treatment of all priority health conditions, including cancer, diabetes, tuberculosis, HIV/Aids, and emerging and re-emerging infectious diseases like Covid-19. As part of the Decadal Plan, South Africa's African herbal medicine interventions will focus on new regulations (in collaboration with the South African Health Products Authority), building capacity for clinical trials, the registration of medicine for clinical application, industrialisation and commercialisation (Figure 3.4). The establishment and building of capacity in best practices and standards will be a priority.

This approach will support both inclusive innovation and manufacturing value-chains, where traditional healers and IK practitioners will be co-owners of industries across the value chain. The Decadal Plan will facilitate the development of a clinical medicines curriculum for higher education degrees, piloting the use of primary, secondary and tertiary health facilities to bring proprietary African herbal medicines into the current national health system.

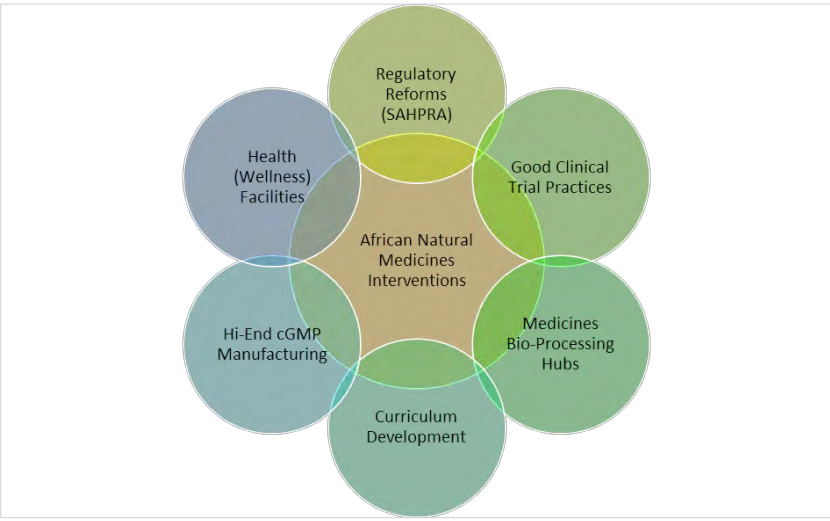

Figure 3.4: African natural medicines interventions

3.5 Energy innovation

Energy security is the uninterrupted availability of modern energy at an affordable price. Long-term energy security involves timely investments to supply energy in line with socio-economic development and environmental needs, while short-term energy security is the

1 https://www.oecd.org/sti/inno/46334068.pdf
2 Health and Healthcare in the Fourth Industrial Revolution Global Future (2019). Council on the Future of Health and Healthcare 2016-2018. http://www3.weforum.org/docs/WEFShaping_-the_Future_of_Health_Council_Report.pdf

ability of the energy system to meet the supply-demand balance. Some studies show that the total economic impact of load shedding over the past 10 years in South Africa could be as high as R338 billion. On the other side of the spectrum, a slow move towards a net zero economy could limit South African companies' access to capital markets, while carbon border adjustment mechanisms could reduce the competitiveness of South African exports. For SA to become a net zero economy, its decarbonisation would have to decline at a rate of 11,7% per annum. However, the 2020 Climate Transparency Report reveals that a significant fossil fuel proportion in the country's energy mix resulted in a carbon intensity level higher than the G20 average. As communicated in South Africa's Economic Recovery and Reconstruction Plan, government will rely on infrastructure-led economic recovery and reconstruction with a view to investment in infrastructure to stimulate various sectors of the economy.

The 2021 South African Energy Sector Report indicates that the industrial sector was responsible for 52% of final energy demand in 2018.[1] Energy-intensive sectors account for most of the final energy demand, with the iron and steel sector leading at 18%, followed by mining and quarrying (10%), non-ferrous metals (8%), non-metallic minerals (5%) and construction (2%). Given that 50% of the final energy demand in the industrial sector is based on fossil fuels (coal at 35%, petroleum products at 5% and gas at 10%), an increase in the production of heavy industrial sectors in support of infrastructure-led growth is likely to lead to an increase in greenhouse gas emissions unless a comprehensive approach is taken to mitigate and remove carbon from the process.

There are barriers to the country's aspirations to move towards a net zero economy. The private sector has begun to recognise the importance of assessing climate-related risks and liabilities, but most day-to-day decision making continues to be dominated by short-term performance. Furthermore, despite public pressure and global activism demanding that climate change be addressed, there has been government inertia owing to uncertainty and a lack of understanding of the full implications of a just labour transition, particularly for workers in fossil fuel-based sectors like mining, which was responsible for a total of 451 427 jobs in 2020, of which 91 459 are in the coal sector.

Decarbonisation needs to be linked to social value, focusing on behavioural dimensions and overcoming inequality. The challenge for South Africa is to consolidate progress and create the momentum that will lead to a transformed energy system.

STI in support of energy innovation

Based on a recent International Energy Agency (IEA) report, close to 50% of the reduction in carbon dioxide required by 2050 will use technologies that currently exist only as prototypes. To avoid "carbon lock-in", investments in energy innovation will be critical over the next decade to bring new technologies to the market in time. The energy STI programme will focus on –

- supporting expected growth in clean energy jobs;
- accelerating the adoption of clean energy technologies by energy-intensive industrial users;
- preparing for the next phase of the transition (post-2030).

[1] The South African Energy Sector Report (2021) http://www.energy.gov.za/files/media/explained/2021-South-African-Energy-Sector-Report.pdf

Support will be needed to accelerate the roll-out of demonstration projects to leverage private investment in R&D and to boost overall deployment levels to help reduce cost. Proxy indicators (e.g. the number of energy-intensive companies that participate in research, development and demonstration programmes that remain competitive while adopting abatement technologies and retain their export markets) will be used to measure progress.

According to the International Energy Agency, increased government expenditure is required in critical areas such as electrification, hydrogen, bioenergy and carbon capture, utilisation and storage. Over the years, the NSI built strong STI capabilities in support of the energy sector under the following RDI flagship programmes:

- Renewable Energy Hub and Spokes: Supports the increased contribution of renewable energy to the energy mix through resource quantification, provision of energy services and ensuring inclusion of SA innovations through localisation.
- Hydrogen South Africa (HySA): Supports the development of value-added components along the hydrogen and fuel cell value chain including local manufacturing of hydrogen and fuel cell components. The Department has developed a Hydrogen Society Roadmap.
- Energy Storage RDI Initiative: Leverages high-quality manganese reserves in SA and other key battery minerals within the Southern African Development Community (SADC) region to develop value-added precursor materials for lithium-ion batteries for the electric vehicle and energy storage markets, while developing skills to support the local manufacturing of the precursor materials.
- Carbon Capture, Storage and Use (CoalCO_2-X) RDI Programme: Focuses on the capture of flue gas from coal-fired boilers and combining the carbon dioxide, nitrogen oxides and sulphur oxides with green hydrogen to produce value-added products such as fertiliser salts, green ammonia and sulphuric acid. While addressing just transition issues, the programme provides opportunities for new economic value chains using existing assets located in coal mining towns and assisting South African exports to remain globally competitive.

Some of these programmes are already producing outputs with a tangible impact. Going forward, the primary focus will be on strengthening the translation of existing interventions while extending the STI focus to new initiatives. Figure 3.5 sets out the milestones that need to be achieved to truly stimulate the establishment of the hydrogen economy in South Africa.

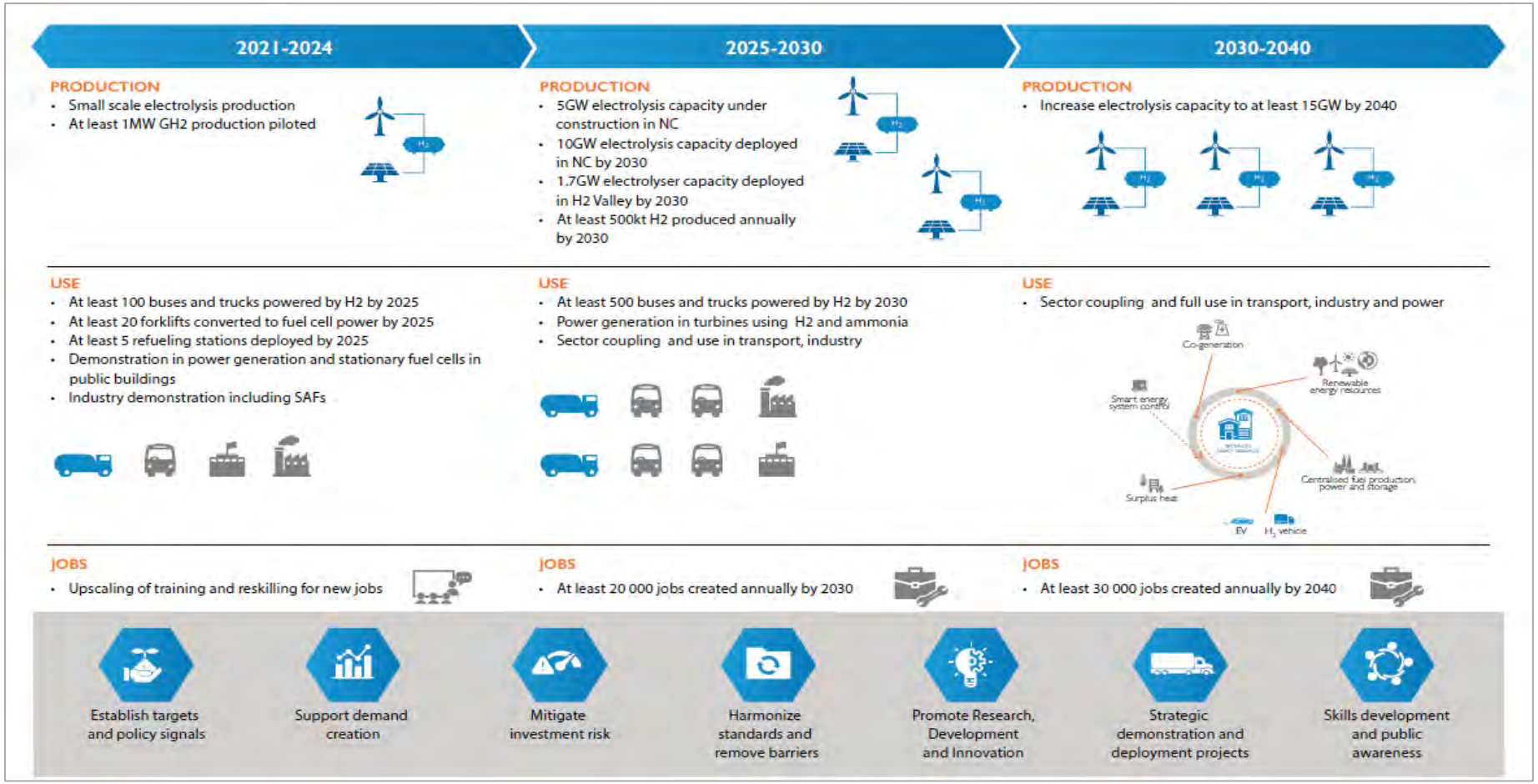

Figure 3.5: Key actions and milestones of the Hydrogen Society Roadmap (Source: DSI Hydrogen Society Roadmap)

3.6 Innovation-enabled capable state

There are a several ongoing policy and technology initiatives across government designed to transform the public sector and build a capable state, including decision-support tools to support the functioning and performance of municipalities and government departments in areas such as energy, sanitation, procurement, spatial planning, human settlements, service delivery, infrastructure, risk and disaster management, health, climate change, education and crime prevention.

STI in support of a capable state

The Decadal Plan seeks to prioritise the further deployment of decision-support tools and data analytics capabilities to support the capable state project. The following RDI programmes are expected to be expanded:

- ICT readiness assessment to guide the deployment of ICTs in schools.
- Municipal Innovation Maturity Index.
- Smart cities decision-support tool.
- The South African Risk and Vulnerability Atlas.
- Spatial Temporal Evidence for Planning in South Africa.
- Bioenergy Atlas.
- Earth observation for human settlements.
- Monitoring de-densification of informal settlements and housing development projects using high-resolution satellite imagery.
- Earth observation and 4IR for service delivery.

Programmes will be supported by a cross-cutting STI skills development initiative aimed at capacitating the public sector to ensure that STI is embedded in service delivery. RDI curricula and training programmes will be designed and implemented to develop public officials' skills in managing, adopting and driving innovation in partnership with academic institutions.

The Innovation for Service Delivery Programme will demonstrate, pilot and evaluate the suitability and viability of technologies and innovations to improve the delivery of basic services, and improve the performance and functioning of government and municipalities in particular. Programme outcomes include an enabling municipal policy environment that can facilitate the diffusion of technologies, as well as the adoption and scaling-up of successful technology pilots and demonstrations across government and society, while promoting economic and entrepreneurship opportunities. There will be an emphasis on increasing youth participation in the NSI. The following RDI activities are proposed:

- Innovative technology solutions for basic service delivery: Technology pilots of appropriate innovations for improving access to basic services, i.e. water resources management, waste management, green and renewable energy solutions, sanitation, human settlements, education and connectivity for communities.
- New decision-support tools to assist the functioning and performance of municipalities and/or the enhancement of existing decision-support interventions in energy, sanitation, procurement, spatial planning, human settlements, service delivery, infrastructure, risk and disaster management, health, climate change and crime prevention.
- Innovation measurements and capacity building: Enhancing learning and capacity building across the targeted municipalities on technology and innovation

management, the innovation capacity of municipalities, and a culture of innovation through the measurement of innovation maturity.

- Innovations for the delivery of basic services will be integrated across the public sector and municipalities through an enabling policy environment.
- Electronic participation and policy modelling platforms for local government will enable open collaboration in developing, testing and piloting public policies.
- Programmes on next-generation sanitation technologies, the 3D printing of houses, and green and smart settlements will be accelerated to create opportunity for the participation of SMMEs and youth innovation enterprises. These will be supported through the implementation of the STI for Sustainable Human Settlements Roadmap.

3.7 Innovation in support of social progress

The innovation for inclusive development (IID) agenda is about government creating an environment for innovation that enables all sectors of society to enjoy equality and equity in access to RDI knowledge infrastructure, participate in creating and actualising innovation opportunities, and sharing in the benefits of STI to advance their own development goals.

The proposed interventions are targeted at enabling livelihoods for youth entrepreneurs, women and people with disabilities; improved access to market and income opportunities for grassroots innovators; and the efficient use of scientific knowledge and tools in providing evidence-based decision support to improve service delivery. At least 10% of IID programme beneficiaries will belong to the designated categories.

The realisation of income opportunities for grassroots innovators will be implemented through several interventions (from ideation and product development to commercialisation and market access) aimed at the creation of sustainable and profitable innovation-based enterprises. About 500 grassroots innovators are targeted for support with various technical and business development interventions by 2030.

STI contribution in support of inclusive development

The Decadal Plan proposes several initiatives to enable inclusive growth and employment opportunities for the unemployed, and the participation of SMMEs, the youth and women in the NSI. These include –

- expanding the resource base for local innovation in the local sphere of government;
- advancing innovation for local economic development;
- inclusion of youth in STI;
- national rollout and expansion of the Grassroots Innovation Programme;
- accelerating the integration of innovation in the local economic growth and development planning.

3.8 Societal grand challenges

3.8.1 The nature and management of SGCs

Since 2008, the OECD's RDI approach is to regard societal challenges (or set of complex problems) as the starting point for the development of science and technology policy and strategy. The missions in traditional science and technology strategies were developed from the perspective of the science base or technological capabilities, whereas current STI policies are informed by key societal challenges.

The following provides context with regards to how the SGCs have been formulated in the Decadal Plan:

- The focused effort of the STI community on the challenges will help South Africa to overcome the long-standing structural problems of PIU. The challenges must be purposefully and coherently linked to other policies and plans (economic, industrial, environmental and social development).
- SGCs are complex and the challenges are not discrete (e.g. climate change overlaps and shares feedback loops with affordable healthcare). Therefore, positive outcomes for one challenge might result in negative outcomes for another (e.g. modernising mining will result in the loss of low-skilled jobs, and the trade-offs have to be managed centrally — making policy coherence as per the White Paper very important).
- Types of knowledge related to the challenges are concentrated in different areas of the NSI, therefore the management structures of the SGCs will have purposefully designed platforms and instruments to facilitate the flow of knowledge through the system.
- Due to their transdisciplinary nature, the SGCs require all NSI actors to be involved in addressing them. Dynamic partnerships will be critical to achieving the outcomes and impacts envisaged. Knowledge produced by all the sciences (including the humanities and social sciences) must be mobilised in the development of appropriate STI interventions included under each of the SGCs.
- The humanities and social sciences must be involved in the conceptualisation, planning, and execution of innovation initiatives in the framing of the Decadal Plan. The humanities and social sciences are critical for the continued redefinition and remaking of South Africa over the next decade.

The principles below will underlie the management of the SGCs (Figure 3.6). The following are some proposed concrete actions required in pursuit of the SGCs:

- Transdisciplinary research that is frequently multi-institutional i.e. involving higher education institutions and corporations.
- A diverse understanding and engagement of a wide range of stakeholders across all stages of research and innovation pathways in non-linear ways.
- Inclusive innovation and a more diverse knowledge system that uses innovation to benefit all citizens, improve science literacy and awareness, and demographic representation in all aspects of the economy.
- A substantial shift towards a culture of co-creation or co-production of knowledge, with formal (academic, government and industry) and informal (civil society and grassroots innovators) actors in the innovation system).

Figure 3.6: Management principles of the SA SGCs for the next decade

3.8.2 Implementation approach to Societal Grand Challenges

In the sections to follow, each of the SGCs his discussed in detail. The interventions listed under each SGC are not exhaustive, as the Decadal Plan must remain responsive to new challenges that may arise over the next decade. Short to medium-term implementation plans will be needed for each SGC to address changes (and emerging problems) in the NSI.

Societal Grand Challenge 1: Climate change and environmental sustainability

Climate change is impacting ecosystems, through changes in mean conditions and climate variability, coupled with other environmental changes such as increased ocean acidification and atmospheric carbon dioxide concentrations, as well accelerated biodiversity loss. As the world has experienced in recent years, these global environmental changes increasingly threaten the viability and resilience of natural ecosystems and the human societies that depend upon them. To understand the ecological dynamics of these environmental impacts, identify hotspots of vulnerability, risks and resilience, and determine management interventions, it is necessary to understand the global systems that determine the climate of the Earth, and biophysical and other factors that underpin the functioning of different life-supporting ecosystems.

While climate change is a global issue, most studies show that a 2°C rise in temperature will translate to a 4°C rise in temperature in South Africa and the African continent. The increase in temperature will be experienced at local level with an increase in droughts, floods and other natural disasters. The ability to manage the risk, which includes predictions around occurrence and severity, is based on an understanding of how local Earth, water and coastal systems interact with global Earth, water and ocean systems — as well as how humans interact with, impact, and are impacted by these natural systems.

As the third most mega-biodiverse country, biodiversity contributes significantly to SA's economy. The Cape Flora Kingdom alone is worth R10 billion to the South African economy annually. The annual value of insects pollinating crops comes to R5,6 billion, and the value of water released by the removal of alien species to R2,6 billion. On the basis of analyses completed through Operation Phakisa (Oceans Economy) [1], it is estimated that South Africa's marine economy has the potential to contribute up to R177 billion to GDP by 2033 and create approximately 1 million jobs. South Africa's territorial waters cover an area equivalent to over half of the country. While the country's unique geological formation anchors extensive extraction and beneficiation of precious metals, it also offers a unique opportunity for studies to understand past climates and for the palaeosciences.

STI contribution building on the current strengths of the NSI in the areas of climate change and environmental sustainability

For almost two decades, South Africa (through the TYIP and NRDS) has invested resources in targeted RDI efforts to capitalise on its unique, comparable and competitive advantages. Significant progress was made setting up key institutions and programmes to drive RDI in strategic areas and develop the necessary research capabilities and skills, including the TYIP's Grand Challenges (Global Change, Energy Security, Space Science and Technology, and the Bioeconomy), as well as the NRDS's science priority areas (marine and Antarctic science, palaeosciences, astronomy, and IKS).

In 2010 the Global Change Research Plan was adopted to direct RDI efforts in global change (Table 3.1).

Table 3.1: Key areas for STI interventions in global change

Understanding a changing planet	Reducing the human footprint	Adapting the way we live	Innovation for sustainability
• Observation, monitoring and adaptive management	• Waste minimisation methods and technologies	• Preparing for rapid change and extreme events	• Dynamics of transition at different scales – mechanisms for innovation and learning
• Dynamics of the oceans around southern Africa	• Conserving biodiversity and ecosystem services, e.g. clean drinking water	• Planning for sustainable urban development in a South African context	• Resilience and capability
• Dynamics of complex internal earth systems	• Institutional integration to manage ecosystems and ecosystem services	• Water security for South Africa	• Options for greening the developmental state
• Linking the land, air and sea		• Food and fibre security for South Africa	
• Improving model predictions at different scales			

Subsequent work has elaborated on and extended beyond this framework, with the focus on generating knowledge and developing appropriate capabilities, including high-end skills, innovative technologies and Earth monitoring systems. Initiatives in this regard include the Applied Centre for Climate and Earth Systems Science, the South African Environmental

[1] Odeku (2020). An Analysis of 'Operation Phakisa' to Unlock the Potential of Ocean Resources in South Africa. https://www.gov.za/sites/default/files/gcis_document/201706/saoceaneconomya.pdf

Observation Network, the Africa Earth Observatory Network, the Southern Ocean Carbon and Climate Observatory, the Foundational Biodiversity Information Programme, the Global Earth Observation System of Systems, AfriGEO (developed under the Group on Earth Observations to understand the linkages in South Africa and Africa to global Earth systems), the South African Risk and Vulnerability Atlas and the risk and vulnerability science centres. Another area of innovation that includes the integrated analysis and visualisation of geospatially enabled data on SDG indicators enhances the ability of policy makers and the public to understand and respond to local circumstances and needs across geospatial space and time. Science-based information is the foundation of resilience building and critical for response measures, including climate change adaptation. Continuing systematic and long-term Earth observations and South Africa's maritime domain awareness satellite programme, while expanding the footprint of decision-support tools will be critical in improving access to climate and broader environmental information and data.

It remains important to sustain and expand the bioeconomy and the ocean's economy, while accelerating movement towards new areas such as the circular economy. Hence this SGC includes STI focus areas such as –

- carbon-neutral transport;
- smart and carbon-neutral cities;
- clean energy solutions;
- sustainable water security;
- sustainable and modernised agriculture;
- zero-waste manufacturing and mining;
- (scientific) understanding of basic functioning of life-supporting ecological and Earth systems, and services they provide;
- systematic Earth observation and long-term monitoring.

As will be the case for each of the SGCs, it is anticipated that domain-specific implementation plans or roadmaps will be developed/adapted to address the anticipated new challenges of the next decade. A good example of what such an implementation plan might contain is found in the Waste RDI Roadmap (Figure 3.8).

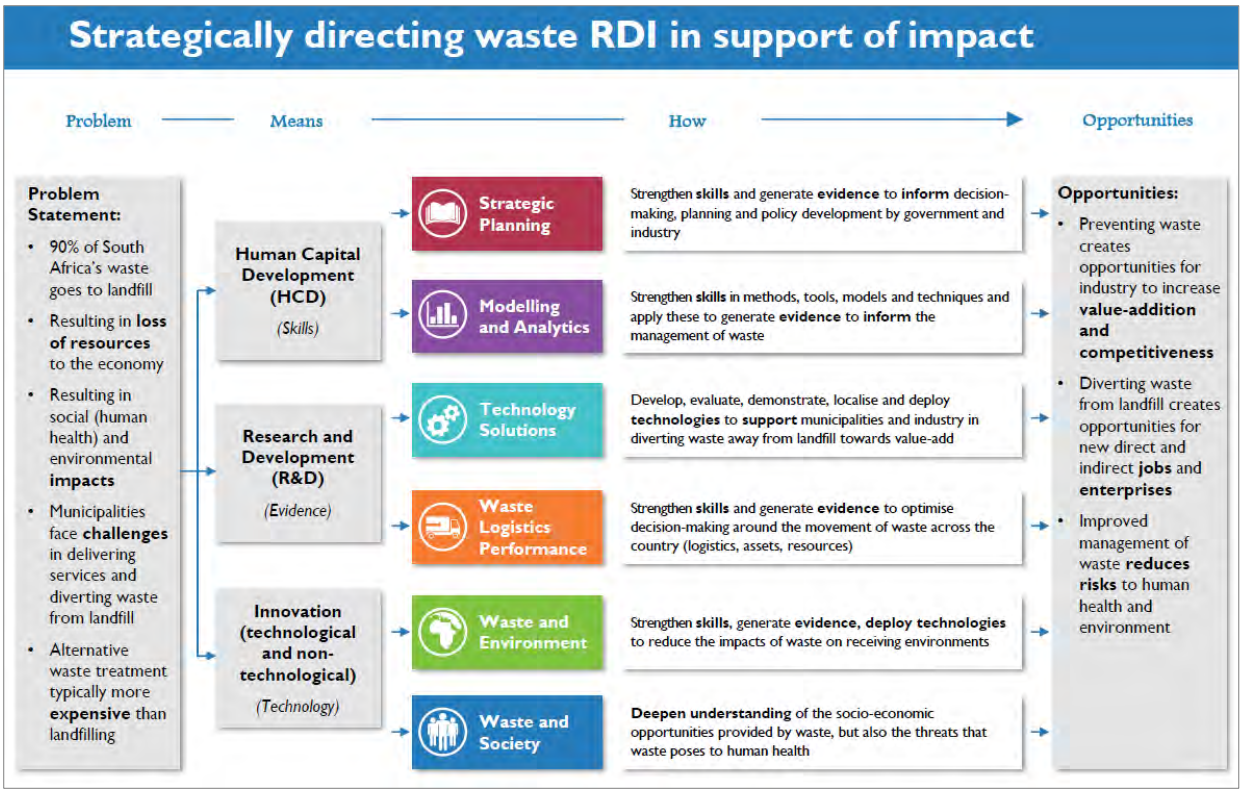

Figure 3.7: Waste RDI Roadmap

To navigate the impact of climate change on society and steer society to environmentally conscious citizenry, a deepened understanding of societal behaviour and change is required. The Global Change Research Plan envisages the social sciences and humanities making a significant contribution to this SGC. Environmental sustainability depends on fundamental changes to a number of interlinked socio-technical systems (e.g. the transport and mobility system), with implications for the economic planning models underpinning these systems. The required shifts cannot be divorced from the need to develop a balanced body of knowledge on the potential of alternative economic approaches and planning models.

Societal Grand Challenge 2: Future-proof education and skills

Unemployment remains a major challenge, especially among young and unskilled people. South Africa's economy is limited by structural challenges such as infrastructure backlogs and poor education outcomes. The poor results in science, technology, engineering and mathematics (STEM) subjects are a particular challenge in the country's public education system. The NDP, like the SDGs, envisages quality education for all citizens by 2030. South Africa has pledged to increase the number of young people and adults with skills for employment, decent jobs and entrepreneurship.

The NDP and SDG objectives have to be achieved within the context of rapid technological change — an opportunity to leverage STI for a rapid, maximised positive impact on education and skills. Despite SA's investment in STEM, there has been limited progress in re-engineering education services in line with emerging or converging technologies such as artificial intelligence, robotics and the IoT. Technology is not a cure-all. While it plays a significant role in creating access to education, it also brings its own set of challenges, e.g. perpetuating the interlinked social and digital divide. A nuanced and balanced approach is required when designing STI interventions to improve education and skills.

By providing relevant skills for the digital world, the country can mitigate job losses due to automation and move closer to NDP and SDG targets. Investing in the co-creation of a human-centred technological future will enable South Africa to develop a society that is technologically enabled to leverage ICTs, robotics, big data, AI and the IoT to deliver services that enhance the quality of lives of all citizens.[1] It will also create a resilient and digitally skilled population able to adapt rapidly to the future digital world. By investing in R&D activities that provide solutions to SA's socio-economic challenges, STI will serve as an enabler to overcome the digital divide and provide equitable access to decent employment opportunities among vulnerable groups, as well as stimulate economic growth.

South Africa's socio-economic challenges require a transdisciplinary approach. However, adequate R&D funding is required to take advantage of the opportunities provided by emerging and converging technologies. The country's funding for digital research has been concentrated on building capabilities in STEM. Over the years, the NSI has built the country's capacities through the space sciences and cyberinfrastructure for physics, Earth science, mathematics, computer science, engineering, big data, supercomputing, cybersecurity, e-science and e-research through a variety of postgraduate teaching and training programmes. Through these projects, students are exposed to skills that are essential for the digital world of the future.

STI contribution in support of future-proofing education and skills

The NSI will enhance collaboration with other government departments and stakeholders to support ongoing national initiatives and the implementation of national strategies to achieve the objectives of the NDP. The NSI will invest in R&D to address the wider digital innovation agenda with a focus on advancing new digital technology fields, and will –

- support the implementation of 21st century skills (coding, robotics) at basic education and post-school level;
- invest in neuroscience research to develop methodologies that could enhance learning outcomes (AI, machine learning, virtual reality);
- support the implementation of the National Plan for Post-School Education and Training (NP-PSET) 2020-2030;
- develop human capacity to harness the skills required for the 4th industrial revolution and a people-centred society to enhance productivity and competitiveness;
- forge partnerships with industries deploying 4IR technologies to enhance RDI and to support workplace learning;
- invest in infrastructure to support massive open online courses using the Internet or mobile applications;
- support the implementation of the National Digital and Future Skills Strategy;
- support access to training and skills development that will prepare society for the digital world and minimise the social and digital divide;
- intensify efforts in partnership with industry associations and sector education and training authorities (SETAs) to develop sector-specific digital skills and capacitate youth that are not in education, employment or training (NEET).

1 https://5g.security/ai/5g-society5-human-evolution/

Societal Grand Challenge 3: Future of society

This challenge explicitly addresses the problems facing South African society: persistent high levels of poverty and unemployment, the fact that our society is one of the most unequal in the world, inefficient service delivery, and continuing high levels of crime that impact the security and safety of citizens.

South Africa's agenda for inclusion and youth in development is founded on the 2013 Youth Employment Accord, the 2020-2030 National Youth Policy, the 2009 African Youth Charter, and the 2005 Commonwealth Youth Charter. The NDP recognises that having a young population is an advantage, provided that most working-age individuals are skilled, and their energies and innovative capabilities harnessed, enabling them to contribute to society and the economy.

According to Statistics SA, South Africa is a demographically youthful population.[1]. The youth continue to face various challenges, including an unemployment rate that is higher than that of the older population. They also contribute a significant percentage to the NEET youth category, which is of concern as it indicates youth at risk of being socio-economically excluded.

There is general recognition that the youth have inadequate skills and education, and that a "skills mismatch" limits the participation of young people and the harnessing of their potential in STI. Inadequate access to knowledge infrastructure to support youth entrepreneurship — particularly in townships and rural economies — is a barrier to the realisation of opportunities for all, particularly at a local level.

Several reviews have highlighted the need for an inclusive NSI that creates economic benefits for the youth and women, and the participation of civil society.

STI contribution in support of the future of society

In an effort to reduce PIU, the Decadal Plan will see the Department of Science and Innovation — through the South African Research Chairs Initiative (SARChI) and the centres of excellence (CoE) —establish an impartial and trusted platform to promote inclusive debate on PIU and deliberate on how to achieve a people-centred, inclusive and sustainable society. To demonstrate the vital role of rigorous research, scientific innovation and new knowledge, the DSI will –

- establish a dedicated CoE to focus on the complex interrelationship between poverty, inequality and unemployment;
- convene a community of practice (CoP) comprising SARChI chairs and CoEs working in the PIU knowledge field;
- provide dedicated funding for monitoring and evaluating interventions aimed at addressing the complex challenges of PIU.

The envisaged CoE on PIU will document the pathways that individual researchers and research projects have taken to achieve impact; how research programmes and knowledge managers can build networks, broker knowledge and synthesise evidence; and how bodies of

[1] Statistics SA (2021). Mid-year population estimates. http://www.statssa.gov.za/publications/P0302/Mid%20year%20estimates%202021-_presentation.pdf

research have been brought together to ensure impact. This will help ensure research translates into impact on policy and practice, and that we better understand how to deliver robust evidence to the right actors, at the right time and in the right way.

The CoP will also recommend strengthened national data systems to realise the full potential of the data revolution to transform the lives of poor people. Forging a new social contract for data that's grounded in principles of value, trust and equity will allow the CoP to reap data's full benefits and improve data governance. By creating a network of researchers, the community of practice aims to –

- consolidate the large investment in the research of the Chairs and CoEs on PIU to provide platforms to ensure that this research is taken into policy forums in appropriate ways to maximise policy impact;
- bring in all the relevant communities working in these areas to ensure that all pertinent evidence is brought to bear, and to triangulate their research findings with possible implementation models based on good practice within the policy community, and NGO and civil society groups;
- offer researchers in various fields an opportunity to connect, debate and collaborate;
- promote and enhance the visibility of the wealth of existing work on PIU;
- emphasise translating existing evidence on PIU interventions into policy proposals;
- effective engagement with policymakers to achieve NDP Vision 2030, SDGs and the Economic Reconstruction and Recovery Plan.

The DSI will build a comprehensive research programme focused on measuring and explaining trends in poverty, inequality and labour market outcomes, geared to improving the interface between science and policy by producing cutting-edge research for inclusive growth and economic transformation in South Africa. Designed as a transdisciplinary programme with an anchor in the social sciences, the PIU research programme will involve health, data, natural and other sciences in co-designed knowledge construction. This will enable diverse portfolios of research to coalesce and become far more than the sum of their parts.

The PIU community of practice can build the critical knowledge required to identify and develop the pathways to sustainability that can reduce inequality and lift people out of poverty. The researchers will be tasked with providing a forward looking narrative and proposing long-term solutions. The DSI will support a research-policy platform to help scope, assemble, procure and interpret evidence for PIU policymaking, and improve the dissemination and policy relevance of research outputs.

3.9 Monitoring and evaluation framework for STI priorities

3.9.1 Preliminary work

As part of developing possible socio-economic impact indicators to measure the implementation of the identified STI priorities, a preliminary analysis — based on both quantitative (big data, semantic, statistical and scientometric) and qualitative (workshops and expert consultations) methodological approaches[1] — was undertaken of the four priority areas of high-tech industrialisation, the circular economy and climate change, health

1 Department of Science and Innovation (2021) South Africa 2030 Science, Technology and Innovation Foresight follow-up data analysis to support the choice of priorities for the Decadal Plan and quantify the possible effects of the priorities

innovation, and education for the future.[1] The analysis sought to validate some of the assumptions made when the STI priorities for the Decadal Plan and their potential contributions to socio-economic development were considered. The four priority areas were primarily selected as a test case, given their cross-cutting application in key sectors identified in the Plan.

The output matrix that shows the links between the four areas (clusters) against the 12 socio-economic and environment indicators is shown in Figure 3.8.

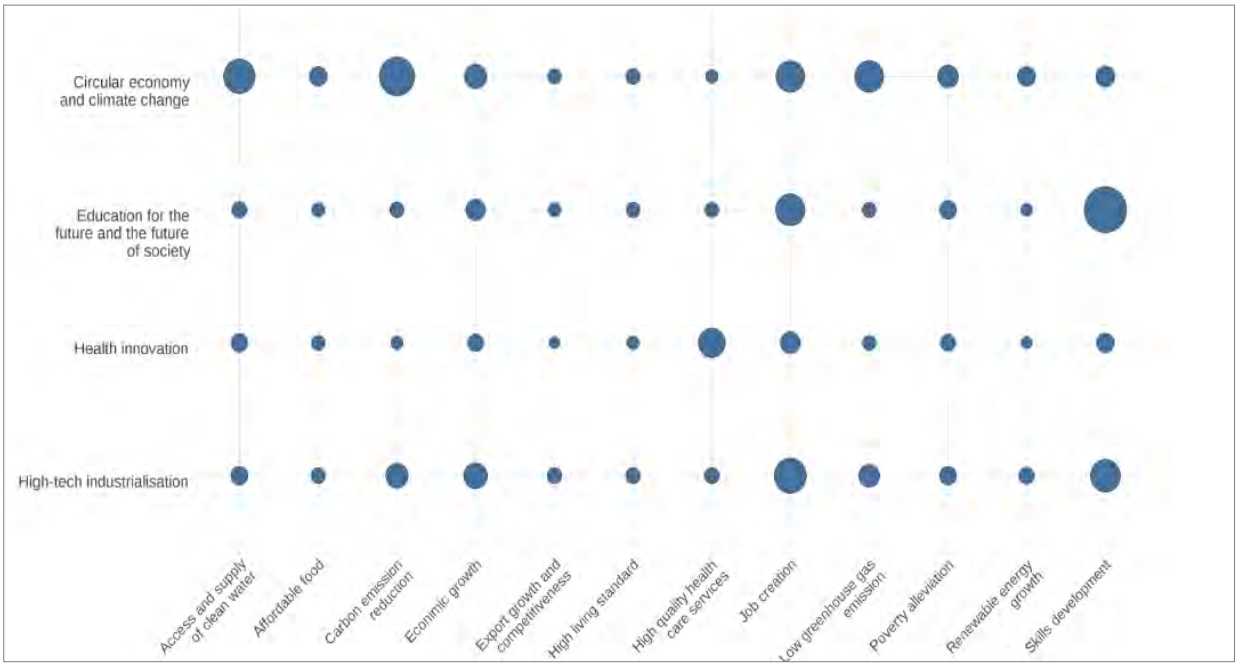

Figure 3.8: The semantic analysis output matrices based the system of intelligent foresight analytics linking the four selected focal areas with the 12 socio-economic and environment indicators[2]

The matrix was built following an analysis of the South African context. The larger the circle, the stronger the impact of the priority area (vertical axis) on the particular indicator(s) (horizontal axis). The analysis revealed the following:

- High-tech industrialisation can have a major impact on economic growth and the creation of new jobs, and is related to skills development.
- The circular economy can drive the reduction of carbon emissions.
- Health innovation can improve the quality of health care services.
- Education for the future and the future of society are strongly linked in respect of the development of future skills.

Detailed matrix analyses of each priority against the 12 indicators are shown in Figure 3.9.

1 Department of Science and Innovation (2021) South Africa 2030 Science, Technology and Innovation Foresight follow-up data analysis to support the choice of priorities for the Decadal Plan and quantify the possible effects of the priorities

2 Economic growth, job creation, high quality health care services, access and supply of clean water, affordable food, carbon emission reduction, low greenhouse gas emission, export growth and competitiveness, skills development, renewable energy growth, and poverty alleviation

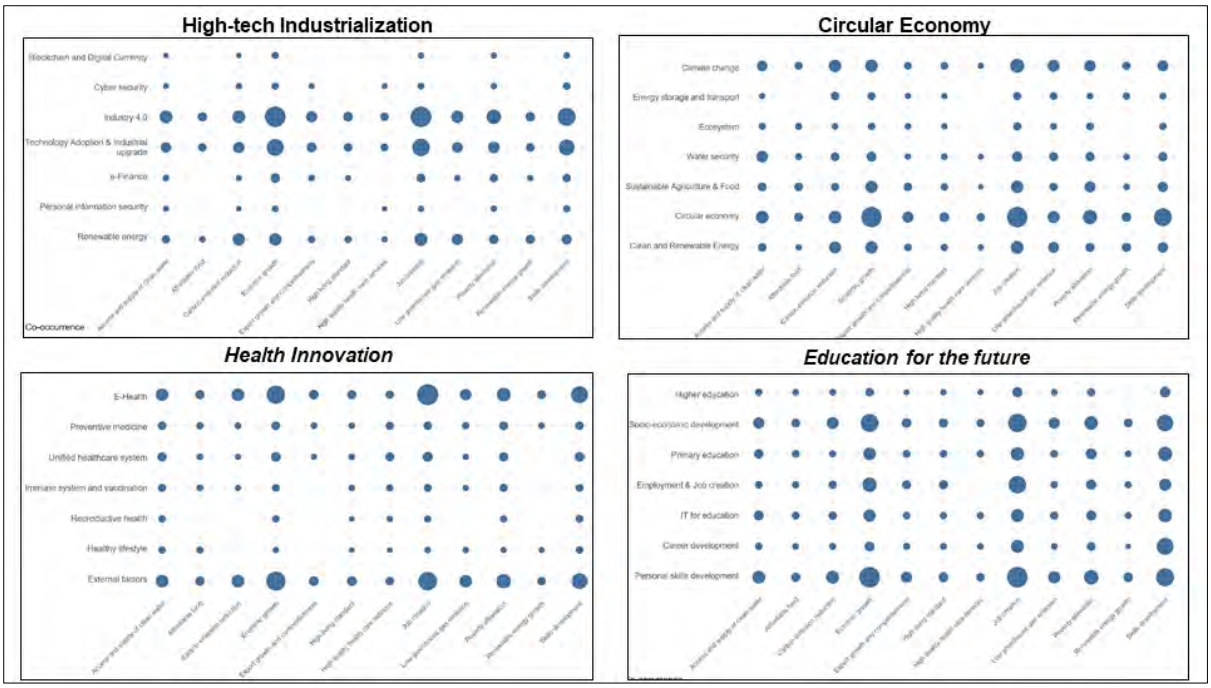

Figure 3.9: Matrix analysis of each priority against the 12 indicators

Overall, the output matrices revealed a strong alignment of the four Decadal Plan priority areas and the socio-economic and environmental indicators.

3.9.2 Future work

The successful monitoring of the implementation and the envisaged outcome of the STI priorities relies to a large extent on the selection of appropriate indicators. Table 3.2 proposes some output-outcome-impact indicator measurements. At a high level, some of the envisaged outcome-impact indicators of the proposed STI interventions include –

- the adoption of digital precision technologies is expected to unlock significant export value for the agricultural sector;[1]
- in the manufacturing sector, the increase of R&D intensity from the current 0,3% level[2] to a medium-to-high level of 3-5%[3], has the potential to drive productivity improvement through the production of high-tech products;[4]
- through high-technology (digital and automation) applications, in particular smart sensors, the realisation of significant productivity improvements in the mining sector;[5]
- improved circularity of the SA economy from the current 7% to the projected global target of 17% by 2033;[6]
- in the health sector, contributing to reduce the prevalence of non-communicable diseases (such as cancer), communicable diseases (in particular, HIV/Aids and tuberculosis), and maternal, infant and child mortality by 28% by 2030;

1Accenture Strategy (2020) Unlocking Digital Value in South Africa's Agriculture Sector (https://www.accenture.com/_acnmedia/pdf-102/accenture-unlocking-digital-value-south-africas-agriculture.pdf); GreenCape (2020). Sustainable Agriculture (https://www.greencape.co.za/assets/AGRICULTURE_MARKET_INTELLIGENCE_REPORT_WEB.pdf)
2 HSRC (2012). Innovation in the South African Manufacturing Sector, 2010-2012
3 OECD (2016). The Working Paper on Taxonomy of Economic Activities based on R&D Intensity
4 The World Bank (2017). Innovation for Productivity and Inclusiveness. South Africa Economic Update No. 10.
5 Von Blottnitz et al. (2021). An Economy-wide Material Flow Analysis to Develop Circular Economy Indicators for South Africa; The Circularity Gap Report 2021 (https://www.circularity-gap.world/2021)
6 Von Blottnitz et al. (2021). An Economy-wide Material Flow Analysis to Develop Circular Economy Indicators for South Africa

- the innovation advances in clean and sustainable energy provision — such as the Hydrogen Society Roadmap, which is expected to contribute $5 billion to the country's GDP by 2050,[1] are expected to play a pivotal role in the just transition agenda.

Monitoring and evaluation (M&E) will be critical in assessing progress made towards achieving the objectives of the Decadal Plan. The M&E Framework will also important in enabling interventions to address shortcomings, lack of progress or other issues that arise during implementation. In line with the Decadal Plan philosophy of positioning the NSI to make an increased positive impact, and balancing impact and with continued investment in the long-term development of the NSI, the M&E process must not only be geared towards the measurement and assessment of outputs realised through the implementation of the Decadal Plan, but also its socio-economic and environmental outcomes and impact.

The National Advisory Council on Innovation (NACI) is at the conceptual stage of developing appropriate input, output, outcome and impact measures for the STI priorities. These indicators and the associated baseline will assist the NSI in tracking the envisaged contribution of the identified STI priorities to attaining socio-economic goals. The envisaged RDI implementation plans will set relevant indicators and targets to ensure effective M&E.

Table 3.2: Tentative indicator measurements for the different Decadal Plan STI priorities

***Decadal Plan* Priorities**	**Tentative indicators**
Modernising key sectors of the economy	**AGRICULTURE**
	• Improved R&D intensity of sector
	• Enhanced agriculture total factor productivity and competitiveness
	• Increased number of plant breeders' rights registered
	• Enhanced drought-tolerant and pest-resistant varieties and cultivars developed through the creation of new genomic breeding platforms
	• Increased number of national decision-support tools based on precision agriculture and digital technologies (e.g. predictive models for agronomy forecasting, disease diagnostics and biosecurity and surveillance and monitoring systems
	• Increased number of national knowledge hubs and platforms that support the development of precision agriculture tools and/or scientifically validated information and databases (e.g. the Biosecurity Research Hub, phenomics platform or big data hubs that support predictive modelling and surveillance)
	• Number of new productive crop/animal value chains enhanced by innovation and contributing to sector productivity/competitiveness
	• Increased number of small-scale farmers with access to predictive models for agronomy forecasting, disease diagnostics and biosecurity, surveillance and monitoring systems, and decision support
	• Enhanced trade through the use of digital platforms and the application of smart technologies to generate information for robust early warning systems
	• Increased number of black farmers accessing formal domestic and international markets through the provision of regulatory, phytosanitary, food safety and quality and accreditation support

1 Department of Science and Innovation (2021). Hydrogen Society Roadmap for South Africa (Available online at: https://www.dst.gov.za/images/South_African_Hydrogen_Society_RoadmapV1.pdf)

Decadal Plan Priorities	Tentative indicators
	• Increased number of niche crop value chains developed to support nutrition security/new growth
	MANUFACTURING
	• Increased R&D intensity of sector
	• Enhanced manufacturing total factor productivity and competitiveness
	• Increased number of newly developed hi-tech applications and process technologies for the benefit of various manufacturing economic subsectors
	• Increased number of manufacturing hi-tech exports
	• Increased size and adoption of high-tech manufacturing in existing sectors in the country for improved productivity
	• Increased number of SMMEs developing hi-tech manufacturing capabilities
	• Improved number of developed high-tech manufacturing products and technologies for existing and new market segments
	• Increased number of space technology demonstrations, pilots and precursor platforms
	• Improved number of newly developed and advanced space mission applications products and services
	• Improved global market share of locally developed CubeSats and space systems and subsystems
	• Increased number of new local communication satellite capabilities, and applications developed to reduce the costs of communication, navigation and surveillance
	MINING
	• Improved mining sector factor productivity
	• Increased R&D intensity of sector
	• Improved effectiveness and efficiency in mining operations for developing and adapting high-tech applications for sustainability
	• Increased R&D intensities and competitiveness of the mining sector
	• Strengthen the integration of key enabling high-technology and mining equipment to improve accuracy in extraction levels
	• Increased use of high-tech equipment, services and processes in mining to drive the sector's sustainability and competitiveness
	• Increased use of high-tech to enable mining equipment tracking, usage and proactive failure warning
New sources of growth	**CIRCULAR ECONOMY**
	• Improved circularity[1] percentage as a result of STI interventions
	• Strengthened ecological cycling (material flows made up of biological nutrients designed to re-enter the biosphere)
	• Increased support for socio-economic cycling (long service lives to close loops through reuse and recycling)
	DIGITAL ECONOMY

1S Von Blottnitz et al. (2021): An Economy-wide Material Flow Analysis to Develop Circular Economy Indicators for South Africa

Decadal Plan Priorities	Tentative indicators
	Artificial intelligence, robotics and cybernetics
	• Increased number of industrialised mobile technologies used to enable building of telecommunication hardware and software in SA
	• Increased adoption of robotic systems to drive growth in key sectors of the economy
	• Enhanced evidence-based decision making for the public sector – A national platform for AI solutions
	• Increased number of developed human-friendly language-related technologies that can be applied to address the country's digital, language and literacy divide and contribute to socio-economic development.
	Cybersecurity and blockchain
	• Percentage reduction of cybercrime affecting SA's GDP by 2030
	• Increased implementation of digital identity in government institutions
	• Increased mentorship and support for start-ups
	Modelling and simulation
	• Improved industrialisation through the application of modelling and simulation tools
	• Increased number of high-fidelity multi-scale modelling and simulation technologies
	• Improved number of consolidated models and validation protocols for models across various industrial applications
Health innovation	**HEALTH INNOVATION**
	• Increased number of locally developed new treatment and prevention technologies
	• Improved availability of health innovation technologies appropriate for resource-poor settings
	• Improved number of locally developed digital health solutions used to assist with service delivery
	• Expanded roll-out of locally developed technologies appropriate for genetic profiling for precision medicine
	• Increased localisation of vaccine and enhanced biomanufacturing capabilities for active pharmaceutical ingredients
Energy innovation	**ENERGY INNOVATION**
	• Increased number of clean energy technology demonstrations, pilots and deployments
	• Increased roll-out of locally developed clean energy technologies
	• Increased exports of green hydrogen derivatives, e.g. green ammonia
	• Increased exports of value-added components for clean energy technologies
	• Increased global green hydrogen market share for South African
	• Percentage of energy RDI funding allocated towards technologies that support the move to a net zero economy (pre-2030 and post-2030)
	• Number of energy-intensive companies that participate in local R&D that remain competitive while adopting clean energy technology and retaining their export markets.
Innovation in support of social progress	**INNOVATION IN SUPPORT OF SOCIAL PROGRESS**
	• Increased number of inclusive innovation support programmes to enhance the delivery of basic services implemented in the public sector, including at municipal level
	• Increased number of decision-support tools available and used in support of decision-making in the public sector and in municipalities

Decadal Plan Priorities	Tentative indicators
	• Number of publicly funded intellectual property assets commercialised by grassroots innovators
	• Number of innovations for local economic development initiatives implemented to strengthen local systems of innovation
	• Improved percentage of academic training programmes available for inclusive innovation
	• Increased percentage of publicly funded intellectual property utilised by start-up innovation companies and SMMEs
	• Expand the number of start-up and SMME inclusive innovation support programmes initiated by higher education institutions in partnership with private companies
	• Expand the number of young people participating in income opportunities through inclusive innovation programmes

CHAPTER 4: HUMAN RESOURCES FOR STI

4.1 Introduction

In line with the NDP, the 2019 White Paper on STI aims to expand and transform human capabilities for STI. Its policy intents refer to –

- the expansion of human resources for STI;
- a more inclusive human resource base for STI;
- the creation of a science literate and science aware society.

The NP-PSET approved in 2021 is the implementation plan for the 2013 White Paper for Post-School Education and Training. The STI and PSET White Papers illustrate the strong systemic linkages between their efforts to attain NDP goals.

4.2 The current state of human resources for STI

4.2.1 Human capabilities at tertiary level

South Africa's gross enrolment at tertiary level as a percentage of its 20 to 24 year-old population is low for an upper-middle-income country. In 2018 the ratio stood at 21,6%, up from 17,7% in 2010. The NDP targets a ratio of 25% by 2030.

In 2018, public universities produced 227 188 graduates. The NDP sets a target of 425 000 graduates a year by 2030. In 2018, 85% of an enrolment total of about 1.3 million students were in undergraduate programmes. Enrolments in postgraduate programmes amounted to only 195 000 or 15% of the total; compared to the NDP's target of 25%.[1]

The NP-PSET aims to increase enrolments in the technical and vocational education and training (TVET) sector to increase the gross enrolment ratio. The NDP proposes that 30 000 artisans be produced per year by 2030. Increased enrolments in community education and training (CET) colleges are also envisaged.

High-end, PhD-level human capabilities are important for national development. The notion of a PhD as a driver of innovation is generally accepted. The number of PhD graduates produced in SA annually more than doubled between 2010 (1 420) and 2019 (3 445). The NDP goal of 5 000 PhD graduates by 2030 is in sight, although forecasts show that PhD graduates from the rest of Africa will outnumber those from SA by about 2023/24 if no additional interventions are introduced to incentivise and support South African students to enrol for doctoral studies.

4.2.2 Human capabilities and the Decadal Plan RDI priorities

South Africa's industrial and economic growth is constrained by a severe lack of skills and the skills development system has not delivered the skills needed to meet economic growth targets. The National Skills Development Strategy (NSDS) III is intended to achieve significant increases in qualifications and skills to support government priorities. The DSI is working with the Department of Higher Education and Training (DHET) to adapt the NSDS III into the Innovation and Skills Development Framework in support of the post-Covid-19 Economic Reconstruction and Recovery Plan and the Decadal Plan. Priorities include modernising key sectors of the economy, which requires innovation skills in support of high-tech applications and productivity improvements. Technological innovation, the circular and digital economies,

[1] Analysis of PSET Trends Towards 2030: National Planning Commission Report, April 2020.

and harnessing the innovation capabilities built by the NSI in health, energy, climate change and education, among other areas, require intensive skills development.

All DSI entities have been requested to develop their own skills development and innovation strategies to support the Decadal Plan and RDI priorities. All government research entities, state-owned enterprises (SOEs) and national facilities will be requested to develop and include their own strategies in their annual performance plans — and work with SETAs in this regard.

This will support government's mass public employment programme and address the NEET challenge by helping produce skills for occupations in high demand.

The DSI has a large portfolio of RDI programmes that provide innovation skills development opportunities, but they need to be articulated with the relevant SETAs. There are opportunities for the development of intermediate (graduate-level) and high-end (PhD-level) skills in the priority areas. The universities of technology (UoTs), which are critical role players in the acceleration of the country's 4IR, need to be supported and positioned differently to universities. The UoTs and TVET colleges should become places where young people with ingenuity and drive invent technologies and launch industries, leading to job creation.

The DSI has made inputs into RDI requirements to implement government's master plans to support competitiveness and job creation in various sectors. Through the Sector Innovation Fund, the DSI is working with industry to unlock competitive industrial development opportunities.

4.2.3 Workplace learning and work integrated learning

The DSI will make opportunities for work integration and workplace learning available in some of its science councils, national research facilities and flagship RDI programmes, such as the hydrogen economy (fuel cells), additive manufacturing, space science, waste management, IKS, technology localisation, the Technology Stations Programme and mLabs. This will extend to upskilling even beyond master's and PhD qualifications in terms of developing specialist research, innovation, commercialisation, entrepreneurship and business skills though internships and professional development.

In today's competitive, technology-driven society, the workforce must be continually reskilled or upskilled as lifelong learning becomes a necessity. The SETAs play an important role in addressing workplace skills needs. The real value-add from the SETAs is the understanding of labour market issues and potential growth areas in their respective industrial and economic sectors. The Decadal Plan has identified manufacturing, agriculture and mining as priority sectors that need to be modernised, and engagement with the SETAs will focus on these three sectors.

With the National Skills Fund, the DSI will look at intensifying its workplace preparation programmes – internships, youth volunteers and professional development programmes.

4.3 Expanding the human resources capacity for STI

There is an urgent need to expand the human resources development pipeline from schooling to the PSET sector and doctoral training. The pipeline is characterised by low levels of competence among learners studying the gateway subjects of mathematics and science, often resulting in far too few learners gaining access to PSET institutions. The PSET system must be diversified and become more responsive to labour market intelligence to meet future

skills requirements. Public financial support for the PSET system needs to be strengthened, especially undergraduate and postgraduate bursaries, throughput rates need to be increased, and further promotion of TVET colleges as institutions of choice is necessary.

Note: In all the tables indicating time frames, ongoing and short term means one to three years, medium term means five to eight years, and long term means eight to 10 years.

Table 4.1: Policy Intent: Increased output of human resources from the research system

Intervention	Time frame	Indicators
Enrolment planning as government steering mechanism to control the mix (TVET colleges and universities, undergraduate and postgraduate, priority and other areas, South Africans and non-South Africans) of students in PSET	Ongoing	Proportion of undergraduate to postgraduate enrolments and graduates by Classification of Educational Subject Matter field
Bolster monitoring of student success in PSET system	Short term	Graduation output rates
Develop and implement sustainable financial ecosystem for student funding, leveraging all sources of funding	Short term	Proportion of postgraduate students receiving financial support from government
Establish a national strategy group on postgraduate education	Short term	Strategy Group on postgraduate Education established
Finalise and implement a digital platform for tracking previously funded postgraduate students	Short term	postgraduate employability and mobility rates
Provide financial support to at least 20% of registered postgraduate students within 10 years to grow and transform research system	Long term	% of postgraduate students supported by government

In the face of skills shortages, graduate unemployment is an indication of a mismatch between the outputs of the PSET sector and the needs of industry and society. Skilled graduates should be absorbed into employment, and many more supported to be innovators, entrepreneurs and eventually business owners and employers. The DSI and DHET, supported by the Department of Small Business Development, will extend and grow initiatives such as mLabs, Living Labs and agricultural innovation hubs that support innovation and entrepreneurship — especially at TVETs and CETs. This will be complemented by a strengthened DHET Entrepreneurship Development Programme.

The DSI will include skills development components in most of its grants for targeted RDI projects. Generally, the DSI will participate more in the many DHET initiatives aimed at skills, innovation and entrepreneurship development at TVET and CET colleges. Skills and community development will be enhanced by increased partnerships between CET colleges and skills centres. Already, earmarked funding within CET budgets is being used to fund skills programmes and capacity building initiatives.

Scientific discovery and innovation are increasingly driven by advanced research infrastructure, equipment and platforms, such as big data. The effective use of these platforms requires specialised expertise. This will present opportunities for intermediate (including from TVET colleges) and high-end skilled graduates.

The link between the proportion of engineers in a national population and the nation's socio-economic and industrial development status is well established. Engineers play a significant role in changing the fortunes of countries — provided that their skills are recognised. They

need an environment that enables them to deliver infrastructure and find innovative approaches to improving agricultural production and exports, for example, or increasing manufacturing and mining output. According to the Academy of Science of South Africa (ASSAf)[1], South Africa's number of engineers per million of population is by far the lowest among BRICS countries (in 2017 South Africa had 265, Brazil 566, India 748, China 1 155, and Russia 2 590).

The need to analyse the nature of shortages (qualifications/skills/work readiness/location/ workplace conditions) cannot be understated in view of the imperative to achieve the economic inclusion of women, youth and people with disabilities in skills development initiatives.

Table 4.2: Policy Intent: Strengthening the skills base of the economy

Intervention	Time frame	Indicators
Entities and science councils identify RDI programmes with skills development components for funding by SETAs through Skills Development Funds and include in their annual performance plans	Short term	Number of RDI programmes Number of recipients benefiting from funds
Engagement with relevant SETAs and SOEs to build intermediate R&D skills in areas aligned to the Decadal Plan and priority areas in energy, water, mining and manufacturing	Short term	Number of SETAs with programmes to build intermediate R&D skills in priority areas
Ongoing review of Programme and Qualification Mix to assess the ability to respond to future skills needs Where possible, adapt programmes to blended modes of delivery to broaden access	Short term	Improved employability rates of PSET graduates
Include skills development components in targeted RDI projects grants	Medium term	Number of RDI funding grants with skills development components Number of beneficiaries receiving funding through these instruments
Use RDI programmes with skills development components for workplace experiential learning opportunities for TVET and UoT students	Medium term	Number of experiential learning opportunities at DSI and its entities' RDI projects Number of students in such programmes
Strengthen and grow initiatives that support entrepreneurship and innovation at TVETs and CETs	Medium term	Number of DSI entrepreneurship and innovation programmes at TVETs and CETs
Skills forecasting to understand and educate for future skills (will be informed by engagements with employer/industry associations and key government strategies/interventions, and must include forecasting of skills for new sources of growth)	Medium term	Skills forecasting capability established in the sector as evidenced by data and reporting
Improve the quality and reputation of TVET colleges to make them institutions of choice in	Long term	Number and proportion of TVET students

[1] Academy of Science of South Africa (2017). Status of Postgraduate Research Training in South Africa Report.

Intervention	Time frame	Indicators
the development intermediate and high-level skills		
More centres of specialisation aimed at building capacity of public TVET college system to deliver trade qualifications and much-needed skills	Medium term	Number of centres of specialisation at TVET colleges
Extend programmes like Technology Stations Programme to TVET colleges, and provide support with appropriate infrastructure	Medium term	Number of technology stations at TVET colleges
Encourage all SETAs to support the development of high-level skills (postgraduate student support) in areas relevant to their sectors	Medium term	Number of SETAs supporting postgraduate studies
Establish and increase skills development centres or multipurpose education and science skills centres in line with District Development Model	Long term	Number of skills development centres or multipurpose education and science skills centres

4.4 A more inclusive STI human resource base

While enrolments and graduations by black people and women at universities have increased, this is yet to translate to the improved upward mobility of black academics . A significant number of mostly black and women lecturers in the university system, including at senior level, who do not have PhDs and are not actively publishing. Most of these academics are at historically disadvantaged institutions (HDIs) and UoTs.

PhD qualification attainment interventions must be focused on institutions and disciplines where they will make a great difference. The general rise in annual PhD graduations presents an opportunity for universities, science councils and even public research institutions (PRIs) to increase the proportion of PhD-qualified staff.

The interventions in this policy intent are focused on transforming the cadre of established researchers and knowledge producers.

Table 4.3: Interventions: A transformed researcher base

Intervention	Time frame	Indicators
Fast-track implementation of Staffing SA's Universities Framework and subsidiary strategies	Current and ongoing	Number of full-time academics in higher education Demographically representative teaching and research workforce in universities % of PhD-qualified academic staff
Boost interventions aimed at PhD attainment by university staff, focusing on HDIs, UoTs, women and black academics	Current and ongoing	Increased % of PhD-qualified staff at HDIs and UoTs
Boost PhD qualification attainment in science councils and national facilities Study institutional cultures that compromise optimal performance, including obstacles to building a cadre of emerging researchers	Medium term	Increased proportion of PhD-qualified staff in science councils and national facilities
Scale up Black Academic Advancement Programme and early career researcher programmes that focus on black and women researchers, to complement	Short term	Number of black and female researchers in the Future Professors Programme

Thuthuka. These programmes will feed into the Future Professors Programme.		
Revise policy for SARChI and CoEs to include compulsory targeted succession planning	Short term	Number of emerging researchers mentored in SARChI and CoE programmes
A national mentoring and supervision skills programme	Short term	Number of participating universities and staff (mentors and mentees)
Attract and support a critical mass of foreign postdoctoral fellows where there is inadequate supervision capacity	Short term	Number of foreign postdoctoral fellows where supervision capacity is inadequate
Boost collaboration with large/international research infrastructures	Short term	Number of postgraduate students trained at these research infrastructures

4.5 A science literate and science aware society

The DSI leads a national science engagement programme aimed at building a society that is knowledgeable about science, scientifically literate and able to form independent opinions on science issues. Its strategy targets various publics such as learners, parents, civil society, and labour. The Covid-19 pandemic raised people's awareness of the importance of scientific issues and the need to make rational and evidence-based decisions. A scientifically engaged society is important for the evaluation and verification of information and subsequent courses of action in a world where the spread of misinformation and fake news is increasing.

Table 4.4: Policy Intent: A science literate and science aware society

Intervention	Time frame	Indicators
Fund and support the South African Agency for Science and Technology Advancement as the national coordinating body for science engagement	Current and ongoing	Measure nature and extent of science engagement
Engage STEM professional bodies and voluntary associations to include science engagement in continuing professional development programmes	Current and ongoing	Number of professional bodies and voluntary associations with science engagement in their continuing professional development programmes
Intergovernmental forum on science engagement programmes to ensure alignment and coordination in implementation	Short term	Intergovernmental forum for science engagement established
Support accredited science engagement programmes at universities, and facilitate the incorporation of such programmes into government's grant funding	Short to medium term	Number of accredited science engagement programmes at universities
Establish more science centres in collaboration with provincial education departments to spatially match science centres to districts in line with the District Development Model	Long term	Number of new science centres

4.6 Desired state of South Africa's human resources for STI

Table 4.5: Current and desired state of SA's human resources for STI

Indicator	Baseline	2030 targets
Average grade 8 Trends in International Mathematics and Science Study scores	264 (per year) 420 (projected for 2023)	500
PSET enrolment	TVET = 688 028 CET = 258 199 Universities = 1 222 030 (2017)	TVET = 2 500 000 CET = 1 000 000 Universities = 1 600 000
Number of Artisans produced/certified	19 100 (2017)	30 000
Learners eligible for university admission	153 610 (2017)	450 000
Graduates (public universities)	227 188 (2018)	450 000
Engineers per million of population	265 (2017)	500
Postgraduate enrolment as a proportion of total university enrolment	15% (2018)	> 25%
Annual doctoral graduates	3 344 (2018)	5 000

CHAPTER 5: EXPANDED AND TRANSFORMED RESEARCH SYSTEM

5.1 Introduction

South Africa has a productive research system, world-class universities, multiple fields of excellence and high international scientific impact in prioritised research fields. However, certain sections of the system are still emerging from inherited structural inequities (demographic, institutional and spatial), resulting in inefficiencies and suboptimal research performance. At a demographic level, in 2016, 34% of scientific papers produced by universities were authored by women, 31% by black researchers, and 20% by researchers who are 60 years and older[1]. The research system should become more inclusive of black and female scientists and academics.

Universities account for more than 85% of the country's scientific publications while other players such as science councils, national facilities, other public research institutions (PRIs) and the private sector account for the remainder. There is a need to increase the contribution of the private sector by, for example, strengthening linkages with universities, science councils, national facilities and PRIs to improve knowledge diffusion and movement of researchers between these players.

The STI White Paper policy intents for an expanded and transformed research enterprise are –

- an expanded and transformed research institutional landscape;
- upgraded and expanded research infrastructure;
- an open, responsive and impactful research system;
- an increased volume and quality of research outputs.

5.2 Expanded and transformed research institutional landscape

A well-functioning research system is configured with adequate but diverse research institutions, and populated by a critical mass of researchers. Such a system should be smart, responsive to national priorities, and free of unnecessary duplications. The Higher Education, Science, Technology and Innovation (HESTIIL) Review Report made recommendations that included the creation of new institutes and science councils, unbundling some of the existing science councils, and creating more platforms for RDI collaboration between universities and industry. These recommendations are discussed below.

After 15 years of sustained investment in SARChI and the CoEs, the consolidation of some CoEs and research chairs to form research institutes to increase the scale and scope of these flagship programmes is being considered. This will diversify and expand the research landscape.

The existing universities in South Africa are not able to meet the demand for university education. There are plans to establish two new universities, one in Ekurhuleni for STI, and one in Hammanskraal, specialising in crime prevention.

The current institutional landscape hinders the seamless and continuous development of research capabilities. Synergies between existing research institutions should be enhanced. The interventions proposed to expand and transform the institutional landscape are shown in Table 5.1.

[1] The State of the South African Research Enterprise, 2019: pp 4-5

Table 5.1: Interventions: Expanded and transformed institutional landscape

Intervention	Time frame	Indicators
Investigate possible separation of the National Research Foundation (NRF) into two bodies – the National Foundation for Research and Innovation and the National Facilities Council	Medium term	Feasibility report
Consider a new advanced engineering and digital technologies institute to catalyse research in computer, information and digital sciences and technologies	Medium term	Feasibility report
Consider incorporating the National Integrated Cyberinfrastructure System (the Centre for High Performance Computing, SANReN and the Data-Intensive Research Initiative of SA) into the new advanced engineering and digital technologies institute	Medium term	Feasibility report
Consider establishing an environmental and climate change research council	Medium term	Feasibility report
Consider establishing a national institute for the study of pandemics (prevention and responses) with embedded vaccine science	Medium term	Feasibility report
Fast-track the establishment of a university for STI in Ekurhuleni, and one for crime detection in Hammanskraal Explore the establishment of yet another university by 2030	Medium term	Number of new universities established
Consider establishing research institutes through the consolidation of some of the research chairs and CoEs, including a polar research institute	Medium term	Number of new research institutes established
Develop and implement an incentive programme to encourage research staff exchanges between historically advantaged institutions and HDIs, between universities and science councils/national facilities, and between universities and industry	Short term	Number of contracted consortium arrangements between historically advantaged institutions and HDIs, and between universities and other PRIs

5.3 Upgraded and expanded research infrastructure

Research infrastructure is key to boosting research productivity, accelerating technology development and innovation, and providing advanced research training for new generations of scientists. Interventions in this regard will seek to cover the five types of research infrastructures, namely, global infrastructure, cyberinfrastructure, high-end infrastructure, scientific equipment and specialised facilities. There is a need to promote reciprocal access to global research infrastructure and establish critical national research infrastructure on a shared-services basis. Other types of more affordable research infrastructures need to be established and supported nationally, provincially and regionally. Existing scientific infrastructure must be upgraded and maintained. Table 5.2 proposes interventions aimed at upgrading and expanding research infrastructure.

Table 5.2: Interventions: Upgraded and expanded research infrastructure

Intervention	Time frame	Indicators
Strengthen and extend macro-infrastructure framework for universities to include TVET and CET infrastructure	Short term	Number of TVET and CET colleges receiving macro-infrastructure grants
Infrastructure and efficiency grants to support teaching, learning and research infrastructure and to reduce maintenance backlogs at universities Coordinated with and complemented by the implementation of DSI's South African Research Infrastructure Roadmap	Short term	Number of research infrastructure grants awarded
Complete the SANReN access project for TVET colleges and rural universities, and extend it to CET colleges	Medium term	Number of TVET and CET colleges accessing broadband though SANReN
Implement the National Big Data Strategy and create regional tier 2 data nodes across the country in specific domains or sectors, or to serve regional needs	Medium term	National Big Data Strategy implemented
Strengthen and expand the National e-Science Postgraduate Teaching and Training Platform with a focus on the delivery of a transdisciplinary and multi-institutional structured master's programme	Medium term	Number of e-science, transdisciplinary and multi-institutional structured postgraduate programmes
Establish and implement a National e-Research Support Programme for research capacity development	Medium term	Number of e-science, transdisciplinary and multi-institutional structured postgraduate programmes
Redirecting and awarding at least 30% of research equipment grants to HDIs and UoTs	Short term	Proportion of research equipment grants made to HDIs and UoTs

5.4 An open, responsive and impactful NSI

Basic science is undertaken to obtain greater knowledge and understanding of observable facts or phenomena, without the intention of pursuing immediate application or use. The value of basic research is knowledge development, which is measured using bibliometric indicators such as citation impact. In the long term, basic research has been the source of many social and technological innovations and applications, resulting in societal transformations.

Researchers should put excellent research at the service of good government. Governments rely on research to inform policy addressing complex societal and global challenges.

The Centres of Excellence Programme is a good example of an initiative established to strengthen basic research and to contribute to –

- information brokerage — providing access to highly developed pools of knowledge, maintaining databases, promoting knowledge sharing and knowledge transfer;
- networking — actively collaborating with reputable individuals, groups and institutions to help realise national, regional, continental and international partnerships;

- knowledge services — analysing strategic information toward policy development, and providing reliable policy advice to government, business and civil society.

There is a need to make publicly funded research and the data generated open, accessible, transparent, collaborative and closer to citizens, and thus more responsive to the needs of society and industry. Given (a) that societal problems know no disciplinary boundaries, (b) that many industrial and technological solutions require different or converging disciplinary perspectives, and (c) the importance of social and human dynamics in science research, transdisciplinary research is key. Transdisciplinary research not only requires flexibility and fluidity that allows for thinking across, beyond and through disciplines, but also requires great depth and rigour in the attendant disciplines.

Research also contributes to developing intellectually engaged citizens who can participate meaningfully in their political, social and cultural lives.

The implementation of the 2021 NRF Framework to Advance the Societal and Knowledge Impact of Research will enable government to be decisive and intentional about supporting research that leads to impact, including scholastic or scientometric impact in the basic sciences or curiosity-driven research.

The South African research system has shown agility and responsiveness to agenda setting. For example, the incentive policy for research outputs from universities is largely responsible for the dramatic increase in research outputs and the country's strong scientific presence in chosen priority areas, including geographic advantage areas.

The Centre for Research on Evaluation, Science and Technology's 2018 State of the South African Research Enterprise report notes that, although the country's research system is "punching above its weight", its research capacity as measured in terms of full-time equivalent researchers per thousand of the workforce is still untransformed and too small. The imperative to expand and transform the research system and make it more inclusive is urgent.

Open science increases the accessibility of research as an important way to help strengthen the linkages between research institutions. Government is moving towards making publicly funded research and associated data open, accessible, transparent, collaborative and closer to citizens, and thus more responsive to society's and industries' needs. Cyberinfrastructure and e-skills development are necessary enablers for open science, open data and open innovation.

PRIs present specific opportunities for reimagining and transforming the research institutional landscape and making it more diverse and inclusive. The 2013 Declaration of Research Institutions allows only institutions classified as research institutions under the NRF Act to receive direct funding from the NRF. This eligibility is dependent on PRIs showing that they have a critical mass of PhD-qualified staff to perform research and the necessary supporting research infrastructure, and therefore have the capacity to mentor/host postgraduate students. PRIs such as museums, cultural and heritage sites, collection and archival institutions, and think-tank research organisations, which serve as knowledge hubs, will be capacitated and nurtured in line with their missions and mandates. Research funding will be extended to disciplines of competence not covered in the NRF Act, e.g. indigenous knowledge systems.

The specific interventions (Table 5.3) to achieve an open, diverse and responsive research system are focused mainly on capitalising on open science and the opportunities it offers in the diffusion and diversification of the knowledge enterprise.

Table 5.3: Interventions: An open, responsive and diverse knowledge system

Intervention	Time frame	Indicators
Implement incentives/programmes to promote transdisciplinary research on complex societal challenges	Short term	Incentive programme for transdisciplinary research developed
Implement the open science policy (once approved)	Short term	Increased adoption of/participation in open science
Operationalise and popularise platforms for open data science	Short term	Number of platforms for open data science
Implement innovation and creative output policy as a form of incentive for knowledge products other than research outputs	Short term	Uptake and utilisation of the creative output policy
Establish formal collaboration mechanisms to align RDI policies and plans better Cascade to TVET colleges	Short term	Formal collaboration agreement signed between the DTIC, DHET and the DSI
Establish national and regional platforms to forge collaboration between universities, science councils/entities, business and industry	Medium term	Number and effectiveness of national and regional collaboration platforms
Implement the Declaration of Research Institutions Framework to support more PRIs	Current and Ongoing	Number of PRIs declared fundable by the NRF
Incentivise and carry out industry-based research studies to promote industry-based master's and doctoral programmes		Number of industry-based master's and PhD programmes

5.5 Increased volume and quality of research outputs

The flagship programmes targeted at established researchers such as SARChI, the CoEs and the National Equipment Programme (NEP) have made significant contributions to increased research outputs from the university sector. However, these programmes have largely benefited historically advantaged institutions. Such flagship programmes need to be equitably allocated for the purposes of achieving a healthy, dynamic and balanced university research system in which all institutions contribute optimally to research outputs.

Government has been advocating for the differentiation (within a diversified South African higher education landscape) of the university sector so that each university is positioned along a self-defined, negotiated and ministerially endorsed trajectory. The HDIs are being urged to exploit their unique socio-economic and geographic locations and milieus as points of departure for the direction of their research advantages and strengths. There is huge potential for HDIs to contribute to knowledge production outputs, particularly in areas relevant to their local context or districts — bearing in mind that community engagement and/or local development in line with the government's District Development Model (DDM) will be enhanced as a field of academic and research endeavour in its own right. The emphasis on research for impact presents critically important opportunities for the social advancement

of communities from predominantly rural and/or underdeveloped parts of South Africa. This would dovetail with the notion of a university that is a development partner of government and society.

According to the 2019 HDI Development Framework, the HDI Development Programme will provide comprehensive support to increase postgraduate and research outputs from HDIs, among others (Table 5.4).

The current DHET Funding Framework has resulted in an emphasis on the quantity rather than on quality of publication output. Recent studies have shown that, as a consequence, the system has witnessed the unfortunate emergence of different forms of unethical and questionable publication practices (such as predatory publication). Against this background the DHET has, in consultation with key stakeholders, developed a Research Quality Framework to ensure that the publications funded under the funding policy display research integrity.

Table 5.4: Interventions: Increased research outputs

Intervention	Time frame	Indicators
Through the HDI Development Programme (now called the Prof. Sibusiso Bhengu Programme), refocus effort and resources to increase the research production of HDIs	Medium term	Increased research outputs from HDIs
Ringfence a portion of resources for flagship programmes (SARChI, CoEs, infrastructure, international cooperation) towards supporting HDIs	Short term	Uptake of SARChI and CoEs programmes by HDIs
Commission a series of scientometric studies of basic disciplines (biological sciences, geological sciences, chemistry, physics, computer sciences, mathematics and statistics, history, sociology, economics, psychology, philosophy and political studies) through the Basic Sciences for Development Support Framework to assess their status and ensure that they continue successfully	Medium term	Several aspects of each field will be assessed, including (i) NRF funding, (ii) capacity and diversity of academic staff, (iii) academic pipeline and (iv) research performance.
Institutionalise ongoing reviews of strategies and funding policies for basic science disciplines	Medium term	Number and frequency of basic disciplines strategies and policies reviews
Approve and implement the research impact policy framework that makes it mandatory for recipients of research funding to show the impact their research will have	Short term	Research impact policy framework approved and implemented
Implement a research quality framework through a national collaborative programme funded under the University Capacity Development Programme	Short term	Evidence of increased adherence to ethical principles in publication practice

5.6 Embedding the humanities and social sciences in the NSI

The contribution of the humanities and social sciences (HSS) to our understanding of the social and cultural aspects of the world is important in its own right, and to complement discipline-specific knowledge in transdisciplinary studies so that societal grand challenges can

be met (Chapter 3). Support for research, data collection, and education and training in the HSS is therefore needed to secure the benefits of innovation.

The analyses and insights emanating from the HSS can help explain ethical issues and conditions under which new technologies are successfully introduced and spread. The long-term sustainable development features of new technologies are not just technological in nature, but increasingly dependent on their degree of acceptance and diffusion in society. HSS are critical in highlighting the social acceptance and integration of new technologies. Research on and the development of new technologies have impacts on international competitiveness and long-term employment growth. Each of these issues goes beyond the individual priority areas considered in this Decadal Plan, and each involves insights from a wide variety of HSS knowledge fields. The interventions aimed at making the HSS as a critical component of the NSI, and at projecting the desired state of the country's research system, are shown in Table 5.5 and 5.6, respectively.

Table 5.5: Interventions: Embedding the HSS as a critical component of science and innovation

Intervention	Time frame	Indicators
Ensure that funding calls include additional resources to enable transdisciplinary participation by the HSS	Short term	Number of transdisciplinary research calls with HSS focus
Feasibility study to establish the demand for institutes of applied HSS	Short term	Feasibility report
Increase support for interventions aimed at supporting "research to policy" work as the companion of the "lab to market" work of the STEM fields	Short term	Evidence of new programmes that support research for policy
Spearhead support for digital humanities as an emerging field that has the potential to inform transformative research in the humanities	Medium term	Increased funding for programmes and a community of practice for the digital humanities

Table 5.6: Projected desired state of South Africa's research system

Indicator	Baseline	2030 targets
Investment in R&D	GERD/GDP has averaged approx. 0,8% for the past 15 years	GERD/GDP at 1,5% in 2030
World share of global scientific publications (Web of Science)	0,39 % (1996) 0,61% (2013) 0,91% (2020)	1% (2030)
Percentage of PhD-qualified academic staff at universities	51% (2019)	75% by 2030
Percentage of PhD-qualified academic staff at universities of technology	31% (2019)	40% by 2030
Percentage of women in research	45,3 % (2017)	50% in 2030
Black-authored papers	16% (2005) 30% (2019)	50% in 2030
Authors under 40 years old	3% (2005) 18% (2019)	25% in 2030

CHAPTER 6: CREATING AN ENABLING ENVIRONMENT FOR INNOVATION IN SOUTH AFRICA

6.1 Introduction

In the context of the rapid changes and technological advances that are disrupting the world at all levels, it is globally recognised that existing assumptions about development and economic models need adjustment. This is particularly true in South Africa. Despite progress since 1994, the country has a highly unequal society, with low economic growth and decreasing investment, as well as increases in unemployment and poverty.[1] The World Bank recommends that "policies to spur innovation can go a long way in addressing unemployment, poverty and inequality in South Africa".[2] As early as 2015, the McKinsey Global Institute estimated that SA could increase GDP growth to 4,7% by 2030 by focusing on what it termed "the big five" priorities, namely, advanced manufacturing, natural gas within a diversified energy mix, agriculture, productive infrastructure, and service exports (particularly to the rest of Africa).[3] The role of innovation in unlocking these priorities is clear.

This chapter outlines initiatives to create an enabling environment for innovation through a whole-of-society approach that supports a coherent and inclusive NSI outcome as per Chapter 4. While innovation is not the only factor in higher economic growth and inclusive development, it remains a significant and vital catalyst with the potential to –

- improve service delivery and decision making for public policy;
- improve the quality of life of South Africans, particularly in poor and rural communities;
- increase the competitiveness of firms; and modernise and revitalise industries;
- develop new industries and support the formation of new technology-based firms;
- exploit new sources of growth;
- promote environmental custodianship.

For innovation to unlock these opportunities, it is necessary to (a) recognise that the sources of innovation are broader than R&D, (b) adopt a whole-of-society approach to innovation embedded in a culture of entrepreneurship and innovation, and (c) ensure that innovation is fundamentally inclusive.

6.2 Limitations of the current innovation environment

The current innovation environment is characterised by a poor economic trajectory, inadequate linkages between traditional and non-traditional innovation actors, and few pro-innovation policies. There is insufficient recognition of the potential of innovation in the informal sector and to support the common good (see also par. 3.2). The innovation efforts of SMMEs are not supported on a scale significant enough to improve their performance, use new sources of growth, or modernise their operations. Innovative solutions arising from R&D investments are not deployed to improve the performance of government departments. The public sector is not positioned as an enabler of innovation or a buyer of local technologies.

The current policy environment is typified by misalignment between government policies and the use and adoption of STI (in trade, economic activities, education, and international

1 South African Reserve Bank. 2017. *Economic and Financial Data for South Africa*. SARB, Pretoria.
2 World Bank. 2017. *South Africa Economic Update: Innovation for Productivity and Inclusiveness*. World Bank, Washington, DC.
3 McKinsey Global Institute. 2015. *South Africa's Big Five: Bold Priorities for Inclusive Growth*. McKinsey Institute, Johannesburg.

relations and collaboration). This manifests in the lack of infusion and expression of innovation in sectoral policies, with the exception of a few public service areas, e.g. sanitation and human settlements, where there have been recent pro-innovation policy reforms.

For example, the current intellectual property policy and regulatory environment, involving permits and certifications, and compliance with industry norms and standards, should be reviewed and reconfigured. An enabling policy environment for innovation utilisation to transform existing sectors of the economy through digital technologies in high-technology industries like health, agriculture and manufacturing is required.

The policy environment has to be transformed to promote diverse competencies and transdisciplinary skills, and a pro-innovation culture shift is needed across the economy and the public sector. Connectivity is a crucial enabler of transdisciplinary knowledge production and an entrepreneurial society. The current enabling environment does not incentivise diverse and transdisciplinary knowledge networks that support lifelong learning and innovative curricula. These networks are essential to whole-of-society innovation in which engagement in STI dialogues is advanced. Transdisciplinary networks could provide context-appropriate approaches entrenching a culture of entrepreneurship in STEM education.

Government and non-government funding instruments and arrangements for innovation support are inadequate, and are not translating efficiently into commercial opportunities or improving the quality of lives. This should be reviewed to harmonise public sector innovation funding instruments and provide fiscal incentives to increase participation in and access to different types of innovation by public and private sectors. The desired environment should enhance technology adoption by SMMEs in both the primary sectors of growth and network industries.

6.3 A historically narrow conceptualisation of innovation

The 2007 OECD review of the South African NSI and the 2012 ministerial review of the STI landscape found that the NSI revolves around traditional players in research and academia. There has been progress since these reviews (e.g. the Sector Innovation Funds), but the involvement of industry and government departments in general in stimulating innovation is limited. The uptake and commercialisation of research outputs is low.

As the 2019 STI White Paper states, over the past 25+ years, considerable effort has been made to support innovation. However, the support has been biased towards research and development organisations, higher education and training institutions, and public research institutions. This bias came at the expense of the rest of post-school education institutions (such as CET colleges), community-based and non-profit innovation support organisations, SMMEs, civil society, etc. Consequently, the focus of innovation support by the state has been the supply side, which limits the role that innovation can play in improving productivity and quality of life.

6.4 Ideas to commercialisation

The National Intellectual Property Management Office (NIPMO), the offices of technology transfer (OTTs) and the Technology Innovation Agency (TIA) must ensure that, where appropriate, publicly funded R&D outputs result in products, processes or services for commercialisation or other positive impact on the lives of South Africans. The Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act), 2008,

mandates the creation of OTTs at all institutions (26 HEIs and 11 science councils). The OTTs must receive disclosures of new intellectual property (IP) creations from researchers, analyse them for commercial potential and engage with TIA (and other funding agencies) for further development and exploitation. Among other things, the OTTs must seek IP protection where appropriate, conclude IP transactions (e.g. licences), establish start-up companies, receive revenue and share benefits with the IP creators.

Between 2008 and 2018, NIPMO received over 2 600 new IP disclosures from institutions. Between 2014 and 2018, institutions reported (a) over 900 granted patents and 300 granted trademarks, (b) 290 licenses concluded, 235 of which yielded revenues totalling R185 million, (c) more than R23 million in commercialisation revenue being paid to over 270 IP creators/enablers within these institutions, and (d) a total of 55 start-up/spin out companies employing 320 people. Between 2008 and 2018, 100 start-up/spin-out companies were formed, 95% from HEIs. Of the 100, 72 were still operational in 2018.

The policy environment and institutional architecture for IP must be enhanced and supported to ensure that IP emanating from publicly funded R&D is identified, developed and commercialised for the benefit of all South Africans.

6.5 A whole-of-society approach to innovation embedded in a culture of entrepreneurship and innovation

As indicated before, various reviews have pointed out that the South African innovation effort is fragmented. Government departments do not work together optimally to drive innovation. There are insufficient linkages between government and business. Despite their mandate to support communities, higher education institutions (HEIs) are often decoupled from their context, foregoing a golden opportunity to stimulate innovation in surrounding communities. To support a whole-of-society approach to innovation, an innovation compact is proposed, along with measures to build partnerships across the economy and support previously neglected innovators.

Such a whole-of-society approach to innovation will be more productive if it can play out in a culture that is knowledgeable about the benefits of RDI, and supportive of innovation and entrepreneurship. A recent report[1] on the status of entrepreneurship in South Africa shows that elements of the entrepreneurial ecosystem need to be overhauled. South Africa's entrepreneurial ecosystem was rated one of the most challenging in the sample of participating economies in 2019. SA ranked 49th of 54 economies on the Global Entrepreneurship Monitor (GEM) National Entrepreneurship Context Index, ahead of only Croatia, Guatemala, Paraguay, Puerto Rico and Iran. On the positive side, the value society gives entrepreneurship in SA showed an upward trend – the percentage of respondents who saw entrepreneurship as a good career choice increased between 2017 to 2019, as did the percentage of those who considered entrepreneurship as having a high social status. However, only 12% of respondents had entrepreneurial intentions, and the fear of failure is high. Despite this, there is clear evidence of purpose-driven entrepreneurship taking hold at a grassroots level — an encouraging sign of a collective will for future business sustainability. The Decadal Plan therefore aims to reinforce the links between innovation and entrepreneurship across society.

[1] Bowmaker-Falconer, A & Herrington M (2020) Igniting startups for economic growth and social change.

6.6 Mainstreaming inclusion in innovation policies and initiatives

Inclusive development encompasses (a) the social ideal that the entire population shares equitably in the benefits of economic progress and (b) the socio-economic value of direct and indirect participation of the people of the country in the development process, regardless of age, gender, race, disability, economic status and spatial location. In 2012, the Global Network for Economics of Learning, Innovation, and Competence Building Systems described inclusive development as pro-poor and supportive of the formal and informal sectors of an economy, aspiring to strengthen linkages and collaboration between these two sectors to advance economic growth. To support inclusive development, innovation policy and initiatives have to be fundamentally inclusive as well.

As stated in Chapter 1, the principle of inclusion is woven into the fabric of the Decadal Plan. With specific reference to the current chapter, this means that the benefits of innovation should be shared by all, and that all potential innovators should be able to participate in the innovation process directly or indirectly.

The STI White Paper moves beyond innovation policy and instruments that mostly respond to the needs of big business and the formal sector (particularly technology-intensive sectors). The development of skills and capabilities transcends prioritising high-end STEM skills. Innovation policy and instruments have to be responsive and accessible to all innovators and support all kinds of innovation. The White Paper aims to support young people and women entrepreneurs/innovators (among others), SMMEs, and civil society innovators. The policy further aims to broaden the spatial footprint of innovation by increasing capabilities for innovation at local and provincial government level, involving citizens in STI projects through transdisciplinary approaches, and transforming the ownership profile of the economy through the appropriate utilisation of publicly funded R&D. The White Paper states that the IP from the publicly funded R&D regime in South Africa has to be reviewed to ensure that it is used to respond to national priorities.

The intention is that the South African NSI will play out across all sectors and include the entire idea-to-market cycle. The NSI will support stakeholders directly involved in enabling STI, producing ideas and technologies, and implementing them (commercialising, applying, using or absorbing them) across all spheres of society.

6.7 The role of the state in enabling innovation

The White Paper on STI recognises that innovation cannot be driven by the state alone, and that the private sector has the major role to play in innovation performance. Innovation in the private sector has in the past been driven through instruments such as the R&D tax incentive, and the sector innovation funds. But these were not sufficient to realise the full transformative potential of innovation on society, and a new approach therefore is required.

While innovation is traditionally seen as playing out mostly in the private sector, in both developed and developing countries, the state has an important role to play in creating an environment conducive to innovation-led growth through increased productivity and competitiveness (including environmental custodianship). Furthermore, the state can stimulate innovation (including social innovation) to improve the quality of life of its citizens.

Government policy, institutions and infrastructure should enable and enhance the role of the state in "directing" innovation and providing a mix of policy interventions for distributing risks

and funding innovations. Its policies should position the state as a facilitator of entrepreneurship, not merely a regulator and administrator.

The government not only plays an important role in stimulating innovation, but also has to become more innovative to improve its own performance. The state can use its innovation and technology policies to nurture certain technologies (e.g. green technologies) to bring about societal change through the disruption of entrenched regimes (e.g. that relate to a carbon-based economy).[1]

6.8 Functional framework for enabling innovation

A whole-of-society approach to innovation requires an enabling environment across spheres of government, economic sectors and society. STI must be integrated into government planning, programmes, strategies and budgeting at national, provincial and local levels.

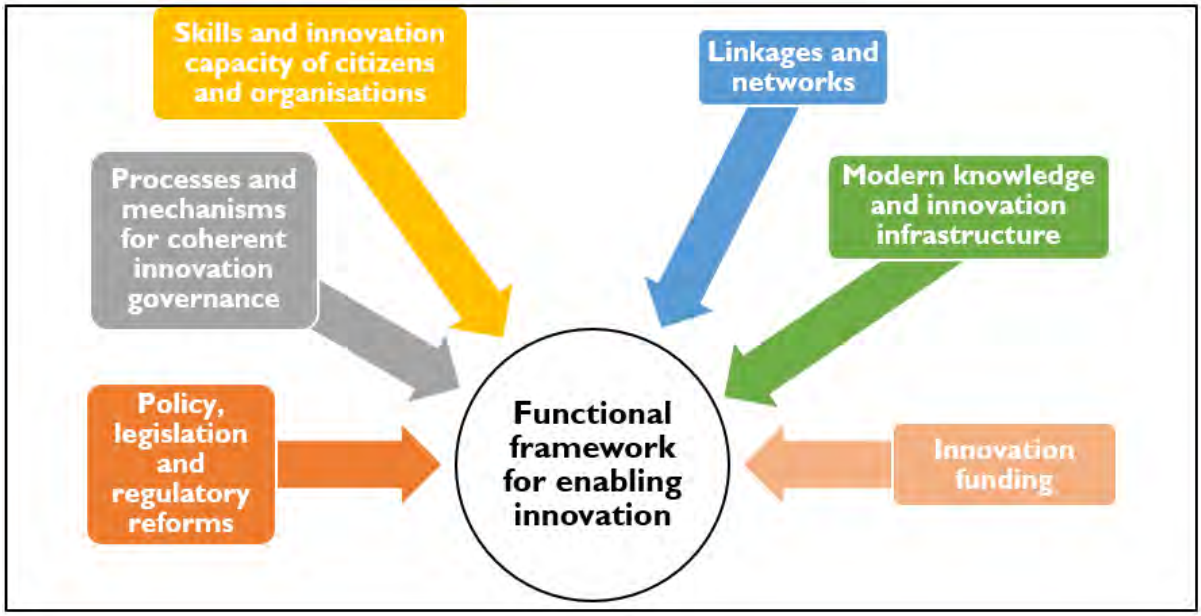

Figure 6.1: Functional framework for enabling innovation

At functional level, innovation requires the following:

- Policy and regulatory reforms: South Africa needs an enabling environment with clear, pro-innovation policies and transparent and agile governance mechanisms that are flexible and able to respond to the evolving role of STI in development programmes and agendas.
- Citizens and organisations with skills and innovation capabilities: People with the appropriate innovation orientation and competencies are needed as part of the enabling environment. Skilling the youth and reskilling the working population in digital skills and skills for the future and 4IR is a prerequisite. The skills and knowledge reorientation relate to the culture of innovation, behaviour and a paradigm shift at individual and societal level.
- Knowledge and innovation infrastructure: Government and non-government-led innovation support platforms are needed, including mechanisms to build innovation capabilities, R&D, technology development, testing and quality assurance infrastructure, tooling and innovation hubs.

[1] Schot, J and Steinmueller, E (2012) Three frames for innovation policy: R&D, systems of innovation and transformative change

- Innovation funding: Government and non-government mechanisms to finance innovation, blended financing instruments, budget coordination, sector innovation funds, provincial and local government innovation budgets, public and private sector co-investments and integrated innovation budgeting in infrastructure funds and provincial GDPs are required.
- Processes and mechanisms for coherent innovation governance: Intergovernmental institutional arrangements and innovation governance will require innovation coalition teams, coordination and championing across the entire system and at all levels of government. Provincial and municipal innovation forums, the Interministerial Committee on STI, sector innovation compacts and public service innovation charters, as well as public-private partnerships, will be critical for innovation coordination by multiple stakeholders.
- Linkages and networks: Innovation is a complex process and linkages between innovation actors are therefore paramount in ensuring that innovation flourishes. Whether these linkages and networks are formal or informal, they serve the purpose of learning, which lies at the heart of innovation. Linkages and networks should be embedded within a culture of learning, entrepreneurship and innovation.
- Initiatives to create an enabling innovation environment: Table 6.1 below depicts the initiatives to be implemented in the next 10 years to create an enabling environment for innovation as conceptualised in the White Paper. These initiatives cut across the domains in the functional framework.

Table 6.1: Implementation initiatives to create an enabling environment for innovation

Intervention	Time frame	Indicators
Develop a strategy to include an entrepreneurship curriculum (covering both traditional teaching-focused and experiential learning) across the education and training landscape, including community colleges and linked to the world of work.	Long term	Number of innovation curriculum and skills of the future introduced in education institutions
Coordinate and support the development of a suite of courses and executive development programmes on innovation (including making use of existing courses) relevant to various economic sectors as well as various institutional environments (e.g. the public sector, SMMEs, academia, civil society and citizens)	Medium term	Number of courses and training modules developed for executives in various economic sectors
Include a focus on entrepreneurship and innovation in South Africa's science engagement strategy	Short term	Report on entrepreneurship and innovation activities of the Science and Engagement Strategy
Institute more prizes and awards, particularly by STI-intensive departments in cooperation with relevant industry bodies and civil society organisations, to herald and profile South African innovators	Short term	Number of South African Innovators awards and prize ceremonies held
Brand South Africa as an innovative country to both an international and national audience	Long term	Number of campaigns to brand SA nationally and internationally

Intervention	Time frame	Indicators
Develop a joint strategy to introducing enablers for incremental innovation (e.g. learning-by-doing and engineering design) by the relevant government departments e.g. the DSI, the DTIC, and the DSBD, supported by industry bodies	Long term	Number of government departments participating in the Incremental innovation mentorship programme 20 industry partners participating in the Innovation Mentorship programme
Increase the value-add of RDI expertise to the recording, protection and utilisation of indigenous knowledge to the benefit of both the knowledge holders and society (see also Chapter 3)	Long term	Percentage of RDI expertise, research studies and recommendations on IKS implemented 90% patents on indigenous knowledge registered in the Intellectual Property database
Develop a South African approach to open innovation and accompanying guidelines.	Long term	Number of public sector initiatives for open innovation
Conduct policy experimentation related to frugal innovation, and develop export strategies for these	Short term Long term	Number of policy experimentations for frugal innovations Number of frugal innovations reaching export market
Forge an innovation compact among STI-intensive and other relevant government departments to ensure a coherent approach to stimulating innovation across areas such as immigration, education and training, environmental custodianship, reskilling labour, trade and investment, and industrial and foreign policy. The compact will serve as a basis for a South African innovation strategy.	Short term Long term	% of innovation and technology utilisation across public sector % of STI uptake in public sector policies
Develop an approach and process to improve the integration of STI-related inputs into Industrial Policy Action Plans, and the programmes of the Industrial Development Corporation	Medium term	Report on innovation in Industrial Policy Action Plans and Industrial Development Corporation programmes
Develop a strategy (including an incentive scheme) to empower civil society organisations (including those in rural areas) to stimulate innovation in their areas of operation	Medium term	Number of civil society and communities empowered on innovation
Significantly increase access to the Internet and digital technologies and community innovation supporting infrastructure	Short term	Number of citizens with access to innovation infrastructure
Develop strategies to bring down the cost of data to citizens	Medium term	% reduction in the cost of data for citizens
Foster an innovation mindset across society by integrating creativity and critical thinking in educational programmes, from early childhood development to post-school education and training (see also 6.1.2)	Long term Medium term	Number of programmes integrating innovation in early childhood development and basic education Number of post-school training programmes for innovation and entrepreneurship

Intervention	Time frame	Indicators
Develop and implement a strategy to facilitate the procurement by government of locally developed technologies	Long term	Proportion of procurement spent on locally developed technologies
Expand the Competitive Supplier Development Programme, championed by SOEs, to include locally developed technologies	Long term	Number of local technologies procured through CSDP by SOEs
Include conditions related to locally developed technologies (and technology transfer where relevant) in all large government contracts, e.g. the Infrastructure Build Programme and fleet procurement for rail	Long term	Report on the number of infrastructure build procurement processes requiring innovation content and local technologies
Review the role of the Public Finance Management Act in relation to R&D-type activities	Medium term	Review and recommendations report on innovation procurement through the Public Finance Management Act
Expand the Technology Acquisition and Deployment Fund	Current and Ongoing	Number of technologies acquired and deployed to improve service delivery through the Technology Acquisition and Deployment Fund
Increase public funding of sector-based R&D needs, with an appropriate balance between direct and indirect support to business	Medium term	% increase of incentives for R&D funding for indirect support for R&D
Incentivise business-HEI-PRI partnerships	Medium term	Incentive programme for HEI-industry IP partnership
Improve the efficiency of and expand technology-based business support interventions such as the Technology Stations Programme and the Technology Localisation Programme	Short term	Report on effectiveness of Technology Stations Programme
Review and improve strategies to support SMMEs through the innovation process up to commercialisation (a comprehensive support package and the establishment of innovation hub-type support centres, including coaching and mentoring services)	Long term	Establish innovation hub-type support centre for innovation SMMEs
Develop a strategy to revitalise the role of SOEs in innovation	Medium term	Strategy for innovation support in SOEs developed
Develop guidelines to link necessary sourcing of knowledge and R&D services from abroad by SOEs to strategise for technology transfer and localisation	Medium term	Strategy for sourcing foreign knowledge and foreign R&D transfer to SOEs
Develop a strategy to increase support to the OTTs based on the research intensity and technology maturity of each particular institution	Medium term	Strategy for supporting OTTs in HEIs to transfer technology with industry partners
Review the current instruments and develop an IP commercialisation strategy for publicly funded R&D	Short term	One commercialisation strategy for publicly funded IP developed and implemented
Implement the recommendations from the review of the IPR Act – expanding the impact of OTTs, supporting open innovation, enhancing	Medium term	Number of IPR Act review recommendations implemented

Intervention	Time frame	Indicators
support for SMMEs and the commercialisation of IP (see 6.6.2), creating an appropriate structure for NIPMO, and positioning NIPMO in the NSI		
Develop guidelines and a regulatory framework to support the transformation of the ownership profile of technology-based firms in South Africa through the appropriate utilisation of IP from publicly financed R&D	Long term	Number of technology firms owned by the youth, women and people with disabilities through the targeted appropriation of publicly financed IP
Develop a SA-specific, second-tier patent system to offer an affordable no-examination protection regime for technical inventions that would not usually fulfil the strict patentability criteria	Medium term	Number of patents protected through affordable second-tier patent system
Include innovation strategies in local economic development strategies and integrated development plans	Long term	Number of integrated development plans/municipal plans incorporating innovation for local economic development
Incentivise innovation initiatives by PSET institutions that include community-based organisations and SMMEs as innovators and beneficiaries of innovation in their geographic locations	Medium term	Number of innovation incentive schemes for community-based organisations and SMMEs
Do policy experimentation with the concept of innovation scouting in communities	Medium term	Number of community innovation scouting initiatives supported and implemented
Support the development of innovation hubs, science parks and cooperative research centres (involving industry, public research organisations and HEIs) to stimulate local innovation ecosystems (see also 6.8.2)	Short term	Number of local systems of innovation and productions supported by local innovation hubs, science centres, public research institutions, HEIs and cooperatives
Develop innovation in municipalities to drive smart cities and communities	Short term	Number of innovations taken up by municipalities Number of smart city initiatives supported
Develop an approach to encourage social innovation and support commercialisation and/or government uptake of resultant technologies by (see also 6.4)	Medium term	Number of local technologies used in government
Include guidelines on how to support grassroots innovation in local economic planning, district management frameworks and provincial growth strategies Create appropriate funding instrument for grassroots innovation as part of the local government funding regime	Short term	Guidelines for co-investment and budget coordination processes for grassroots innovators
Empower civil society organisations through training and access to business services, where needed	Short term	Number of civil society organisations receiving innovation support and empowerment funding

Intervention	Time frame	Indicators
Encourage local business organisations to invest their corporate social responsibility funding in innovation-enabling initiatives	Medium term	An incentive programme for companies supporting youth innovation as part of their corporate social investment
Develop an approach to entrench an innovation culture across government working with public sector entities responsible for innovation in the public sector	Medium term Short term	Number of innovation leaders incentivised through schemes for innovative leadership Number of innovation programmes awarded recognition in public sector and municipalities Number of government departments and municipal entities participating in innovation measurements
Develop innovation-related training for officials from different levels of government through the National School of Government in collaboration with HEIs	Short term	Number of Innovation training modules introduced for public sector officials in HEIs
Scale up e-government strategies across government	Long term	Number of e-government services and initiatives introduced across government
Set up STI units in all STI-intensive departments to coordinate RDI in the relevant sectors, and to serve as sites of policy experimentation	Long term	Number of STI and R&D personnel/units established in sector departments
Develop innovations to support the fight against corruption	Long term	Number of anti-corruption innovation programmes introduced

CHAPTER 7: EXPANDED AND TARGETED STRATEGIC INTERNATIONALISATION

7.1 Introduction

This chapter proposes measures and programmes to expand the internationalisation of South African STI initiatives as set out in the White Paper. It seeks to build on NSI milestones achieved since 1994, including policies to address human and institutional capacity development challenges, and new priorities and missions, while addressing institutional fragmentation and inadequate funding. The 2019 White Paper also advances the interface between science and economic diplomacy, a new area of focus, with innovation featuring as a crucial element of South Africa's internationalisation efforts. This is a significant shift, as NSI collaborative programmes were previously restricted to a science diplomacy approach that emphasised R&D collaboration.

The Decadal Plan postulates new policy interventions to achieve a more enhanced, efficient and strategic focus in international STI cooperation. New opportunities for collaboration with international partners — accompanied by a renewed vigour for supporting the development of STI capacity in SA and Africa — are now seen as fundamental to internationalisation. South Africa increasingly recognises that, to create a stable economy, it will have to attain a competitive edge in knowledge creation, exploitation and technological innovation. This will facilitate sustainable and inclusive industrial development and economic transformation — paving the way for poverty alleviation, job creation and reduced socio-economic inequalities. In each of these instances, international cooperation serves as an enabler.

Figure 7.1 Evolution of internationalisation in STI policies

To understand the objectives that inform STI internationalisation over the next 10 years, it is important to trace the evolution of science diplomacy as an intrinsic feature of the country's NSI and STI policymaking. This evolution, illustrated in Figure 7.1, reveals the shifts in direction taken to inform the DSI's position on the use of international partnerships. These shifts also attest to opportunities in economic diversification, beneficiation, integrated knowledge

economies, and innovation ecosystems on the continent, which in future could promote external economies of scale for South Africa. In essence, SA's strengths ought to inform the expansion of the NSI's footprint on the continent and globally.

Extensive science diplomacy interventions instituted to respond to SA's STI policies and strategies have largely resulted in the expansion of the country's NSI. These achievements tend to be concentrated in historically advantaged institutions. In this context, expanded internationalisation requires interventions aimed at promoting the inclusion of HDIs and individuals such as women and black people as active participants and beneficiaries of SA's investments in science diplomacy.

Most importantly, these intended outcomes demand a reorientation of South Africa's STI internationalisation towards the expansion of the NSI. This new direction will build on gains from international R&D cooperation, while positioning science diplomacy as an enabler of SA's economic competitiveness. More specifically, science diplomacy will be a conduit for driving the competitiveness of sectors in which South Africa retains a comparable and competitive advantage as highlighted in Chapter 3, while also stimulating the exploitation of new sources of economic growth such as the circular and digital economies.

Targeted strategic interventions will draw on the synergies between science and economic diplomacy and trade, to allow manufacturing SMMEs using locally developed technologies and SMMEs in traditional and new sectors of the economy, cooperatives, township and rural traders to enter regional, continental and global value chains and gain access to international markets. The African Free Trade Continental Area will offer opportunities for South Africa and its counterparts on the continent to fast-track infrastructure development and tap into new markets through the development of value chains for locally beneficiated mineral resources and locally developed manufacturing technologies. In the medium to long term, this could pave the way for improved economic performance and a better quality of life.

To promote South Africa as an innovation investment destination and exporter of innovation requires a science diplomacy orientation characterised by new and dynamic international partnerships that link NSI actors with non-traditional and non-state actors, such as multinational enterprises, philanthropic organisations, venture capital, and regional and continental banking institutions.

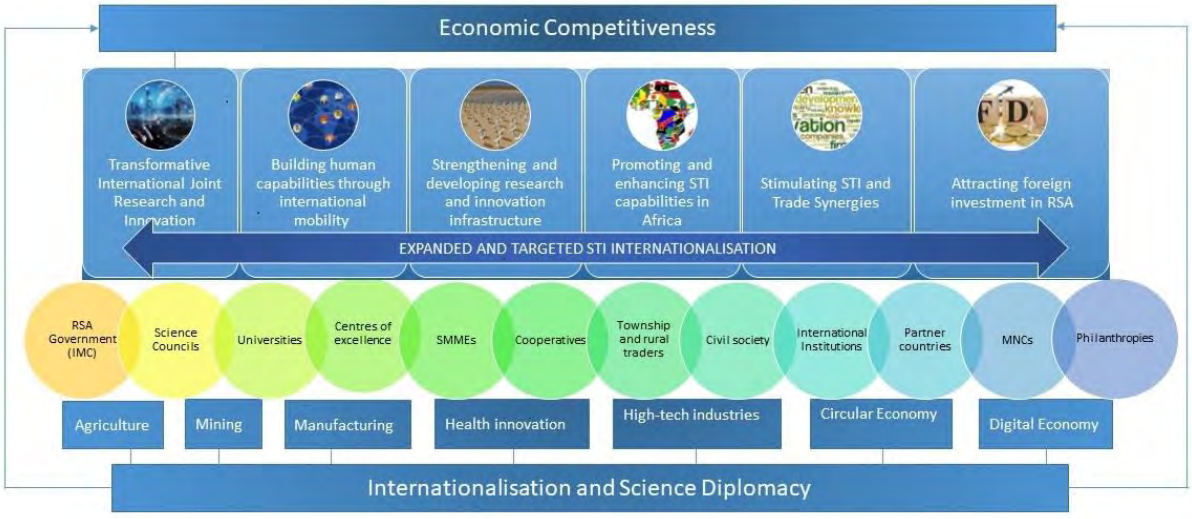

Figure 7.2 Internationalisation and science diplomacy to enhance economic competitiveness

7.2 Enhanced strategic focus

There are a number of interventions to facilitate a new strategic direction.

Transformative international joint RDI engagements

Building and expanding RDI collaboration between South African and international scientists and scholars, including the development of international research partnerships, remains a high priority.[1] International joint RDI engagements, undertaken at a bilateral and bi-regional level, will need to be supported by collaborative instruments to ensure the inclusion, where appropriate, of women, the youth, black people, HDIs and civil society.

Table 7.1: DSI interventions by the DSI to facilitate this new direction

Interventions	Indicators	Time frames
Initiate and influence decision-making Develop international programmes and cooperation frameworks in regional, continental and global policy dialogue forums, particularly on matters aligned to priorities identified for driving SA's economic development	Number of international policy dialogues and technical exchanges that support the implementation of Decadal Plan priorities	Ongoing
	Number of international STI initiatives focused on SDGs supported by South Africa	Short term
Develop and implement international joint research calls and programmes that incorporate DSI's transformation targets, facilitating an increase in the participation of HDIs, women and black researchers	Number of initiatives to specifically advance the elimination of gender imbalances in SA's international STI partnerships	Ongoing
	Number of new/existing initiatives and mechanisms created for the inclusion of HDIs in international partnerships	Short term
Design transnational joint innovation calls in partnership with entities, science councils, the private sector and SMMEs for implementation through bilateral and multilateral partnerships, focused on applied research in vibrant and emerging industrial sectors with a view to yield innovative services and technologies for local and international uptake	Number of new initiatives and mechanisms created to promote research in emerging industrial sectors through international partnerships	Short term
	Number of multilateral and bilateral partnerships supporting innovation for societal benefit and public good through the NSI	Short term

Building human capabilities through international mobility

With the growth of internationalisation in universities, it is essential for scientists, researchers and students from South Africa to gain experience and exposure in academic and research institutions elsewhere in the world. This will be reciprocated through collaborative instruments that will enable their counterparts to come to South Africa. Intergovernmental policy integration and greater coordination between the DSI, DHET, DIRCO and partners within the NSI will be key to derive maximum benefit from international cooperation aimed at building human capabilities in priority STI domains.

The increased mobility of scientists and researchers has been met with well-incentivised opportunities to relocate to other countries for short stints and, in some instances,

1 Policy Framework for the Internationalisation of Higher Education in South Africa, 2017

permanently.[1] Recent studies reveal that more than half of top American tech companies were founded by immigrants or their children.[2] International STI cooperation can play a significant role in attracting top global talent with the aim of expanding South Africa's STI capabilities.

Many highly skilled A-rated South African scientists and entrepreneurs are taking up opportunities in North America and Europe. While this might raise concern about losing much needed technical skills, it also opens new opportunities to leverage the presence of South Africans in other countries to build international networks of RDI excellence aimed at addressing gaps in scientific domains, while creating potential market and trade opportunities to build the economy. A mechanism will be needed to locate these individuals and forge the necessary partnerships through consultative processes involving DIRCO, counterpart ministries, and research and higher education institutions. Best practices could be adopted from similar programmes in other countries.

Table 7.2: Interventions by the DSI to facilitate these priorities

Intervention	Indicator	Time frame
Mobility calls and programmes to facilitate knowledge generation and knowledge exchange between SA scientists and researchers and their counterparts in other countries	Dedicated programme to coordinate human capital development through international cooperation with DHET	Short term
	Number of SA scientists and researchers in international mobility programmes	Short term
	Number of international training/capacity-building programmes specifically targeting women, black people and other historically disadvantaged individuals	Short term
Leverage international training programmes for capacity development in the uptake and diffusion of digital skills	Number of SA students participating in international training programmes	Short term
	Number of artisans and technicians supported in high-tech industries through international partnerships	
Design and implement an instrument to track SA scientists and entrepreneurs in the diaspora and identify mechanisms to build strategic partnerships with them and their host countries	Number of international engagements to forge knowledge or innovation networks implemented with South Africans in the diaspora	Medium term
Knowledge generation and knowledge exchange programmes that attract global STI talent in areas crucial to boosting SA's economic competitiveness	Number of programmes attracting global STI talent to build RDI capacities in Decadal Plan priority areas	Medium term

Strengthening and growing research infrastructure capabilities

International cooperation has been an enabler in maximising the use of national infrastructure to address not only local challenges, but also mutually held socio-economic

1 Beyond the Brain Drain: How Diaspora Scientists are Bridging Nations, American Association for the Advancement of Science (AAAS)
2 More than Half of the Top American Tech Companies were Founded by Immigrants or the Children of Immigrants, CNBC, 2018

problems with a global dimension. Many research infrastructure programmes have proven too large, complex and expensive for one country. Science diplomacy has played a key role in facilitating reciprocated sharing and joint development of large STI infrastructure and will continue to do so. As host to major infrastructure facilities such as the Square Kilometre Array, Southern African Large Telescope, South African Environmental Observation Network and the planned Space Infrastructure Hub (meant to exploit the burgeoning multi-million-rand international space industry), South Africa could position itself as a centre for world-class basic and applied research in highly specialised and emerging fields. The existing infrastructure and skilled workforce in these facilities, and the wider industry supporting them, can be used to strengthen ties with similar actors in established spacefaring nations with astronomy capabilities.

Beyond space and astronomy infrastructure, SA's other research infrastructure capabilities, as contained in the National Integrated Cyberinfrastructure System and recently unveiled state-of-the-art Photonics Prototyping Facility, position it to attract scientists from across the globe for sharing and transferring invaluable skills and to train young scientists and researchers. Through the provision of broadband Internet access, reliable electricity supply, cybersecurity and data for monitoring crop yields, natural disasters and disease outbreaks, SA's research infrastructure capabilities present promising commercial prospects beyond the country's borders (e.g. by providing data for monitoring crop yields, natural disasters and disease outbreaks), which in the medium to long term could be realised through the interface between science and economic diplomacy.

Table 7.3: Interventions by the DSI to facilitate these priorities

Intervention	Indicator	Time frame
Strengthen research and technical competencies at national infrastructure facilities through scientific mobility programmes with partner countries	Number of researchers awarded international mobility grants to build technical competencies required at research infrastructure facilities	Short term
Mobilise support from international public and private sector partners to attract financial investment to support existing and new national and globally distributed research infrastructure hosted in SA	Increase in funds leveraged from international partners to support national research infrastructure	Medium term
	Increase in funds leveraged from international partners to support globally distributed research infrastructure hosted in SA	Medium term
Facilitate the reciprocal sharing of research infrastructure in the region and continent, particularly ICT and astronomy to monitor space weather, stimulate precision agriculture, track unfolding weather patterns, mitigate the impact of natural disasters and disease outbreaks, and reduce cybercrime	Number of reciprocal research infrastructure-sharing initiatives between SA and counterparts on the continent to advance the objectives of Agenda 2063 and SADC Vision 2050	Medium term

Promoting and enhancing STI capabilities in Africa

Africa, endowed with comparative advantages in natural and human resources, is the last frontier for growth and development in the global economy. By harnessing STI, this comparative advantage could catapult African countries into unique knowledge economies offering African solutions to the world. Building on this foundation, South Africa will continue to position itself as a custodian of STI-led development on the continent in alignment with its commitment to strengthen institutional arrangements for regional and continental STI governance. This will be done by increasing joint knowledge generation and innovation outputs and by expanding the use of scientific knowledge in support of innovation for sustainable industrial development. This will also be done through joint technology development and support geared at intra-Africa partnerships for technopreneurs, SMMES, tech stations and science parks. As such, an important aspect of the DSI's science diplomacy is to strengthen innovation ecosystems in both the region and continent. Part of this will see greater support for programmes that advance intra-Africa mobility and trade as espoused in the SADC Vision 2050, Agenda 2063 and the Science, Technology and Innovation Strategy for Africa 2024.

Given the capabilities that SA has built in the priority sectors highlighted in Chapters 2 and 3, the DSI will work closely with the DTIC, DSBD and DIRCO to increase SA's share of intra-Africa trade through the export of technologies within these domains. This shift in approach will be informed by open STI collaboration, allowing the DSI and stakeholders within the NSI to cooperate with their counterparts on the continent and other international institutions to co-generate solutions, oversee the production of new knowledge and commercialise this knowledge. Significant investment and co-investment by the DSI, NSI stakeholders, partner countries and international institutions will be paramount in achieving these objectives.

Table 7.3: Interventions by the DSI to facilitate these priorities

Intervention	Indicator	Time frame
Work with the NRF and similar science granting councils elsewhere on the continent to promote and identify African research chairs in industrial sectors that present competitive advantages for the continent	Number of African research chairs appointed in support of Africa's industrialisation	Short term
Promote the establishment of African centres of excellence and centres of competence similar to SA's initiatives and link to them	Number of African centres of excellence/competence established to strengthen human and institutional STI capabilities in support of Africa's industrialisation	Medium term
Mobility incentive schemes to facilitate knowledge generation and knowledge exchange between South African scientists, researchers and postgraduate students, and their counterparts in African countries	Number of joint research publications facilitated in collaboration with African partners	Short term
	Number of researchers awarded mobility grants in support of knowledge generation and human capacity building initiatives with African partners	Short term
	Number of South African master's and PhD students obtaining access to African training programmes	Short term
Regional and continental instruments to build the capabilities of African women in STEM and women technology entrepreneurs, as well as promoting their recognition	Number of regional and continental women in STEM programmes/initiatives supported in response to Agenda 2063 and SADC Vision 2050	Short term

Stimulating STI and trade synergies

The UN General Assembly[1], in its 2019 resolution on STI for achieving the SDGs, noted the importance of a country's innovation index for measuring economic performance. In 2019, SA's technology balance of payments, a registry of commercial transactions related to technology and know-how transfers, totalled US$1,7 billion, one of the lowest among the world's emerging economies.[2] To use innovation performance as a key marker of economic competitiveness, it is necessary to broaden the scope of priorities informing international STI cooperation. SA's science diplomacy will need to move from science-related initiatives to specific innovation and commercialisation initiatives. In this instance, the objective would be to draw on science diplomacy as an enabler to –

- improve opportunities for technology diffusion to benefit small firms;
- promote the commercialisation in foreign markets of IP filed in SA by technology start-ups and SMMEs that have been supported in kind or financially by the DSI;
- promote the commercialisation of publicly funded IP beyond SA's borders;

1 The UN Department of Economic and Social Affairs Indigenous Peoples (2019) Science, Technology and Innovation for the SDGs (https://www.un.org/development/desa/indigenouspeoples/science-technology-and-innovation-for-the-sdgs.html

2 World Bank (2019) World Development Indicators

- make innovation and economic diplomacy the conduits for driving industrialisation and economic competitiveness.

Table 7.4: Interventions by the DSI to facilitate the implementation of objectives

Interventions	Indicators	Time frame
Develop mechanisms to include the DSI in bilateral and multilateral trade negotiations (with the DTIC and DIRCO)	Number of processes undertaken towards the signing of partnership agreements to support the export of DSI-funded innovations and services	Medium term
Develop mechanisms for inclusion of DSI-supported SMMEs and technology start-ups in international trade missions (with the DTIC, DSBD and DIRCO)	Number of international partnerships that support SMMEs/co-operatives facilitated by the DSI and its entities in collaboration with the DTIC, DSBD, DIRCO	Medium term
	Number of international cooperation instruments that support South African grassroots innovators	Short term
	Number of South African researchers and innovators supported through seed funding to explore international partnerships	Short term
Position SA as a regional and continental hub for manufacturing medium to high-tech innovations and services	Number of grassroots innovations for which support packages provided by the DSI and international partners have enabled commercialisation	Medium term
	Number of SMMEs supported by the DSI to gain access to foreign markets	Medium term
	Portion of publicly funded IP items commercialised beyond SA	Long term

Attracting foreign investment

The globalisation of STI requires SA's international STI cooperation to anticipate a future where knowledge production and use are increasingly multipolar and globally networked.[1] In line with general efforts to promote SA as a preferred foreign investment destination, the Decadal Plan will use dedicated interventions that seek to increase STI-orientated foreign investment secured by South Africa, and align this investment better with national priorities and their supporting indicators. Interventions will seek to leverage incentives, such as potential co-investment by the South African government, through public-private partnerships, tax credits or the meeting of obligations related to, for example, the National Industrial Participation Programme. A memorandum of understanding between the DSI and the DTIC may be required to attract STI-linked foreign direct investment.[2]

1 Serger, S & Remøe, SO (eds) (2012). International Cooperation in Science, Technology and Innovation: Strategies for a Changing World
2 White Paper on STI 2019

Table 7.3: Interventions by the DSI to facilitate implementation of these priorities

Interventions	Indicators	Time frame
Support programmes that actively promote a healthy investment climate, including macro-economic stability, mature regulatory and policy frameworks and well-developed infrastructure related to an improved quality of life	Number of engagements undertaken to leverage financial resources through international partnerships	Short term
Showcase South African STI capabilities to potential international investors through dedicated investment promotion platforms	Number of international technology demonstration initiatives hosted to showcase SA's STI capabilities and attract foreign investment	Short term
	Amount invested by international partners via DSI-supported technology demonstration initiatives	Short term
	Number of implementation plans to support specific South African sector master plans through international R&D cooperation	Medium term
Design and implement mutually beneficial schemes to attract international companies, particularly private sector organisations and multinational corporations, to conduct their R&D in South Africa	Number of new R&D-led industrial development opportunities initiated by the DSI with support from international partners	Medium term
	Number of private sector organisations/multinational corporations conducting R&D in SA	Medium term
Identify and facilitate access for South African institutions and SMMEs to international competitive RDI grants (e.g. Horizon Europe) aimed at fostering university-industry linkages for stimulating economic development in accordance Decadal Plan priorities	Number of international competitive grants accessed by South African institutions and SMMEs	Short term
	Amount of foreign funds invested in SMMEs through international competitive grants to promote RDI-led economic development	Short term

CHAPTER 8: AN INCLUSIVE, COHERENT AND COORDINATED NSI

8.1 Introduction

The 2019 White Paper on STI retained the NSI concept as a useful organising framework, while recognising that there may be unintended negative consequences to this approach[1], such as environmental degradation and the exclusion of sections of the population, both from sharing in the benefits of innovation, and from participating meaningfully in the NSI.

The 2012 Report of the Ministerial Review Committee on the South African STI Landscape[2] found that the NSI concept had not at the time gained sufficient traction across government to ensure coherence and coordination. It was found that the NSI was fragmented and hence largely ineffective, and that new governance approaches were required to ensure policy coherence and programme coordination, as well as to ensure harmonised approaches to the management and funding of public STI institutions. This was also the finding of the 2020 HESTIIL review. The NSI is not yet inclusive, and the Decadal Plan therefore outlines initiatives to enable inclusion in a coherent and coordinated NSI.

8.2 Defining coherence and coordination in the NSI

A coherent NSI requires consistency and logical connections between innovation-related policies, e.g. on competition, immigration and procurement. It means that all NSI actors pursue broadly the same STI agenda. Such coherence leads to policy certainty, which will help to attract investment in the NSI. For a coordinated NSI, programmes that encourage NSI actors to work together, pooling their resources, to achieve the desired outcomes effectively and efficiently are needed.

The imperative for inclusion extends beyond demographic transformation to involve aspects such as spatial inequality (e.g. with STI activity being concentrated in urban areas and areas centred around HEIs, while rural areas are neglected and local authorities lack the capacity to facilitate grassroots innovation). Inclusion also relates to the need to transform the ownership profile of the economy, e.g. by leveraging intellectual property from publicly funded R&D. The Decadal Plan prioritises intensified interactions and partnerships throughout the NSI and initiatives that mainstream inclusion in every aspect of the NSI. All people, regardless of gender, race, age, disability, socio-economic status or geographical location should be able to share in the NSI's benefits and participate meaningfully in it, directly or indirectly.

8.3 Policy context

Since the adoption of the White Paper, the following changes have taken place in the STI institutional landscape:

- The Department of Science and Technology (DST) was renamed the Department of Science and Innovation (DSI) in June 2019, and its mandate expanded to specifically include innovation. The Decadal Plan will enable this mandate.
- The DSI and DHET now report to one Minister, the Minister of Higher Education, Science and Innovation. This provides opportunities for synergies to strengthen both the implementation of the NP-PSET and the Decadal Plan.

1 Schot, J. and Steinmueller, E. 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy, 47: 9

2 The Department of Science and Technology (DST). 2012. The Science, Technology and Innovation Landscape in South Africa. Pretoria: DST

- The DDM, a cooperative service delivery management model, was launched by government towards the end of 2019.

As a result of the 2020 global Covid-19 pandemic, governments across the globe had to cut and reprioritise public budgets to address its impact. In South Africa, these adjustments in public budgets are playing out against the backdrop of a state with a severely constrained fiscus. Now, more than ever, coherence and coordination are needed to protect and, over time, increase STI budgets through partnerships with industry and initiatives designed to leverage synergies and cooperation between government departments.

8.4 Strategic governance of the NSI

Strategies to improve the governance of the NSI, as set out in this Decadal Plan, include –

- high-level inclusive structures to set the agenda for the NSI, namely an annual Presidential STI Plenary involving all NSI actors (government, academia, industry, civil society), as well as an Interministerial Committee on STI (IMC);
- an agreement across government on initiatives to improve the enabling environment for innovation e.g. an innovation compact;
- a mechanism to enable the use of the budget to improve coordination, e.g. an STI Public Budget Coordination;
- a harmonised set of incentives and instruments to improve coordination at the sector and programme level, e.g. RDI plans, and public-private partnerships (PPPs) to leverage the capabilities and resources of the private sector;
- clarification of the role of the DSI as opposed to STI-intensive line departments related to the type of STI activities undertaken, including the reviewed strategic management model (SMM);
- an institutionalised M&E and policy learning framework for the NSI.

High-level structures for agenda setting

Inclusion as it relates to optimising the role of civil society in STI planning and government-industry cooperation in STI initiatives runs as a theme through the Decadal Plan. At the highest level of government, an STI Presidential Plenary will convene annually with captains of industry, academic experts, civil society (including labour) and government leaders to discuss the direction and progress of the NSI, as well as the funding required for specific large STI interventions (Table 8.1).

An IMC on STI will support the Presidential Plenary by, for example, commissioning analyses of performance and joint funding strategies. The IMC will be guided by the decisions of the Presidential Plenary.

Table 8.1: Roles and membership of the STI Presidential Plenary and the IMC

Presidential STI Plenary Bringing government, business, academia and civil society together for an annual meeting.	• Recommend a high-level, whole-of-society STI agenda • Reflect on progress with large and high-profile STI programmes and recommended actions • Joint commitment of funding
IMC on STI Bringing together STI-intensive departments, clusters and enabling	• Create an enabling environment for innovation via an innovation compact to drive coordination • High-level agenda setting for STI across government

departments such as National Treasury, DPME and the Department of Cooperative Governance and Traditional Affairs	• Approve decadal implementation plans and cross-departmental RDI plans • Pool public funding to support STI strategies • Monitor the performance of the NSI and STI strategies
Department of Science and Innovation	• Provide secretariat services for the IMC and Plenary • Set the STI agenda with inputs from line departments • Institutionalise M&E and foresight at NACI and expand analytical capacity • Develop an STI Investment Framework

The reviewed Strategic Management Model

The 2004 SMM prescribed specific STI roles for government departments (Figure 8.1). However, the model has been criticised by, among others, the 2012 Ministerial Review Committee on the STI Landscape, as being responsible for the fragmentation of the public STI endeavour because it restricts the role of the DSI (then DST) to emerging areas, and therefore mostly to R&D-based activities.

NACI undertook an internal review of the SMM against the background of the White Paper on STI calling for a conceptualisation of innovation that extends beyond R&D (Figure 8.2). The involvement of the DSI should be broadened while it continues to support sector-specific STI by way of RDI plans to support the strategies of the sector lead departments. The NACI review recommended that the new SMM should make provision for instruments to improve cooperation with the private sector, as well as an innovation compact across government.

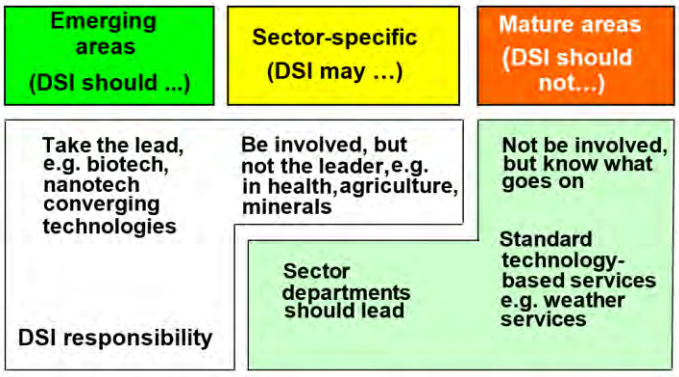

Figure 8.1: STI focus areas of the DSI versus those of other government departments, as per 2004 SMM

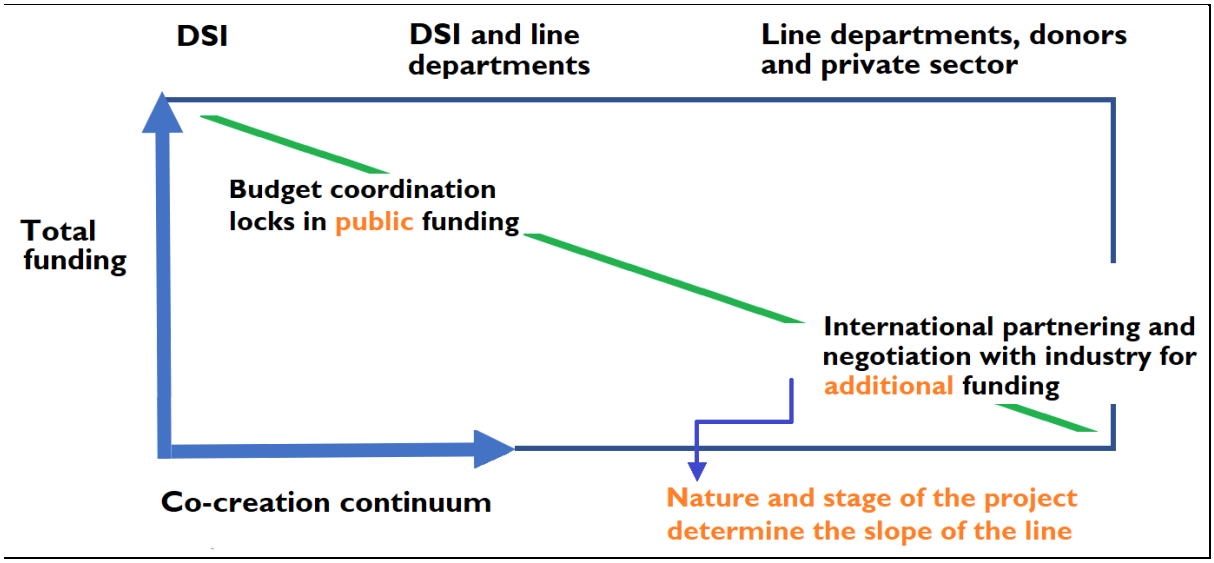

Figure 8.2: Conceptual framing of the new SMM based on budget coordination showing how the involvement of the DSI in all types of STI initiatives across society is being conceptualised

The innovation compact

The innovation compact will ensure policy coherence and certainty related to innovation, the absence of which negatively impacts business and foreign investment in South Africa. It will ensure synergy among initiatives and incentives, preventing duplication (which wastes resources and negatively influences the contribution of innovation to addressing SA's priorities) (Table 8.2). It will also ensure that the relevant NSI actors are committed to cooperating to enhance innovation performance, and to pooling their resources (funding, knowledge and systems).

The innovation compact will therefore embody an agreement on the innovation-related initiatives that government and other actors in the NSI will drive, e.g. RDI plans and other cross-cutting innovation enablers. The compact signifies a joint commitment by the relevant departments to undertake and contribute financially to such initiatives. The innovation compact signatories will be the members of the IMC and the attendees of the Presidential Plenary.

The priorities of the innovation compact are –

- targeted education and skills to support innovation;
- stopping IP leakage from publicly funded R&D;
- public procurement of locally developed technologies;
- improving capabilities across government to support innovation, as well as to increase the spatial footprint of innovation in SA in line with the DDM;
- the development of an artificial intelligence strategy and ethics framework.

Table 8.2: An innovation compact to ensure a coherent and collaborative approach to enabling innovation

Scope of the innovation compact	
1.	Commitment to relevant RDI plans to meet national priorities
2.	A more innovative and entrepreneurial culture in SA
3.	Future-proof education and skills development to support innovation in SA

4.	Measures to address IP issues such as the leakage of IP from SA's publicly funded R&D
5.	Legislation to support South African innovation, e.g. public procurement of locally developed technologies, tax incentives, competition policy, immigration regulations and the setting of standards
6.	Programmes to collaborate with and support industry, including SMMEs and cooperatives
7.	Initiatives to support more inclusive innovation, e.g. an increased spatial footprint, empowerment of previously disadvantage individuals, communities and institutions, and purposeful support for youth, women and people living with disabilities
8.	Stronger convergence of STI internationalisation and South African trade agreements
9.	Strategies to improve the capabilities of government not only to be more innovative itself, but also to enable it to support innovation across South Africa
10.	Redistributive and other support measures for those that may be at risk from rapid technological change, e.g. low-skilled workers, rural communities, and mature industries
11.	Measures and standards to protect the environment from degradation (e.g. from poorly managed industrialisation) and restore it
12.	Legislation to address ethical issues related to technological advancement and innovation, e.g. an artificial intelligence strategy

8.5 Initiatives to facilitate an inclusive, coherent and coordinated NSI

The interventions to give effect to the governance goals are outlined below in Table 8.3.

Table 8.3: Governance initiatives to create an inclusive, coherent and coordinated NSI

SYSTEM GOAL 1: AN INCLUSIVE, COHERENT AND COORDINATED NSI				
Outcomes		**Implementation initiatives**		**Indicators**
1.	Enhance policy coherence and programme coordination in the NSI	1.1	Set up an Interministerial Committee representing STI-intensive departments, DPME and National Treasury to do high-level STI agenda setting, committing resources to large interdepartmental initiatives, and monitoring the progress of the NSI (on the basis of credible evidence and analysis)	Investment into interdepartmental projects initiated by these structures
		1.2	Develop and implement a South African innovation compact	As per the focus areas, e.g. reduced IP leakage, increase in government use of locally developed technologies
		1.3	An annual STI Plenary convened by the Presidency and representing government, academia, business and civil society to serve as a collaborative platform to discuss the needs and progress on the initiatives of these NSI actors, as well as a broad investment strategy across government and business	Investment by business in Presidential and ministerial STI initiatives
		1.4	Strengthen NACI to fulfil its new roles in terms of the STI White Paper, including supporting the STI Interministerial Committee with advice and analysis	Utilisation of NACI advice

SYSTEM GOAL 1: AN INCLUSIVE, COHERENT AND COORDINATED NSI				
Outcomes		**Implementation initiatives**		**Indicators**
		1.5	An independent review of the SMM to determine how it has performed, and how to maximise its strengths and minimise its weaknesses	Completion of the review
		1.6	Set up STI units in all STI-intensive departments (where there are not already such units), and develop an engagement framework to use them as sites for policy experimentation as well as building capacity in STI policy and implementation	Number of STI units set up
		1.7	Develop sector RDI plans in support of sector strategies, and update them regularly	Sector RDI plans in all prioritised sectors
2.	Improve inclusion and build more linkages across the NSI	2.1	Review the effectiveness of collaborative STI instruments to increase partnerships among government, academia and the business sector (including SMMEs)	Private sector investment into collaborative projects
		2.2	Develop and implement guidelines for including civil society in STI agenda setting and other STI-related initiatives across all spheres of government	Number of agenda-setting processes including civil society
		2.3	Develop and implement a comprehensive SA STI transformation framework, focusing on gender, the youth and people with disabilities, in concert with other dimensions of transformation such as spatial and sectoral transformation	Participation metrics for gender, youth, people with disabilities, rural areas, townships, etc.
		2.4	Develop and implement a framework for gender equality and the empowerment of women in and through STI, in line with the Gender-Responsive Planning, Budgeting, Monitoring, Evaluation and Auditing (including the establishment of an NSI gender desk and the inclusion of competent gender focal points in the DSI and its entities, as well as training for managers and gender focal points on gender matters	Gender-Responsive Planning, Budgeting, Monitoring, Evaluation and Auditing indicators prescribed by Cabinet
		2.5	Develop and implement guidelines and instruments focused on the inclusion and empowerment of youth in and through STI initiatives for SA to leverage its youth dividend	Participation of youth in STI initiatives
		2.6	Develop and resource a study of the role of STI in the lives of people with disabilities, as well as a longitudinal survey to measure their inclusion in the NSI	People with disabilities benefitting from and participating in STI
		2.7	Develop guidelines on how to include STI planning, and particularly inclusive innovation approaches, in local economic	STI-related investment in local economic development strategies

SYSTEM GOAL 1: AN INCLUSIVE, COHERENT AND COORDINATED NSI				
Outcomes		**Implementation initiatives**		**Indicators**
			development planning by local authorities, within the framework of the DDM	
3.	Strengthen the governance of public STI institutions	3.1	Implement the recommendations of the HESTIIL Review Panel – as approved by the Minister	As per the recommendations e.g. industry-based higher education specialisations
		3.2	Develop and implement a harmonised governance, funding and M&E framework for relevant PRIs to ensure financial sustainability, effective development of their STI base (e.g. personnel and infrastructure), as well as linkages to their sector environments and lead departments to drive responsive STI initiatives	Progress on the STI bases of STI public entities
4.	Expand the NSI	4.1	Establish new NSI institutions, in line with the recommendations of the HESTIIL Review Panel — as approved by the Minister	Outputs from new institutions

CHAPTER 9: INCREASED FUNDING FOR STI

9.1 Introduction

This section specifies how financial resources are to be mobilised in support of the vision of the 2019 White Paper to increase funding for the NSI, develop funding priorities, improve funding efficiencies and to institutionalise a framework for guiding public STI investment.

These strategies recognise that the public component of the NSI is far wider than just the DSI and that funding and co-funding from other STI-intensive departments can be used to implement Decadal Plan initiatives. The public budget for STI will be coordinated through high-level governance structures (i.e. a Presidential STI Plenary and the STI Interministerial Committee), supported by the DSI. A strengthened NACI will provide analysis and evidence to support STI budget allocations.

The four key thrusts proposed for financing STI are public investment, private investment, partnerships and collaborations, and improved governance and monitoring, evaluation, research and learning (MERL) (Figure 9.1).

Figure 9.1: Proposed key thrusts for STI financing

Government investment in STI has a particular role in the NSI. It opens new opportunities in areas where the private sector and other actors have limited incentives to invest, and helps build platforms to improve the ecosystem for innovation. Government and private sector investment need to complement each other — ideally to share risks and, later, the rewards of innovation investment. Different forms of partnerships are required across the system to fund, implement and monitor key programmes, involving actors within the government sector, private sector, civil society and international community.

In alignment with the NDP, government has strategies – with commitments and targets – to increase productive investment, industrialisation and competitiveness. The White Paper sets a target to increase gross expenditure on research and development (GERD)[1] as a percentage of GDP to 1,5% over the next decade and an aspirational GERD/GDP[2] of 2% a decade later. Government's Medium-Term Strategic Framework (MTSF) or five-year plan for 2019-2024

1 GERD is the total intramural R&D investment in an economy.
2 2019 White Paper on STI

sets a GERD/GDP target of 1,1% by 2024. These ambitious targets require substantial additional investment and commitment from the public and private sectors.

In South Africa, five institutional sectors perform domestic R&D, namely, government, science councils, higher education, business, and not-for-profit organisations. Domestic R&D has three main sources of funding (the public and private sectors and foreign funders) and three main types of research activity (basic, applied and experimental). However, GERD as a percentage of GDP indicates the intensity of R&D in an economy. Setting GERD/GDP targets signals government's appreciation at policy level of the importance of R&D investment in a country's development path. Countries with high R&D intensity generally have advanced technological innovation capabilities. Increased R&D investment will result in economic growth, economic recovery, and inclusive growth and development through, RDI to revitalise and modernise existing industries/sectors, to create new sources of growth and stimulate RDI-led industrial development, and to support a capable and developmental state[1].

Ongoing budget reforms in government require priorities for government investment to be reviewed and updated regularly to remain relevant to national development aims. The upfront determination of STI targets would facilitate increased investment in STI in various sectors. The following section outlines the White Paper policy intents in increasing STI funding.

9.2 Policy Intent 1: Increase levels of funding across the system

To achieve the GERD/GDP targets, government (national, provincial and local), the private sector and international partners will have to spend an estimated R53,5 billion by 2024/25 (1,1% of GDP) and R84,7 billion by 2030/31 (1,5% of GDP) (Figure 9.2). The overall estimated percentage to grow GERD to achieve the targets, using a targeted growth rate scenario, is 6% annually for the first five years and 10% for the subsequent five years.

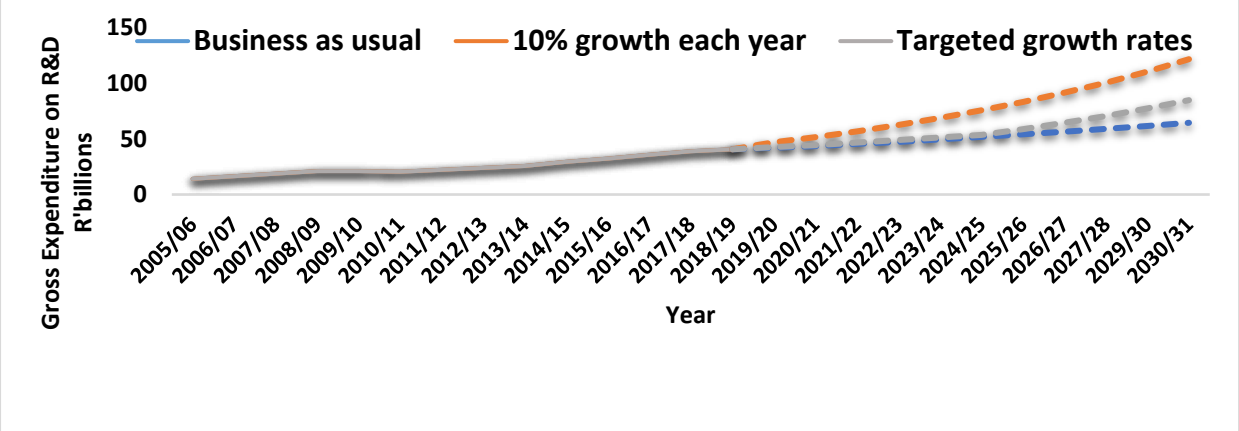

Figure 9.2: Setting targets for GERD (Source: National R&D Survey and calculations based on the 2005/06 to 2019/20 R&D data series and 2015 GDP base year)

The efforts of all funding partners complement one another in improving the STI performance of the South African NSI. Although the bulk of the increased R&D funding should come from the private sector, government has an important role to play — firstly, by creating an investment-enabling environment, and secondly by increasing its own levels of funding. The current analysis (2019/20) of the sources of funding from the National Survey of Research and

3 Role of Science, Technology and Innovation in South Africa's Economic Recovery Plan

Experimental Development (R&D survey) suggests that 56% comes from the government, followed by the business sector at 27%, and foreign sources at 14%. Other local sources, for example individual donations, make up the remaining 3%. All these proportions translate to R34,5 billion in rand terms.

STI funding from national departments

In Chapter 3, the concept of sectoral RDI plans was introduced. The revised SMM proposes that the DSI fund type one RDI activities (research and new areas), while sectoral departments and the private sector fund type two sectoral domains. Type three activities (standard technology-based focus) will need to be funded by line departments, the private sector and local government. The success of the *Decadal Plan* depends on line departments budgeting for sectoral RDI funding (types two and three). The PRIs reporting to the various line departments could be channelled through the PRIs.

The funds of national line departments should also be aligned with the existing sectors prioritised in this Decadal Plan. The Reports on Government Funding for Scientific and Technological Activities Survey (STA surveys) are beginning to show the importance of allocating funds for STI, e.g. the Department of Home Affairs' projects Who Am I Online, automated biometric identification system and national immigration information system. Scientific and technological activities (STAs) are carried out to support various functional areas of national government departments, and the surveys give an indication of the extent to which STA budgeting and spending aligns with the policy priorities. This will inform options about prioritisation and budget allocations going forward.

Provincial funding for STI

R&D cuts across all provinces, although it is not evenly distributed because of the size and composition of the research institutions and firms, as well as their level of funding. Provincial distribution of R&D activity has changed slightly over the years. Most R&D activity is performed in Gauteng, the Western Cape and KwaZulu-Natal, but the proportion of total R&D performed in these provinces changed between 2007 and 2018. Over this period, R&D performance in the Western Cape, Eastern Cape, North West and Limpopo increased, while the levels in Gauteng and KwaZulu-Natal declined. There could be various reasons for this, e.g. funds not being used for their intended purposes or provinces not investing enough in STI.

The spatial footprint of STI in the country is important. A study by the Human Sciences Research Council (HSRC) highlighted that the Gauteng, Western Cape and KwaZulu-Natal provincial governments have started setting aside portions of their budgets for R&D investment. This will contribute to upscaling NSI activities. It is imperative that national strategies are translated into the strategies of entities at all levels of government.

9.3 Policy Intent 2: Improve funding priorities across the system

The estimated funding required to reach the GERD/GDP targets needs to be spent in national priority areas. Chapter 3 proposes catalytic spending (focused on the NDP levers), innovation-led industrialisation (establishing R&D-led new industries, supporting existing industries) considering the marginalised, and opportunities for exports. Sectoral RDI plans need to be funded. Investment is needed to modernise key existing sectors of the economy and new sectors that will bring in new sources of growth (the circular and digital economies, 4IR and converging technologies).

Innovation to support a capable state will be accelerated in the next 10 years (2030/31), through collaboration with stakeholders like the South African Local Government Association. These innovations will use artificial intelligence and data analytics to modernise services in all spheres of government. The National Policy Data Observatory, currently being incubated at the Council for Scientific and Industrial Research, is one of the instruments that will be used to track socio-economic and health impacts and support decision-making.

The collaboration fund

The traditional argument for government involvement in STI is the existence of positive externalities (e.g. creating knowledge and technology flows, increasing R&D collaboration, improving human capital mobility, etc.). Governments in many countries therefore support STI directly through funding or tax incentives and actively manage many public research organisations, including in areas such as health and agriculture. This model remains valid when policy is based on an innovation systems approach, but there are currently challenges with systemic failures. Policy interventions to establish and strengthen collaborative linkages and eliminate coordination failures are therefore needed.

As discussed in Chapter 3, because of the complex, transdisciplinary nature of the societal grand challenges, particular attention is needed to ensure that the social sciences and humanities are integrated into natural scientific and technological approaches. According to the 2014-2016 Business Innovation Survey (BIS), the business sectors were not collaborating with traditional knowledge producers (e.g. universities and government research institutions).

The Decadal Plan therefore proposes a collaboration fund for STI to eliminate coordination failures in the system. It will be designed with an anchor in the humanities and social sciences, and with a focus on increasing collaboration between knowledge producers, such as universities or government research institutions, with business. The collaboration fund will also be used for inter-institutional funding. Collaborative grant making is becoming especially attractive in emerging fields where the ability to leverage resources and build capacity is crucial. The allocation of this funding to priority areas will also assist in building critical mass in those areas.

It is evident that government does not have sufficient financial resources to meet growing STI needs. To help close the gap, the Decadal Plan emphasises collaboration with business, labour and civil society. The collaboration fund will play a pivotal role in attracting private-sector investment for STI projects.

Financing mechanisms to improve STI performance

While government must make a concerted effort to increase funding for STI activities, other funding will have to be secured through public-private sector collaboration. Government continues to provide public funding that benefits the private sector by supporting partnerships between stakeholders.

Improvements in STI performance are possible through various STI financing instruments, incentives and initiatives. These range from financial support to non-financial support or contingent support, and in-kind support (such as providing land or equipment). Some of the STI financing mechanisms that the NSI has invested in over the years include a tax incentive to stimulate business R&D, the Sector Innovation Funds, public-private partnerships, technology for new industry development, the Technology and Human Resources for Industry Programme, seed funding, technology development, commercialisation support, the Small Business Innovation Fund, and the sovereign innovation fund (the Innovation Fund). STI initiatives, such as bioeconomy calls for proposals, the Technology Acquisition Deployment Fund, and the Technology Localisation and Technology Station Programmes, will respond to different elements that support the procurement, uptake and market entry of locally developed technologies.

Regulations should be sound and enable an environment in which financing mechanisms thrive, such as those made under the IPR Act. There are also opportunities for domestic private sector firms to participate in international cooperation and partnerships (including funding for human capacity and infrastructure development, and various other incentives).

Given the importance of transformation, funding mechanisms will take into cognisance marginalised communities (including women, people with disabilities, the youth, rural and poor communities, individuals, and SMMEs based in rural areas). These communities will be included in the planning and budgeting process.

The innovation compact (Chapter 8) will harmonise funding processes and mechanisms between key funding partners, as well as highlight funding areas and identify potential partners with shared interests. These partners will enter into a memorandum of agreement to ensure that technologies advance smoothly from early-stage development funding/proof of concept to commercialisation or company scale-up funding. The intention is to ensure a seamless transition between functions and financing mechanisms and to ensure that appropriate seed-funded technology is supported along the innovation value chain. The above STI funding mechanisms should align with sector STI plans in all prioritised sectors.

9.4 Policy Intent 3: Improve funding efficiencies

In addition to increasing funding, existing funding must be optimised through better coordination, reduced duplication of effort and improved synergies. The efficiency of public NSI institutions, to which most of this funding is allocated, will need to be enhanced where necessary.

In optimising funding within the NSI, the STA survey reports highlight a decline in baseline funding due to budget cuts, especially for PRIs. Given the importance of PRIs in improving service delivery, it is necessary to secure the baselines for PRIs. Efficiency within the PRIs and STI intensive departments can be optimised by introducing a budget coordination process to ensure STI contributes to improving service delivery.

The STI budget coordination will inform the STI planning and governance arrangements envisaged in the 2019 White Paper. It is envisaged that an investment framework will be introduced as an instrument within the STI budget coordination process, to secure the baseline for the budget priorities of the Decadal Plan. Budget coordination will give RDI more prominence in government planning and optimise public funding for RDI across government. The practice of strategic priority setting for budget allocation is prevalent in many countries, particularly those with formal national development plans.

While it is important to achieve optimum alignment of all STI activities across government, care should be taken to avoid overly complex administrative procedures and disruptions to existing funding processes. The budget coordination process will therefore be phased in, in consultation with National Treasury, the DPME and other government departments.

The STI investment framework will operate at a strategic and system level, with a baseline analysis to inform the draft framework, guided by NACI. The investment framework will guide funding towards priorities identified in the Ten-Year Implementation Plan, which will incorporate sectoral RDI targets formulated through an evidence-based consultative process with all science-intensive government departments. For practical operationalisation purposes, the proposed process must fit into the National Treasury budget process.

9.5 Policy Intent 4: Institutional framework for guiding public STI

A high-level implementation of MERL modalities will be undertaken in consultation with the National Treasury and the DPME. The STI investment framework will therefore be incorporated into the MTEF guidelines for the budget planning. The final departmental allocations for annual appropriations will be guided by the approved STI investment framework. There will be engagement with DPME to ensure continued MERL using common indicators. In standardising the MERL system across government, it is envisaged that departments will indicate an STI budget in their annual performance plans and ensure that funds are used for their intended purpose.

Opportunities for existing tools to enhance evidence for policy decisions include a forward-looking STA analysis report, surveys of R&D intention in the business sector, intellectual property and technology transfer surveys, business innovation surveys, and a research and development information platform (formerly the Research Information Management System). Their purpose will be to provide leading indicators for planned investments in R&D and related activities as shown in Table 9.2.

Table 9.1: Funding interventions and indicators for STI policy intents

Policy intent	Intervention	Indicators
Policy Intent 1: Increase funding across the system	Public investment – STI budget commitments and R&D expenditure and performance from across government, including HEIs and science councils	GERD funding increases (R&D surveys) • % of GERD from government* (further disaggregation of government into national, provincial and municipal government and research institutions) • % of GERD from foreign funders • % of GERD from other funders STI budget increases (STA surveys) • % of total government budget going to STI • % of total funding for STIs from parliamentary allocations • % of total government STI budget coming from provinces GERD in the following categories (R&D surveys) • % of GERD from government (further disaggregation of government into national, provincial, municipalities and research institutions) • % of higher education expenditure going to R&D • % of science council expenditure going to R&D
	Private investment – STI investment by domestic business, non-governmental sector and foreign/international sources	GERD funding increases (R&D survey) • % of GERD from foreign funding sources • % of GERD from other funding sources • % of STI business funding GERD expenditure increases (R&D survey) • % of not-for-profit expenditure on R&D • % of business expenditure on R&D (including SOEs)
Policy Intent 2: Improve funding priorities across system	Modernise existing sectors (e.g. agriculture, mining and manufacturing)	% of funds toward modernising traditional/mature sectors Number of incentives geared towards modernising traditional/mature sectors
	New sources of growth (circular and digital economies, 4IR and converging technologies)	% of funds to support new sources of growth Number of incentives geared towards new sources of growth

	Innovation for capable state (innovation for service delivery)	% of funds toward innovation for a capable state Number of incentives geared towards a capable state
Policy Intent 3: Improve funding efficiencies	Budget coordination framework	% of STI budget and performance per department (national government departments, provincial departments, municipalities and PRIs) % of STI budget and performance of overall total national budget (national government departments, provincial departments, municipalities and PRIs)
Policy Intent 4: Institutional framework for guiding public STI	Standardised MERL template for monitoring STI funding	Number or % of national government departments, provincial departments, municipalities and PRIs using the standardised MERL template

**Government-funded R&D includes funds generated by science councils and HEIs through business with other institutions (in addition to their Parliamentary grants)*

CHAPTER 10: MONITORING, EVALUATION AND POLICY LEARNING

10.1 Problem statement and desired end state of the M&E system

The 2019 White Paper on STI adopted an NSI approach[1] (infused with elements of a transformative[2] innovation policy approach) to frame its policy intents. According to NACI[3], STI systems are typically open and constantly change in response to exogenous factors in the environment and endogenous factors such as changes in policy and strategy. A national system of innovation typically consists of many institutions and organisations (public and private) whose missions, strategies and portfolios change over time. Linkages, interactions, and resource flows between these entities are also not static; they respond and adapt to new demands and priorities. Change is one of the few constants in the dynamic world of STI.

The challenge is how to monitor change and measure progress over time amid such complexity. The following points illustrate this:

- It is necessary to ensure that the White Paper policy intents (as well as the more specific programmatic goals and strategies arising from the White Paper) are met. This requires a monitoring and evaluation (M&E) approach that is aligned with the overall theory of change of the White Paper.
- Based on the very premise of the White Paper, i.e. that STI can contribute to inclusive and sustainable socio-economic development, it is necessary to measure the change in and direction of the contribution of STI. Such an endeavour would typically have to monitor multiple (often non-linear) causal pathways and address the real challenges related to the lack of good quality data.
- Change and progress across the previous two dimensions occur at different levels in the system, requiring an M&E approach that allows for deep structure and adaptability.
- To make sense of measurements reflecting change, it is necessary to have standards against which to measure the difference. Although international benchmarks may provide some direction, these standards need to be customised for the South African environment.
- It is necessary to ensure that the required policy learning based on the results of M&E takes place in the system. Such learning should feed into the planning of NSI initiatives to continuously improve the outcomes and impact of STI on national priorities and the attainment of the SDGs.
- Finally, to make it possible to address all the above challenges, the M&E and policy learning institutional landscape needs to be purposefully designed to ensure synergy, effectiveness and efficiency.

The complexities notwithstanding, since the adoption of the 1996 White Paper on Science and Technology roughly 25 years ago, a culture of review has been instituted in the NSI (particularly in the public higher education sector and the public research sector). Although recent analyses have highlighted some concerns with the types of reviews carried out

1 The Department of Science and Technology (DST). 2019. White Paper on Science, Technology and Innovation. DST, Pretoria
2 Schot, J. and Steinmueller, E. 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy, 47:9
3 National Advisory Council on Innovation (NACI). 2020. A Monitoring and Evaluation Framework for the South African Science, Technology and Innovation System. Johann Mouton and Robert Tijssen on behalf of the Centre of Excellence in Scientometrics and STI Policy, hosted jointly by Stellenbosch University and the Tshwane University of Technology.

(predominantly institutional reviews and relatively few programmatic reviews), good progress has been made on the front of STI-related M&E.

10.2 Promoting reflection, learning and evidence-informed policy and decision making

The Decadal Plan seeks to translate the White Paper vision into reality. To realise this objective, it is essential to continuously develop the capability for the NSI to reflect, learn and self-correct. The Decadal Plan identifies several outcomes and indicators for meeting the societal grand challenges. These are summarised as follows:

- South Africa could be one of the top three emerging economies in the global pharmaceutical industry, based on an expanded NSI using the nation's IKS and rich biodiversity.
- Develop technology platforms for vaccine discovery, development and production based on innovation linkages between the public sector, private sector, academia and civil society.
- Strengthen generic drug manufacturing R&D programmes aimed at technology know-how and the piloting of active pharmaceutical ingredients (APIs) through public-private partnerships — supporting technology platforms for API research and manufacturing should be for a significant and accelerated impact.
- An NSI enabling a just energy transition.
- Increased access to affordable healthcare services through the development of RDI capabilities in new treatment and prevention. Precision medicine, digital health, use of indigenous knowledge and vaccine production.
- Investment in neuroscience research to develop methodologies that could enhance learning outcomes (AI, machine learning, virtual reality).
- Harness the benefits of innovation to help improve firm competitiveness and productivity, which will ultimately contribute to the modernisation of SA's key industrial sectors.
- Implement RDI interventions to work towards zero waste to landfill, as well as address climate change and adaptation.
- Strengthen and increase funding of RDI capabilities in biotechnology, advanced manufacturing, space science, and ICT to drive improvement and productivity in the manufacturing/production sector, economic growth in terms of GDP contribution, new high-tech SMMEs development.
- Contribute towards a locally relevant and globally competitive workforce by funding focused postgraduate centres and students.

Increasing the technological and digital intensity of firms (especially SMMEs) in key industrial sectors will allow SA to fully leverage the benefits of future technological and industrial step changes.

10.3 Towards a measurement framework

The Decadal Plan is concerned with making a difference. Its implementation will require continuous M&E. This Chapter draws from several sources (such as the NDP, SA Innovation Scorecard and NACI NSI M&E Framework) in identifying the first set of systemic indicators constituting the Decadal Plan measurement framework (Table 10.1). The second set of indicators will emerge from a study analysing and quantifying the contributions toward STI-

enabled inclusive and sustainable socio-economic development. Complementary studies will be required in future to enhance understanding of trends and what is being achieved, or not achieved.

Table 10.1: Proposed indicators for monitoring, evaluation and policy learning

Indicators	Baseline
Economic	
Economic growth attributable to technical progress	To be determined
National income derived from knowledge-based industries	To be determined
Proportion of workforce employed in knowledge-intensive activities	To be determined
Knowledge-intensive services exports	To be determined
Medium and high-technology employment (as share of total manufacturing employment)	31,76% in 2020
High and medium technology exports (per capita/US$)	39 253 in 2018
High-technology exports (% world share)	0,07% in 2018
Medium and high-technology exports (% of manufacturing exports)	47,98 in 2020
High-tech knowledge intensive (number of enterprises)	To be determined
Innovation-active firms as % of total	69,9% during 2016 – 2018
Innovative firms by type of innovation (%) Product innovation Process innovation	 48,2% in 2016-2018 34,6% in 2016-2018
Innovation rates in firms by sector Industry Services	 70,7% in 2016-2018 69,4% in 2016-2018
Medium and high-technology value-added as % of total manufacturing	25,05% in 2020
Technology balance of payments	
Technology payments % GDP	0,42% in 2018
Technology payments % GERD	55,13% in 2018
Technology payments (R million)	20 280 in 2018
Technology receipts per capita (rands)	41,88 in 2018
Technology payments per capita (rands)	351 in 2018
Technology receipts % GDP	0,05% in 2018
Social Progress Index	80th in 2021
Number of full-time equivalent researchers	28 358,6 in 2019
Bachelor's, honours, master's and PhD graduates: Stocks – headcounts by field, SET, university, diversity (race, gender, age) field, university	
Total SET graduates (%)	27,2% in 2020
Master's SET graduates (%)	46,7% in 2020

Indicators	Baseline
Doctoral SET graduates (%)	49,8% in 2020
Number of SET graduates as a percentage of total graduates	29%
Profile of permanent higher education staff (academic staff with PhD, by gender, race, age group, nationality and employment status)	47% in 2017
Employment of technicians in research and development: Total (headcount)	10 080 in 2019
% women	43,3% in 2019
Per million inhabitants	180,1 in 2019
Total SET graduates available to the economy	
Total researchers (FTE) per 1 000 people employed	1,9 in 2019
SET tertiary students as % of all tertiary student enrolments	28,6% in 2018
Annual number of doctoral graduates	3 552 in 2020
Number of students achieving 50% in mathematical literacy and mathematics	54,5% for mathematical literacy in 2019 and 23,0% for mathematics in 2021
World share of research outputs	0,83% in 2020
Top 10% most cited publications (% world share)	6,97% in 2018
Percentage of world share of publications for emerging technologies research areas:	
Internet of Things	0,65% in 2019
Additive manufacturing	0,41% in 2019
Quantum computing	0,50% in 2019
Nanotechnology	0,57% in 2020
Robotics	0,32% in 2019
Artificial intelligence	0,50% in 2020
Innovation-driven entrepreneurship (as % of early-stage entrepreneurial activities)	29,7% in 2017
Digitalisation	
Population with access to Internet (%)	62,40 in 2018
Mobile broadband subscriptions (per million population)	778 854 in 2018
Fixed broadband subscriptions (per million population)	19 155 in 2018
Reduction of high domestic cost of broadband Internet connectivity	
Mobile broadband cost as % of gross national income per capita, 1,5 GB	3,95% in 2018
Fixed broadband cost as % of gross national income per capita, 5 GB	6,54% in 2018
Start-up/spin-out companies (incorporated annually)	
Universities	17 in 2018
Science councils	0 in 2018
University-industry collaboration	

Indicators	Baseline
Co-publications	4,4% during 2016-2019
R&D collaborations	36th in 2020 Global Innovation Index
Co-authorship of academic papers with other countries (% of total)	52,7% in 2018
With USA (%)	19,1% in 2018
With Brazil (%)	2,7% in 2018
With China (%)	4,4% in 2018
With India (%)	4,3% in 2018
With Russia (%)	1,9% in 2018
Private co-funding of public R&D expenditure	
Patent granted	
Total	1 023 in 2020
Companies and Intellectual Property Commission (CIPC)	313 in 2020
African Regional Intellectual Property Organization (ARIPO)	49 in 2020
United States Patent and Trademark Office (USPTO)	155 in 2020
European Patent Office (EPO)	80 in 2020
Brazil	28 in 2020
Russia	8 in 2020
India	29 in 2020
China	26 in 2020
South African nanotechnology patents published:	
Total	1 in 2020
CIPC	0 in 2020
ARIPO	0 in 2020
USPTO	0 in 2020
EPO	0 in 2020
Brazil	0 in 2020
Russia	0 in 2020
India	0 in 2020
China	0 in 2020
South African biotechnology patents publications at:	
Total	27 in 2020
CIPC	0 in 2020
ARIPO	0 in 2020
USPTO	10 in 2020
EPO	5 in 2020
Brazil	1 in 2020
Russia	1 in 2020
India	0 in 2020
China	1 in 2020

Indicators	Baseline
Plant breeders' rights (PBRs) granted by USPTO	10 (13th of all countries granted PBR certificates by USPTO) in 2019
Proportion of resident patents applications	31,2% in 2020
Number of actionable invention disclosures reported to the National Intellectual Property Management Office	231 in 2018
Resident trademark class count per 100 billion USD GDP (2017 purchasing power parities)	3 250 in 2020
Total designs registration	1 751 in 2020
Resident design count per 100 billion USD GDP (2017 purchasing power parities)	143 in 2020
Resident design registration counts as % of world share	0,06% in 2020
GERD/GDP	0,62% in 2019
GERD composition by sector (%)	Business: 31 in 2019 Government: 5,5 Higher education: 41,1 Science councils: 18 Not-for-profit: 4,4
R&D expenditure in the public sector (%)	64,6% in 2019
Annual venture capital investments as % of GDP	0,03% in 2020
R&D expenditure in the business sector (R million)	10 704,5 in 2019
Total innovation expenditure as % of GDP	2,55% in 2016
Gross fixed capital formation in information, computer and telecommunication as % of total	3,12% in 2021

10.4 Decadal Plan interventions to implement M&E policy intents of the 2019 White Paper

Table 10.2 below itemises the interventions that will be implemented to give effect to the policy intents of the 2019 White Paper in M&E and Policy Learning.

Table 10.2: Interventions to create expanded M&E and policy learning capabilities in the NSI

Outcomes		Implementation initiatives	
1.	Improved understanding of systemic SA STI performance, and the contribution of STI to achieving SA's NDP goals through the adoption of a multi-perspective	1.1	Review NACI M&E Framework for the NSI, including an analysis of implementation options, standards/benchmarks, indicators and the Innovation Scorecard for South Africa
		1.2	Develop a data strategy to support the NACI M&E Framework
		1.3	Develop capacity at NACI so that it can assume its role as the NSI M&E institution charged with collating M&E information and analysis from various sources, translating it into advice on innovation policy across government. In time NACI should develop the capacity to oversee the implementation of the M&E Framework.

Outcomes		Implementation initiatives	
	M&E Framework for the NSI	1.4	Develop NACI capability and plan for regular foresight exercises (e.g. every five years or as requested by the IMC
		1.5	Conduct feasibility study on establishing an STI Observatory centered around (but not limited to) the DST-NRF CoE in Scientometrics and STI Policy (hosted jointly by Stellenbosch University and Tshwane University of Technology). A characteristic of the proposed STI Observatory would be functional linkages to relevant M&E institutions in SA including research chairs and CoEs at HEIs, ASSAf and the Centre for STI Indicators at the HSRC, as well as abroad (e.g. the UNESCO Global Observatory and the African STI Observatory), and the inclusion of HDIs, industry associations and professional bodies.
2.	Increased M&E skills and capabilities for the NSI	2.1	Develop a strategy to expand the M&E capabilities of the NSI, including increased postgraduate training and shorter-term executive type training, locally and abroad, as well as internships. This will include mandate-focused initiatives to enhance the STI policy competencies of government officials through ongoing training at accredited institutions.
		2.2	Establish a national STI M&E community of practice under the auspices of NACI and linked to existing similar initiatives, e.g. at the DPME, National Treasury and appropriate DSI-NRF CoEs and South African Research Chairs
3.	An effective and vibrant knowledge-policy interface in the NSI	3.1	Strengthen the policy advisory mandates and capabilities of credible sources of STI information and analysis such as ASSAf, SARChI research chairs and CoEs. This will require a strategy to increase the mobility of officials and researchers across the government-academia interface.
		3.2	Include a policy advice agenda in the general STI agenda approved by the IMC to improve the relevance and timeliness of STI policy advice
		3.3	Design strategies for a policy dialogue platform, with a focus on involving civil society, business associations and professional bodies, alongside academia and government